



**REPORT TO
30 FAIRLIGHT PTY LTD**

**ON
GEOTECHNICAL SLOPE STABILITY RISK
ASSESSMENT**

**FOR
PROPOSED RESIDENTIAL DEVELOPMENT**

**AT
30 FAIRLIGHT STREET, FAIRLIGHT, NSW**

Date: 12 July 2021

Ref: 34216Brpt

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Table B: Summary of Risk Assessment to Life

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Figure 2: Geotechnical Sketch Plan

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Vibration Emission Design Goals

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1 INTRODUCTION

This report presents the results of a geotechnical slope stability risk assessment for the proposed residential development at 30 Fairlight Street, Fairlight, NSW. The location of the site is shown in Figure 1. The assessment was commissioned by Aaron Hatch of 30 Fairlight Pty Ltd and was carried out in accordance with our proposal dated 25 May 2021, Ref: P54225B.

As shown in the supplied preliminary architectural drawings by DKO Architecture (NSW) Pty Ltd (Project No. 00012781, Drawing Nos DA000, DA200 to DA203, DA300 to DA303, DA400 and DA401) the existing house at the site will be demolished and an apartment building constructed. The new building will have one basement parking level, with three levels of units above. The basement is proposed at RL42m, which is the street level at the south-eastern corner of the site, but will require excavation to a maximum depth of about 5.5m towards the rear of the site. The basement will extend to the eastern, southern and western boundaries and will be offset about 5.5m from the northern boundary. The portion of the site to the rear of the basement will require excavation to a depth of about 1.5m to 2m to form a level landscaped area, with retaining walls constructed along the boundaries to allow this excavation.

The purpose of the assessment was to complete a walkover inspection of the site as a basis for comments and recommendations on geotechnical issues for the proposed development to assist with the DA. As part of the assessment we have completed a geotechnical slope stability risk assessment to assess the risk to both property and life for the proposed development.

2 ASSESSMENT PROCEDURE

A walkover inspection of the site was completed by our Principal Geotechnical Engineer, Mr Daniel Bliss, on 25 June 2021. The attached Figure 2 presents a geotechnical sketch plan showing the principal geotechnical features present at the site. Figure 2 is based on the survey plan by Usher & Company (Ref: 6348-DET, dated 31/3/21). Additional features on Figure 2 have been measured by hand held inclinometer and tape measurement techniques and hence are only approximate. Should any of the features be critical to the proposed development, we recommend they be located more accurately using instrumental survey techniques. Figure 3 defines the mapping symbols used.

The slope stability risk assessment was carried out in accordance with the Australian Geomechanics Society (2007c) guidelines (Reference 1). The attached Appendix A defines the terminology adopted for the risk assessment together with a flowchart illustrating the Risk Management Process based on the guidelines given in AGS 2007c.

3 SUMMARY OF OBSERVATIONS

The site is located on the side of a hill that slopes down to the south and south-east at about 5° to 8°. The site itself has been flattened with each area in the site supported by retaining walls that step up the hillside towards the north.

Along the western portion of the the street frontage is a three car garage cut into the hillside, with the walls of the garage supporting the garage excavation for a height of about 3.1m. On the roof of the garage is a tiled deck, with cracking in the tiles present above the rear wall of the garage, which may indicate settlement of the backfill behind the wall. To the east of the garages the site frontage is supported by sandstone block retaining walls of about 1.1m in height with a set of stairs leading from the street into the site. These walls appeared to be in fair condition. The house within the subject site is located above the garage roof and comprises a single storey brick house, supported on sandstone block subfloor walls so that the southern end is raised above the roof of the garage by about 0.7m and above the ground surface at the south-eastern corner by about 1.7m. The ground surface on the eastern side of the house slopes down to the south at about 5°. The house appeared to be externally in good structural condition.

At the rear of the house is a level paved area in front of terraced gardens formed by timber sleeper retaining walls. Two walls are present, each retaining about 0.6m in height, and the walls appeared to be in fair condition. Above these walls is a level grassed area on the western side of the site and an inground swimming pool within the eastern portion, with a small brick shed to the north-east of the pool. At the rear of the pool is a masonry retaining wall with a tiled facing retaining a height of about 0.8m. This wall appeared to be in poor to fair condition.

To the north of the site a 0.6m timber sleeper retaining wall is located about 0.2m into the adjoining property. Behind this wall is a gently sloping grassed area, with the rear of a unit building fronting Berry Avenue located about 8m from the common boundary. A concrete block retaining wall is located close to the boundary to the north-west of the site, supporting 3 Berry Avenue, as shown on Figure 2.

The property to the west of the site contains a single storey brick house with sandstone block subfloor walls similar to the house within the subject site. Along the central portion of the common boundary, the property to the west is supported by a concrete retaining wall, in poor condition, to a maximum height of about 1.3m, but the rear portion of this wall comprises a mortared cobble wall. The western wall of the garage within the subject site is likely to support the front portion of the adjoining property. Along the street frontage of the adjoining property is a sandstone block retaining wall, which retains a height of about 2m adjacent to the subject site and appeared to be in fair condition with a slight bulge observed within the wall.

The eastern side of the site is supported by a concrete block retaining wall with a maximum height of about 1.9m, above a driveway within the adjoining property. The wall generally appeared to be in good condition. The ground surface within the adjoining property steps up via a retaining wall at the northern end of the driveway so that the area containing the swimming pool within the subject site is at a similar level to the ground surface within the rear portion of the adjoining property. The adjoining property to the east contains

a four storey brick unit building with the lowest level cut into the hillside to be at about street level. The building is located about 5m from the common boundary and appeared to be in good external condition.

Sandstone is exposed at various locations within the area of the subject site, including at 28 Woods Parade to the west, 1 Berry Avenue to the north, 125 Sydney Road and in Griffin Street to the north-east, and 7 Fairlight Street to the east. The sandstone was generally assessed to be distinctly weathered to slightly weathered and of at least low to medium strength.

4 SLOPE STABILITY RISK ASSESSMENT

Based on our walkover inspection, we consider the potential landslide hazards associated with the site and the proposed development are as follows:

- A. Stability of the basement retaining walls or rock cuts.
- B. Stability of the retaining walls around the rear landscaped area.
- C. Stability of the overall hillside slope.

The attached Table A summarises our qualitative assessment of each potential landslide hazard and of the consequences to property should the landslide hazard occur. The terminology adopted for this qualitative assessment is in accordance with Table A1 given in Appendix A. Table A indicates that the assessed risk to property varies between “Very Low” and “Low”, which would be considered ‘acceptable’ in accordance with the criteria given in Reference 1.

We have also used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life for the person most at risk. The temporal and vulnerability factors that have been adopted are given in the attached Table B together with the resulting risk calculation. Our assessed risk to life for the person most at risk is about 7×10^{-6} . This would be considered to be ‘acceptable’ in relation to the criteria given in Reference 1.

Based on the above slope stability risk assessment the proposed developed can be constructed to achieve an ‘acceptable’ level of risk, provided the recommendations given in Section 5 are followed during design and construction of the proposed development.

5 COMMENTS AND RECOMMENDATIONS

5.1 Inferred Subsurface Profile and Geotechnical Investigation

Based on the results of our walkover inspection, we infer that the subsurface profile at the site would comprise areas of fill covering residual soils that grade into weathered sandstone at relatively shallow depths. Based on the sandstone exposures in the vicinity of the site we expect that the sandstone would not be deeply weathered and sandstone of medium strength would be encountered shortly into the sandstone

profile. With the proposed depth of excavation we would expect that sandstone of high or possibly very high strength may be encountered.

The above inferred subsurface profile has been used for the preliminary geotechnical comments and recommendations provided herein. Based on this the principle geotechnical issues for the proposed development are the support of the excavations for the proposed basement, including any rock faces, and the risk of damage to adjoining structures during rock excavation. Each of these issues are discussed further below.

The subsurface profile must be confirmed by completing a geotechnical investigation of the site once access is possible. The geotechnical investigation should comprise the drilling of boreholes to below the base of the proposed excavation and since we expect that sandstone will be encountered coring of the sandstone will be required to reach such depths. The geotechnical investigation should be carried out following demolition of the house and creation of access for a drilling rig. That would then allow the boreholes to be drilled with the rig throughout the site to profile the depth and quality of the sandstone. Given the size of the site we recommend the drilling of four cored boreholes, but other shallow boreholes should be drilled in between the deeper boreholes and close to the site boundaries to profile the surface of the rock and assess the final retention requirements. The extent of such probing should be assessed following completion of the initial four boreholes.

The comments and recommendations provided herein must be reviewed and amplified as part of the geotechnical investigation.

5.2 Sydney Water Tunnel

As shown on the supplied survey plan and Sydney Water plans obtained through the DBYD service, a service tunnel passes below the site running roughly east to west. The drawings indicate that the tunnel is within rock, is unlined, with dimensions of 6570x6570, but the depth is not provided on the plans. We recommend that more specific details of the tunnel be obtained, such as the depth and its exact location so it can be taken into account in the design and construction of the proposed development.

Sydney Water should also be contacted to provide their design requirements for this tunnel, which may include reduced bearing pressures over the tunnel or placement of footings either side of the tunnel so that loads span over the tunnel. There may also be restrictions on vibrations during excavation in relation to the tunnel.

The advice provided herein must be reviewed once the Sydney Water requirements are known.

5.3 Adjoining Properties

Prior to demolition and excavation dilapidation surveys should be completed on the adjoining properties to the east, west and north. However, since the building to the north extends to Berry Street the dilapidation

survey could be limited to the units close to the subject site. The unit layout should be reviewed to determine the extent of the dilapidation survey. The dilapidation surveys should comprise detailed inspections of the adjoining properties, both externally and internally, with all defects rigorously described, i.e. defect location, defect type, crack width, crack length, etc. The respective owners of the adjoining properties should be asked to confirm that the dilapidation reports represent a fair record of actual conditions. The preparation of the dilapidation reports will also help to guard against claims for damage present prior to demolition and excavation.

Care must be taken during demolition that support is not removed to the adjoining properties. For most of the site this should not be of concern as the retaining walls on the eastern and southern boundaries support the subject site and most of the walls on the western and northern boundaries are of low height. However, the western wall of the garage would support the adjoining property and so this must be demolished with care. We expect that the existing wall will need to be propped during demolition and then a permanent retention system installed prior to final demolition. However, the final approach will depend on the location of the existing wall in relation to the boundary and the proposed retaining wall. This should be determined as part of the design and programming of the demolition and retention.

During excavation the vibrations transmitted to the adjoining properties must be monitored and actions taken if excessive vibrations are measured. Further comments on this are provided below in Section 5.4.

5.4 Excavation

Excavation to the required depth of about 5.5m is expected to encounter fill and residual soils, but for the most part sandstone bedrock, likely to be of up to high strength.

Excavation of the soils will be achievable using conventional excavation equipment, such as the bucket of a hydraulic excavator. If any extremely weathered sandstone is present, although unlikely, it may also be excavated using such equipment.

Excavation of the sandstone bedrock will require the use of rock excavation equipment, such as hydraulic rock hammers, ripping hooks, rotary grinders or rock saws. Hydraulic rock hammers must be used with care due to the risk of excessive vibrations being transmitted to the adjoining properties. If a rock hammer is used, the vibrations transmitted to the adjoining properties at least to the east and west must be quantitatively monitored at all times during rock hammer use. Vibration monitors should be solidly fixed to the adjoining properties, with the monitors attached to flashing warning lights, or other suitable warning systems, so that the operator is aware when acceptable limits have been reached so that excavation can cease. If permission to attach monitors to the adjoining buildings is unable to be obtained then they should be set up on the site boundaries. Reference should be made to the attached Vibrations Emission Design Goals sheet for acceptable limits of transmitted vibrations.

Where the transmitted vibrations are excessive it would be necessary to change to alternative excavation techniques, such as a smaller rock hammer, ripping hooks, rotary grinders or rock saws. A rock saw should also be used to cut a slot around the excavation perimeter prior to using a rock hammer to break out the

rock from between the saw cuts, in order to limit the transmitted vibrations. However, the effectiveness of this would need to be confirmed from the results of vibration monitoring. We expect that some of these less vibration emitting techniques will need to be used and the use of a rock hammer may be limited to the central portion of the site or may not be able to be used at all.

The excavated material will need to be classified for disposal purposes prior to being removed from site.

5.5 Groundwater

Groundwater is not expected to be a significant issue for this site, but some seepage may occur into the excavation, which would tend to occur along the soil/rock interface and through joints within the sandstone, particularly during and following rainfall. Such seepage should be able to be controlled during construction using gravity drainage and conventional sump and pump techniques.

In the long term, drainage should be provided behind all retaining walls and at the base of the all rock cuts. The hydraulic engineer should inspect the completed excavation to assess if the designed drainage system is adequate for the actual seepage flows.

5.6 Retention

Since we expect that sandstone will be shallow and of good quality the retention required is likely to comprise retaining walls to support the upper soils and unsupported excavation of the sandstone. However, this should be assessed as part of the geotechnical investigation of the site.

As mentioned above, particular attention should be paid to the western wall of the existing garage so that support of the adjoining property is maintained. If this wall is located inside the boundary then it may be possible to construct a piled retaining wall behind the garage wall prior to demolition, but if the existing wall is located on the boundary it may need to be left in place and a new retaining wall constructed in front. The exact location of this wall should be determined to assess the retention required for this portion of the site.

Along the eastern boundary the site is supported by a retaining wall and we assume that this wall will be removed during demolition and a retaining wall constructed below the level of the adjoining property as required.

Where space permits, temporary batters within the soils are likely to be able to be formed at no steeper than 1 Vertical in 1.5 Horizontal (1V:1.5H) where sandy soils are encountered, or 1V:1H for cohesive soils or poor quality sandstone. However, it is unlikely that sufficient space will be available for temporary batters.

Where space is not available for temporary batters retention systems will need to be installed prior to the start of excavation, such as contiguous or soldier pile retaining walls. The suitability of various retention system will depend on the material to be retained and the depth that needs to be supported and so should be assessed in detail as part of the geotechnical investigation.

Excavations within good quality sandstone should be able to be cut vertically without support, which should be confirmed as part of the geotechnical investigation. In addition, during excavation the sandstone cut faces must be inspected by a geotechnical engineer at depth intervals of no more than 1.5m to check for inclined joints, weak seams or other defects that require additional support. Such additional support may comprise shotcrete and mesh, rock bolts, or dental treatment of thin seams and must be installed prior to further excavation.

Retaining walls supporting no more than 3m may be preliminarily designed based on a triangular earth pressure distribution using an active earth pressure coefficient, K_a , of 0.3 and a bulk unit weight of 20kN/m^3 . This is for areas where some resulting ground movements can be tolerated and no structures are located behind the walls. Where movements are to be kept low or the walls are restrained by other structural elements in front of the walls, an 'at rest' earth pressure coefficient, K_0 , of 0.6 should be used.

The above coefficients assume horizontal backfill surfaces and where inclined backfill is proposed the coefficients will need to be increased or the inclined backfill taken as a surcharge load. All surcharge loads must be allowed for in the design, plus full hydrostatic pressures unless measures are undertaken to provide complete and permanent drainage behind the wall.

Although good quality sandstone will be self supporting in the long term, it will fret and deteriorate over time. Therefore, if rock faces are to be left exposed allowance for ongoing maintenance to clear debris from drains at the base of the rock faces must be made. To reduce this permanent walls may be constructed against the rock faces and gaps between the rock faces and the walls filled with gravel. Alternatively, the rock faces may be covered with shotcrete, with strip drains behind, to reduce the maintenance required.

5.7 Footings

Since we expect that sandstone will be encountered in the excavation all footings should be founded within the sandstone to provide uniform support and reduce the risk of differential settlements. We expect that pad or strip footings founded within the sandstone would be appropriate. However, the footing design will need to take into account the requirements due to the Sydney Water Tunnel that passes below the site as discussed in Section 5.2 above.

Allowable bearing pressures within the sandstone would start of 1000kPa for sandstone of very low strength, increasing to the order of 3500kPa or more within sandstone of medium to high strength. The appropriate bearing pressure for the design of the footings will need to be assessed as part of the geotechnical investigation.

The footing excavations will need to be inspected by a geotechnical engineer to confirm that the appropriate quality sandstone has been encountered. The extent of such inspections will depend on the quality of the sandstone and the design allowable bearing pressure adopted.

6 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the detailed design and construction phases of the project. In the event that any of the detailed design or construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and JK Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

A waste classification is required for any soil and/or bedrock excavated from the site prior to offsite disposal. Subject to the appropriate testing, material can be classified as Virgin Excavated Natural Material (VENM), Excavated Natural Material (ENM), General Solid, Restricted Solid or Hazardous Waste. Analysis can take up to seven to ten working days to complete, therefore, an adequate allowance should be included in the construction program unless testing is completed prior to construction. If contamination is encountered, then substantial further testing (and associated delays) could be expected. We strongly recommend that this requirement is addressed prior to the commencement of excavation on site.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

Reference 1: Australian Geomechanics Society (2007c) *'Practice Note Guidelines for Landslide Risk Management'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp63-114.

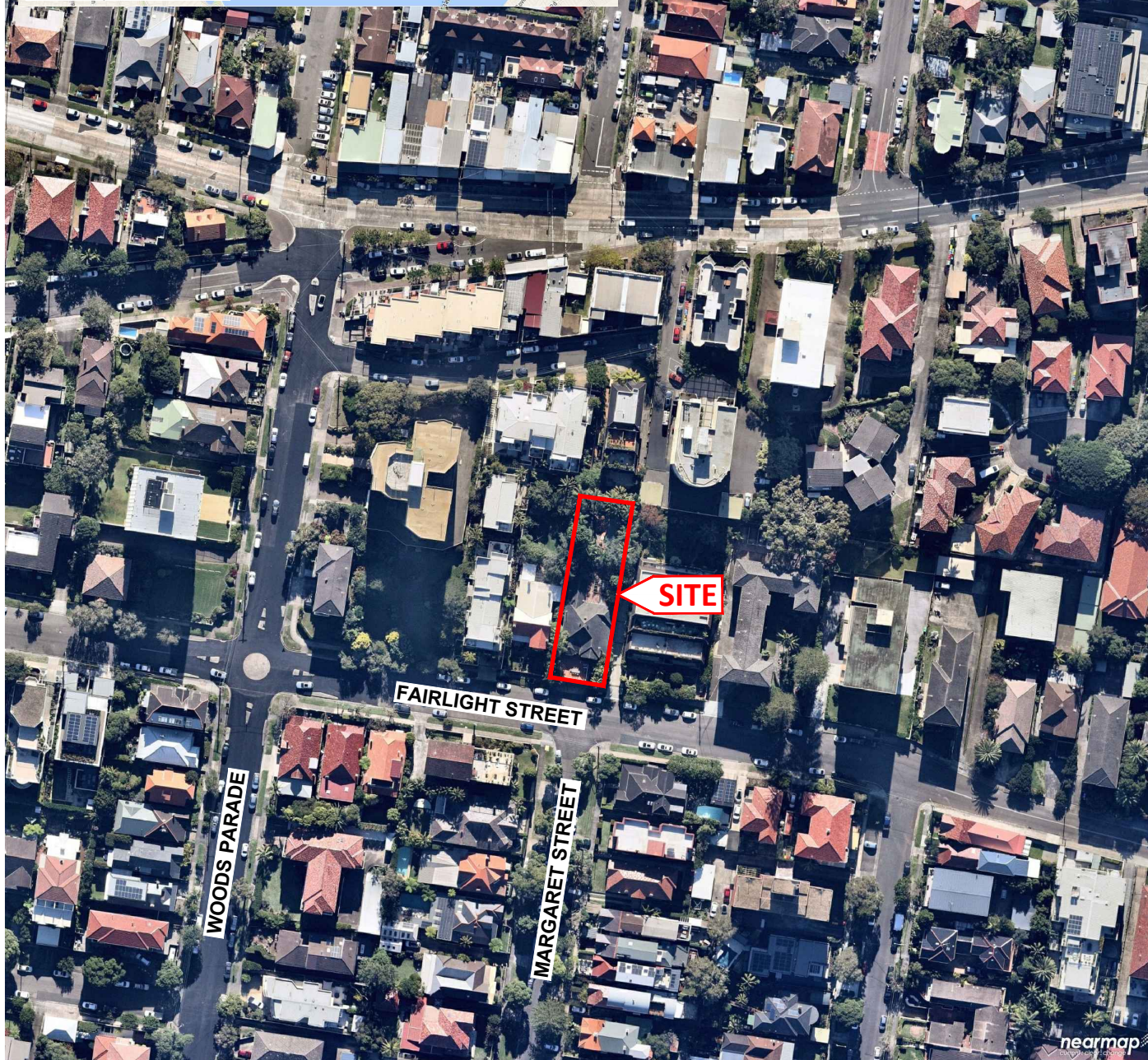
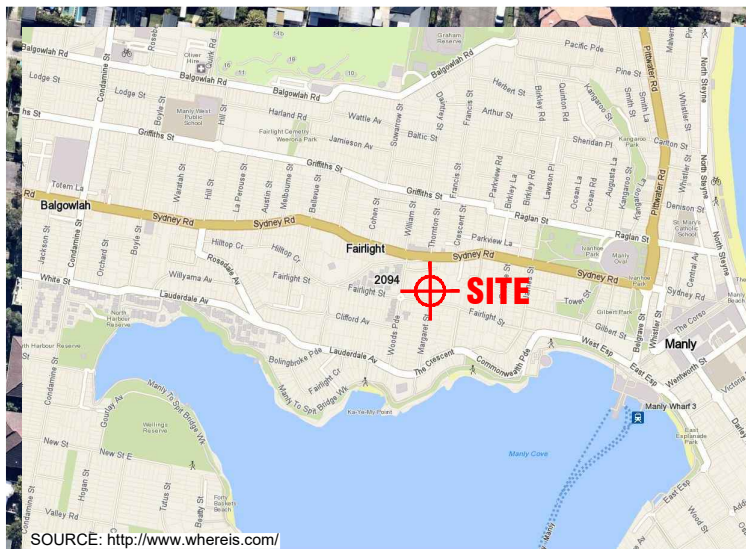


TABLE A
SUMMARY OF RISK ASSESSMENT TO PROPERTY

POTENTIAL LANDSLIDE HAZARD	A	B	D
	Stability of Basement Retaining Walls or Rock Cuts	Stability of Retaining Walls for the Rear Landscaped Area	Stability of the Overall Hillside Slope
Assessed Likelihood	Rare	Rare	Barely Credible
Assessed Consequence	Major	Minor	Major
Risk	Low	Very Low	Very Low
Comments	Assumes retaining walls engineer designed and properly constructed. Assumes all rock cuts progressively inspected by a geotechnical engineer and stabilisation measures implemented as required.	Assumes retaining walls engineer designed and properly constructed.	Sandstone expected at shallow depth so overall hillside instability barely credible.

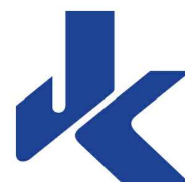
TABLE B
SUMMARY OF RISK ASSESSMENT TO LIFE

POTENTIAL LANDSLIDE HAZARD	A	B	D
	Stability of Basement Retaining Walls or Rock Cuts	Stability of Retaining Walls for the Rear Landscaped Area	Stability of the Overall Hillside Slope
Assessed Likelihood	Rare	Rare	Barely Credible
Indicative Annual Probability	10^{-5}	10^{-5}	10^{-6}
Person most at risk	Person within unit building	Person with rear landscaped area	Person within unit building
Duration of Use of area Affected (Temporal Probability)	Say 20 hours per day = 0.833	Say 4 hours per week = 0.02	Say 20 hours per day = 0.833
Probability of not Evacuating Area Affected	0.9	0.5	0.9
Vulnerability to Life if Failure Occurs Whilst Person Present	0.8	0.5	0.8
Risk for Person most at Risk	6×10^{-6}	6×10^{-8}	6×10^{-7}
Total Risk for Person Most at Risk	7×10^{-6}		



AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

Title: SITE LOCATION PLAN	
Location: 30 FAIRLIGHT STREET, FAIRLIGHT, NSW	
Report No: 34216B	Figure No: 1
JKGeotechnics	



This plan should be read in conjunction with the JK Geotechnics report.

TOPOGRAPHY

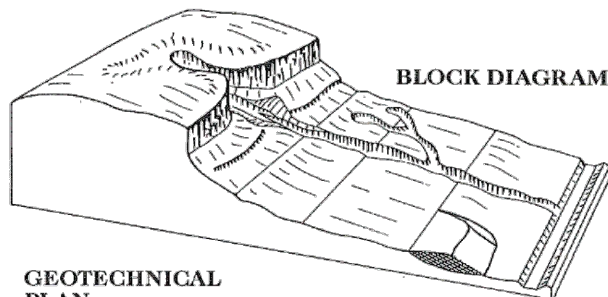
Symbol Ground Profile

		convex	} well defined or angular break of slope
		concave	
		convex	} poorly defined or smooth change of slope
		concave	
		breaks of slope	} convex and concave too close together to allow the use of separate symbols
		changes of slope	
		sharp	} ridge crest
		rounded	
		Cliff or escarpment or sharp break 40° or more (estimated height in metres)	
		Uniform Slope	} Slope direction and angle (Degrees)
		Concave Slope	
		Convex Slope	
		Top	} Cut or fill slope, arrows pointing down slope
		Bottom	
		Hummocky or irregular ground	

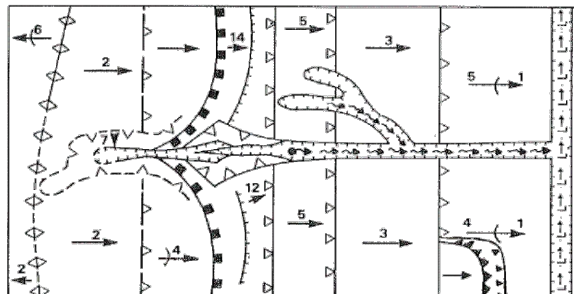
OTHER FEATURES

	Boulder
	Seepage/spring
	Swallow hole for runoff
	Natural water course
	Open drain, unlined
	Open drain, lined
	Fenceline
	Property boundary
	Dry Stone Wall
	Major joint in rock face (opening in millimetres)
	Tension crack (opening in millimetres)
	Masonry or concrete wall
	Ponding water
	Boggy or swampy area

EXAMPLE OF USE OF TOPOGRAPHIC SYMBOLS:

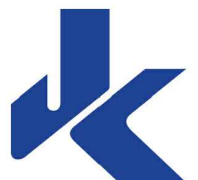


GEOTECHNICAL PLAN



(After Gardiner, V & Dackombe, R. V.
(1983), Geomorphological Field Manual;
George Allen & Unwin).

Title:	GEOTECHNICAL MAPPING SYMBOLS	
Location:	30 FAIRLIGHT STREET, FAIRLIGHT, NSW	
Report No:	34216B	Figure No: 3
JKGeotechnics		



This plan should be read in conjunction with the JK Geotechnics report.

VIBRATION EMISSION DESIGN GOALS

German Standard DIN 4150 – Part 3: 1999 provides guideline levels of vibration velocity for evaluating the effects of vibration in structures. The limits presented in this standard are generally recognised to be conservative.

The DIN 4150 values (maximum levels measured in any direction at the foundation, OR, maximum levels measured in (x) or (y) horizontal directions, in the plane of the uppermost floor), are summarised in Table 1 below.

It should be noted that peak vibration velocities higher than the minimum figures in Table 1 for low frequencies may be quite ‘safe’, depending on the frequency content of the vibration and the actual condition of the structure.

It should also be noted that these levels are ‘safe limits’, up to which no damage due to vibration effects has been observed for the particular class of building. ‘Damage’ is defined by DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls. Should damage be observed at vibration levels lower than the ‘safe limits’, then it may be attributed to other causes. DIN 4150 also states that when vibration levels higher than the ‘safe limits’ are present, it does not necessarily follow that damage will occur. Values given are only a broad guide.

Table 1: DIN 4150 – Structural Damage – Safe Limits for Building Vibration

Group	Type of Structure	Peak Vibration Velocity in mm/s			
		At Foundation Level at a Frequency of:			Plane of Floor of Uppermost Storey
		Less than 10Hz	10Hz to 50Hz	50Hz to 100Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use.	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 and 2 and have intrinsic value (eg. buildings that are under a preservation order).	3	3 to 8	8 to 10	8

Note: For frequencies above 100Hz, the higher values in the 50Hz to 100Hz column should be used.



APPENDIX A

**LANDSLIDE RISK
MANAGEMENT
TERMINOLOGY**

LANDSLIDE RISK MANAGEMENT

Definition of Terms and Landslide Risk

Risk Terminology	Description
Acceptable Risk	A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
Annual Exceedance Probability (AEP)	The estimated probability that an event of specified magnitude will be exceeded in any year.
Consequence	The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
Elements at Risk	The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.
Frequency	A measure of likelihood expressed as the number of occurrences of an event in a given time. See also 'Likelihood' and 'Probability'.
Hazard	A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.
Individual Risk to Life	The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
Landslide Activity	The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg. seasonal) or continuous (in which case the slide is 'active').
Landslide Intensity	A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, or kinetic energy per unit area.
Landslide Risk	The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.
Landslide Susceptibility	The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
Likelihood	Used as a qualitative description of probability or frequency.
Probability	<p>A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.</p> <p>These are two main interpretations:</p> <ul style="list-style-type: none"> (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an 'objective' or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

Risk Terminology	Description
Probability (continued)	(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.
Qualitative Risk Analysis	An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.
Quantitative Risk Analysis	An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.
Risk	A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
Risk Analysis	The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification and risk estimation.
Risk Assessment	The process of risk analysis and risk evaluation.
Risk Control or Risk Treatment	The process of decision-making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.
Risk Estimation	The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.
Risk Evaluation	The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.
Risk Management	The complete process of risk assessment and risk control (or risk treatment).
Societal Risk	The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.
Susceptibility	See 'Landslide Susceptibility'.
Temporal Spatial Probability	The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.
Tolerable Risk	A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.
Vulnerability	The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

NOTE: Reference should be made to Figure A1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

Reference should also be made to the paper referenced below for Landslide Terminology and more detailed discussion of the above terminology.

This appendix is an extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

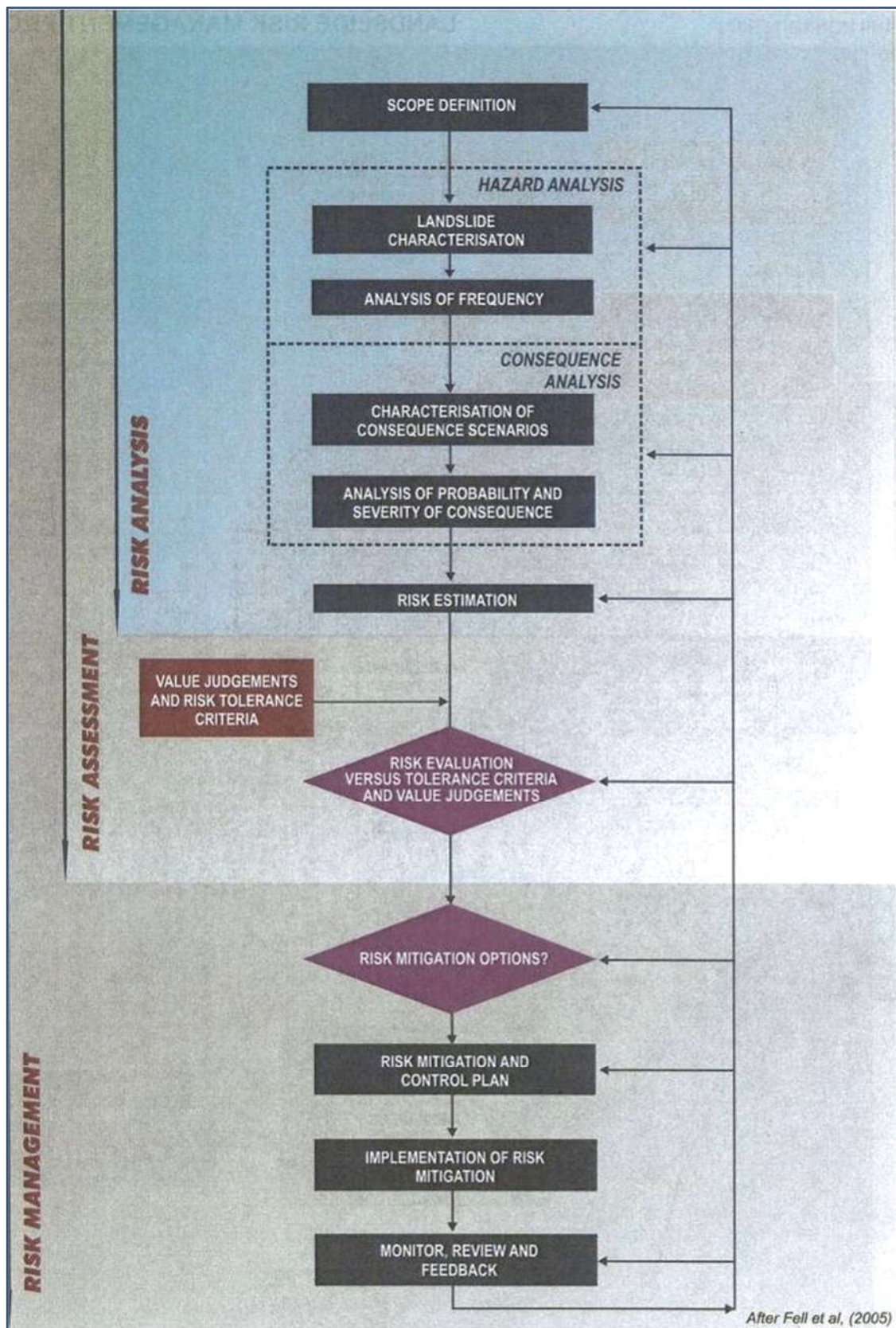


FIGURE A1: Flowchart for Landslide Risk Management.

This figure is an extract from GUIDELINE FOR LANDSLIDE SUSCEPTIBILITY, HAZARD AND RISK ZONING FOR LAND USE PLANNING, as presented in Australian Geomechanics Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: 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	5×10 ⁻²	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10 ⁻²		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10 ⁻³	5×10 ⁻³	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10 ⁻⁴	5×10 ⁻⁴	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10 ⁻⁵	5×10 ⁻⁵	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10 ⁻⁶	5×10 ⁻²	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not *vice versa*.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

TABLE A1: LANDSLIDE RISK ASSESSMENT
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) 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.

Extract from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in Australian Geomechanics, Vol 42, No 1, March 2007, which discusses the matter more fully.

AUSTRALIAN GEOGUIDE LR2 (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 fall 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 groundwater table) is the single most important cause of landslides (GeoGuide LR5). 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
- Groundwater 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:

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.

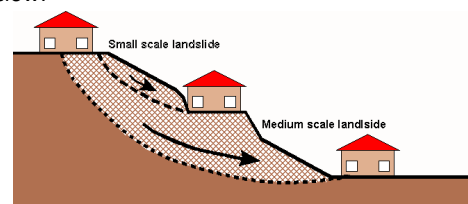


Figure 1

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.

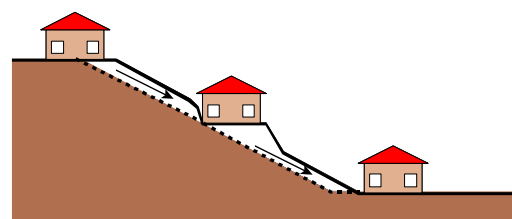


Figure 2

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.

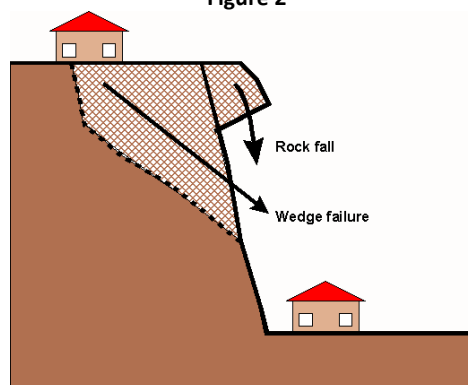


Figure 3

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.

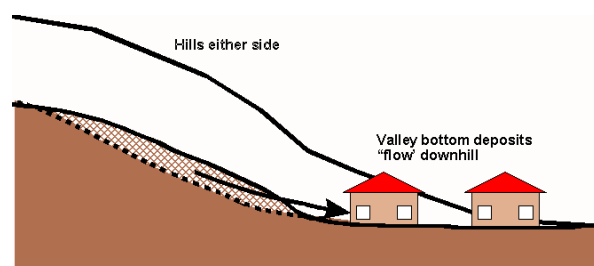


Figure 4

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
- 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 LR7 (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 (see 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 normally covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, then 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 the repairs and temporary loss of use if the 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 tolerable" 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 risk 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. 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 today. If this were not so, there would be no risk at all and clearly that is not the case.

In NSW, the planning authorities consider that 1:1,000,000 is the maximum tolerable risk for domestic housing built near an obvious hazard, such as a chemical factory. Although not specifically considered in the NSW guidelines there is little difference between the hazard presented by a neighbouring factory and a landslide: both have the capacity to destroy life and property and both are always present.

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:

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APPENDIX B

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION



SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

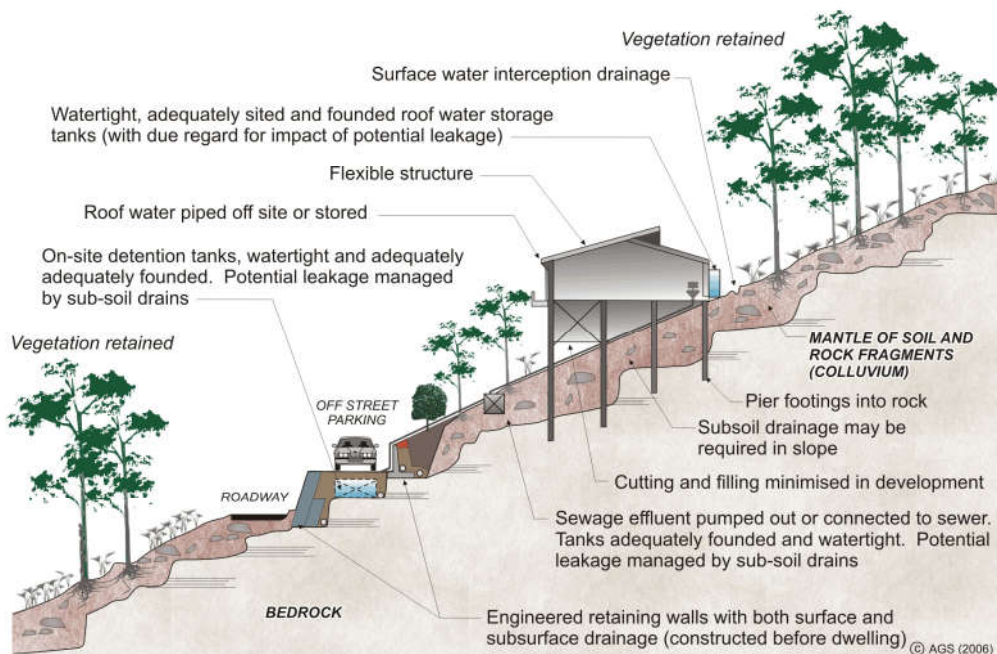
GOOD ENGINEERING PRACTICE		POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements.
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance (including onto properties below). Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc. in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on bedrock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within bedrock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide generous falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge of roof run-off into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use of absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by a geotechnical consultant.	
SITE VISITS	Site visits by consultant may be appropriate during construction.	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident seek advice. If seepage observed, determine cause or seek advice on consequences.	

This table is extracted from PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT as presented in *Australian Geomechanics*, Vol 42, No 1, March 2007 which discusses the matter more fully.

AUSTRALIAN GEOGUIDE LR8 (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 FOR **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 due to 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 fulfill 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.

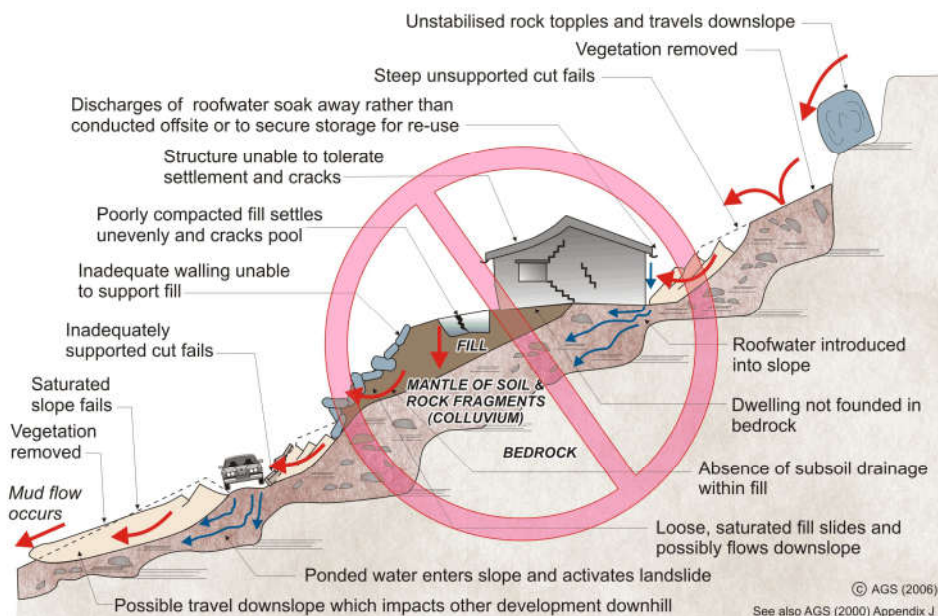
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

EXAMPLES FOR **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 soaks 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 herringbone, 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:

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