GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for	Warriewood Vale Pty Ltd
	Name of Applicant
Address of site	8 Forest Road, Warriewood, NSW

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, Daniel Bliss *on behalf of* *JK Geotechnics Pty Ltd*
(Insert Name) (Trading or Company Name)

on this the 8 October 2020 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
*we/*I have:

Please mark appropriate box

☐ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☑ We are willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. *We/*~~I~~ confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and *are/*am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my/*our* report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Report to Warriewood Vale Pty Ltd on Geotechnical Risk Assessment for Proposed Residential Apartment Development at (Part of) 8 Forest Road, Warriewood, NSW

Report Date: 8 October 2020 **Report Ref No**: 33371BMrpt2

Author: Matthew Pearce

Author's Company/Organisation*:* JK Geotechnics Pty Ltd

Documentation which relate to or are relied upon in report preparation:

Architectural drawings by Jackson Teece (Project No 2019068, Drawing Nos DA-010, 020, 030, 109, 110, 112 dated 17/7/20, 120, 201 to 204, and 300, various amendments, dated 21/8/2020 {UNO})

~~I am~~ *We are* aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ~~ensuring~~ *confirming* that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk, *as discussed in the Report*.

Signature	
Name	Daniel Bliss
Chartered Professional Status	MIEAust CPEng
Membership No.	969495
Company:	JK Geotechnics Pty Ltd

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for Warriewood Vale Pty Ltd
Name of Applicant

Address of site 8 Forest Road, Warriewood, NSW

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Report to Warriewood Vale Pty Ltd on Geotechnical Risk Assessment for Proposed Residential Apartment Development at (Part of) 8 Forest Road, Warriewood, NSW

Report Date: 8 October 2020 **Report Ref No**: 33371BMrpt2

Author: Matthew Pearce

Author's Company/Organisation: JK Geotechnics Pty Ltd

Please mark appropriate box

- ☑ Comprehensive site mapping conducted 1 October 2020 (date)
- ☑ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ☐ Subsurface investigation required
  - ☑ No Justification: Sufficient previous investigation information to characterise subsurface conditions...
  - ☐ Yes Date conducted ……………………………………………
- ☑ Geotechnical model developed and reported as an inferred subsurface type-section
- ☑ Geotechnical hazards identified
  - ☑ Above the site
  - ☑ On the site
  - ☑ Below the site
  - ☑ Beside the site
- ☑ Geotechnical hazards described and reported
- ☑ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ☑ Consequence analysis
  - ☑ Frequency analysis
- ☑ Risk calculation
- ☑ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the ~~specified conditions are achieved~~ *recommendations presented in the Report are adopted.*
- ☑ Design Life Adopted:
  - ☑ 100 years
  - ☐ Other …………………………………………….
    specify
- ☑ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ☑ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☐ Risk assessment within Bushfire Asset Protection Zone.

~~I am~~ *We are* aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ~~ensuring~~ *confirming* that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk *as discussed in the Report*.

Signature	DBliss
Name	Daniel Bliss
Chartered Professional Status	MIEAust CPEng
Membership No.	969495
Company	*JK Geotechnics Pty Ltd.*

REPORT TO

WARRIEWOOD VALE PTY LTD

ON

GEOTECHNICAL ASSESSMENT
(In Accordance with Pittwater Council Risk Management Policy)

FOR

PROPOSED RESIDENTIAL APARTMENT DEVELOPMENT

AT

(PART OF) 8 FOREST ROAD, WARRIEWOOD, NSW

Date: 8 October 2020
Ref: 33371BMrpt2

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For and on behalf of
JK GEOTECHNICS
PO BOX 976
NORTH RYDE BC NSW 1670

DOCUMENT REVISION RECORD

Report Reference	Report Status	Report Date
33371BMrpt2	Final Report	8 October 2020

Table of Contents

ATTACHMENTS

1 INTRODUCTION

This report presents the results of our geotechnical assessment of the proposed residential apartment development within part of 8 Forest Road, Warriewood, NSW. The location of the site is shown in Figure 1. The assessment was commissioned by Ms Michelle Ramjan of Jackson Teece on behalf of Warriewood Vale Pty Ltd, in accordance with our proposal (Ref P51886SM, dated 21May 2020) and email dated 15 May 2020. The site was inspected by our Associate Geotechnical Engineer on 1 October 2020, in order to assess the existing stability of the site and the effect on stability of the proposed development.

The proposed residential apartment building will be located within a portion of 8 Forest Road formed as part of a subdivision, which is subject of a separate DA. We have prepared a separate geotechnical risk assessment report for the subdivision, Ref 33371BMrpt**1** dated 8 October 2020.

Details of the proposed residential apartment development are presented in Section 5 below. In summary however, it is proposed to construct a residential apartment building with three above ground levels over a single common basement level requiring excavation ranging from depths of about 2.3m in the north-eastern corner of the building to about 6.3m in the south-western corner.

This report has been prepared in accordance with the requirements of the Geotechnical Risk Management Policy for Pittwater (2009) as discussed in Section 6 below. It is understood that the report will be submitted to Council as part of the DA documentation. Our report is preceded by the completed Council Forms 1 and 1a.

2 ASSESSMENT METHODOLOGY

2.1 Walkover Survey

This stability assessment is based upon a detailed inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs. These features were compared to those of other similar lots in neighbouring locations to provide a comparative basis for assessing the risk of instability affecting the proposed development. 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 (Reference 1).

A summary of our observations is presented in Section 3 below. Our specific recommendations regarding the proposed development are discussed in Section 7 following our geotechnical assessment.

The attached Figure 2 presents a geotechnical sketch plan showing the principal geotechnical features present at the site. Figure 2 is based on the Partial Detail Survey of Lot 1 DP 5055 prepared by Pulver Cooper & Blackley (Ref. 87815, Rev G, dated 9/11/2017). Additional features on Figure 2 have been measured by hand held inclinometer and tape measure 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 instrument survey techniques. Figure 3 presents a typical cross-section through the site based on the survey data augmented by our mapping observations. Figure 5 defines the geotechnical mapping symbols used.

2.2 Desktop Study Assessment of Subsurface Conditions

In order to assess the subsurface conditions the following was carried out:

- Review of a supplied Preliminary Contamination and Geotechnical Assessment report prepared by Cardno, Ref. CGS2698, dated 12 October 2015,
- Review of the published information including geological maps and publicly available previous geotechnical reports for the site,
- A search of our project database for previous geotechnical investigations we have completed in the vicinity of the subject site, and

3 SUMMARY OF OBSERVATIONS

We recommend that the summary of observations which follows be read in conjunction with the attached Figures 1 to 4.

- No. 8 Forest Road is a large property backing onto the lower slopes of the plateau at the rear (west) of the Warriewood valley, and extending onto the valley floor up to the southern side of Narrabeen Creek.
- The site of the proposed residential apartment building, is within the valley floor where surface levels range from about RL28.5m in the south-western corner to RL23.5m in the north eastern corner. The site is located towards the northern end of 8 Forest Road and is about 75m by 75m in size and generally slopes down to the north-east at about 3° to 4°, although was slightly steeper along the western and southern fringes. At the time of the walkover the site was unoccupied and grass covered, with only two small trees. Where exposed, surface material appeared to be silty sand and gravel fill except in the south-western corner where there appeared to be some light grey natural sand.
- To the west and the south of the site are hillsides sloping up at about 20° from the site, with the sloping flattening off to about 10° to 15° towards the crest near the southern boundary of 8 Forest Road. The hills are covered in native forest with variably dense undergrowth and occasional outcrops of sandstone bedrock towards the crest.
- To the south-west of the site is a derelict house clearly built upon a sandstone outcrop of about 3m in height. Further north of the old house are further exposures of sandstone outcrops of a similar height located approximately 10m to 15m from the building.
- An unsurfaced bush track extends south-westwards into the forest, from in front of the aforementioned house, following what appeared to be a natural drainage channel on the hillside. The drainage channel was dry at the time of the site visit. The drainage has been channelled eastwards along the southern side of the site towards an unlined culvert on the eastern side of 8 Forest Road, which then fell to the north.

- About 20m to the north of the proposed building is the densely vegetated Narrabeen Creek which meanders towards the east. One partial exposure of the creek bank was assessed to slope at about 35° over a length of about 2m to 3m.
- Adjacent to the creek in the north-eastern corner of 8 Forest Road is a single storey fibro building (now a display building) and a gravel surfaced parking area.
- In the north-western portion of the valley floor is a densely vegetated mound, probably comprising a fill stockpile.

4 GEOLOGY AND SUBSURFACE CONDITIONS

The Sydney 1:100,000 geological map indicates the site to be underlain by Hawkesbury Sandstone which overlies the Newport Formation of the Narrabeen Group. The Newport formation comprises interbedded laminate, shale and sandstone and is indicated on the map to border the Hawkesbury sandstone to the east of the site. A further 250m to the east, the map shows Quaternary period soils fanning out from Narrabeen Creek (and Fern Creek), comprising stream alluvial and estuarine sediments of silty to peaty quartz sand, silt and clay with ferruginous or humic cementation in places.

The Preliminary Contamination and Geotechnical Assessment by Cardno, Ref. CGS2698 dated 12 October 2015, included the excavation of four test pits using a 5 tonne excavator and two boreholes within the area of the proposed residential (and community) lot subdivision to the east of the proposed apartment building. In TP010, rock was encountered at 1.9m depth while in the other test pits rock was deeper than the termination depth of the test pits, 2.5m. In BH002 to BH003 Standard Penetration Tests (SPT) were carried out in the upper fill and soils to a limited depth of 6m and then these boreholes were extended by rapid auger techniques (without insitu testing) to depths ranging from 12m to 14.5m depth in an attempt to probe for rock, but no rock was encountered.

A search of our project database revealed that we completed a preliminary geotechnical investigation in 2005 (Ref 19312VBrpt, dated 14 April 2020) for a larger site that was then known as Sector 5 of the Warriewood Valley Urban Land Release, which incorporated the subject site. The investigation comprised a number of limited depth boreholes within the now 8 Forest Road site, including 2 boreholes (BH8 and BH9) within the footprint of the proposed apartment building. Copies of the borehole logs for these boreholes are attached in Appendix C.

The locations of the relevant boreholes and test pits from the above two previous investigations are shown on Figure 4, which also shows the depths at each location where rock was encountered, or the termination depths if rock was not encountered. The proposed subdivision and basement outline (as per Jackson Teece architectural drawing DA-030 &109) are also shown on Figure 4, overlain on a Nearmap aerial image. It should be noted that the surface RLs of the Cardno test locations are unknown.

The results from the above investigations have been used to summarise the subsurface conditions as described below. In summary, the boreholes and test pits completed to date within (or adjacent to) the footprint of the proposed building encountered relatively shallow fill and topsoil overlying colluvial, residual and/or alluvial soils to variable depths. Rock was encountered at shallow depths only at the southernmost location (TP007). The northern and eastern locations did not encounter rock. The pertinent details of the encountered subsurface conditions are described below.

Topsoil and Fill

Topsoil and fill was encountered to depths ranging from 0.15m to 0.8m and predominately comprised silty sand.

Colluvial and Residual Soil

Within the southern portion of site colluvial sandy soil, with a sandstone boulder, was encountered in BH8 to a depth of 1.5m. Colluvial sand was also encountered in TP007 to TP009 to depths of about 1.3m to 1.9m and was assessed to be of loose to medium dense relative density.

A layer of about 0.5m to 0.6m of residual clayey sand or sandy clay was encountered beneath the colluvial soil, overlying the rock, in TP007 and TP008.

Within the northern portion of the site colluvial sand extended to depths of 3m to 5.3m (BH001 to BH003).

Alluvial Soil

Alluvial silty clay, sandy clay and clayey sand was encountered beneath the colluvium or fill/topsoil, except in the TP007 to TP009. Where tested, the clayey soils were assessed to be of very stiff to hard strength, while the clayey sandy soil was assessed to be of medium dense relative density. The alluvial soil extended to at least the termination depth of each of the boreholes, i.e. 6m for BH8 and BH9, and 16m, 14.5m, and 12m in BH001, BH002 and BH003, respectively.

We have also carried out geotechnical investigations with other areas of Warriewood and at locations in the range of 350m to 450m from the site, but also slightly further into the Warriewood valley than the subject site, our previous investigations encountered soils extending to depths of greater than 9m, 17m and 34m below surface levels, with rock not being encountered. The materials at depth generally comprised interbedded silty clay and sandy clay and a trace of ironstone gravel. The strength of the soils at depth was generally very stiff to hard or of medium dense to dense relative density.

Sandstone Bedrock

While outcrops were observed within about 10m of the proposed building and appeared typical of Hawkesbury Sandstone, sandstone bedrock was only encountered at two test locations (TP007 and TP008), at depths of 1.9m and 2.3m below surface levels, with insufficient penetration to identify if it was Hawkesbury Sandstone or Newport Formation bedrock. The bedrock level drops down to the north and east to depths greater than 16m since it was not encountered in BH001. It is likely that the top of the rock will also transition from the typically better quality Hawkesbury sandstone, to the more deeply weathered Newport Formation. The surface of the sandstone is likely to comprise a series of vertical steps rather than a sloping surface.

Groundwater

Groundwater was not encountered in BH8 or BH9 within the borehole depth of 6m (≈RL21m to ≈RL19m). However, there may not have been sufficient time for groundwater levels to stabilise. Groundwater levels in the boreholes closer to the creek were at about RL19m, but no longer term monitoring of groundwater levels was carried out.

5 PROPOSED DEVELOPMENT

We understand from the provided architectural drawings by Jackson Teece (Project No 2019068, Drawing Nos DA-010, 020, 030, 109, 110, 112 dated 17/7/20, 120, 201 to 204, and 300, various amendments, dated 21/8/2020 {UNO}), that the proposed residential apartment development will comprise the following:

- Three above ground levels, separated into 4 blocks (A to D) over a single common basement level.
- The proposed basement has an irregular outline but is about 72m (north to south) by 55m to 75m (east-west) with a ramp in the north-eastern corner. The basement is proposed at RL22.4m within the southern portion, falling to RL21.4m within the northern portion. This will require excavation ranging from depths of about 2.3m in the north-eastern corner of the building to about 6.3m in the south-western corner.

The footprint of the proposed basement is indicated on Figures 2 and 4.

6 GEOTECHNICAL ASSESSMENT

The property exhibited no signs of instability. The development area has gentle slopes of about 3° to 4° except the southern most extent where slopes are at about 10°. The hillside upslope from there is about 18° but due to several exposures of sandstone bedrock in this steeper portion of the hillside, we infer relatively shallow soil cover on the moderate to steep slopes.

Several metres to the west of the proposed basement are sandstone outcrops upon which is the derelict house. The outcrops were about 3m in height, generally massive and appeared stable.

On the middle and upper slopes to the south of the site there were a limited number of rock outcrops present greater than about 1m in height which appeared to be stable and comprising relatively massive units. There were a few detached floaters but these were generally non-rounded and it is almost inconceivable that they may rolling down the moderate hillslopes and impact the proposed residential apartment building.

The creek bank was densely vegetated limiting observations. The creek was only trickling during the site walkovers (during relatively dry periods of weather). The creek bed appeared to be not more than about 1m to 2m depth. A limited exposure of creek bank was estimated to slope at about 35° (at or slightly steeper than the expected angle of repose of the expected soils) so we surmise the stability of the creek bank is somewhat assisted by the root systems of the vegetation.

6.1 Potential Landslide Hazards

We consider that the potential landslide hazards associated with the site and the proposed apartment building development to be the following:

A Instability of the hillside slope upslope of the proposed access road.

B Instability of the creek bank on the northern side of the proposed access road.

C Instability of the rock outcrops exposed on the hillside to the south and west of the site.

D Instability of the proposed basement retaining walls.

These potential hazards are indicated in schematic form on the attached Figures 2 and 3.

6.2 Risk Analysis

The attached Table A summarises our qualitative assessment of each potential landslide hazard and of the consequences to property should the landslide hazard occur. Use has been made of data in MacGregor *et al* (2007) to assist with our assessment of the likelihood of a potential hazard occurring. Based on the above, the qualitative risks to property have been determined. 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 and the Pittwater Council Risk Management Policy.

We have also used the indicative probabilities associated with the assessed likelihood of instability to calculate the risk to life. 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 10^{-7}. This would be considered to be 'acceptable' in relation to the criteria given in Reference 1 and the Pittwater Council Risk Management Policy.

6.3 Risk Assessment

The Pittwater Risk Management Policy requires suitable measures 'to remove risk'. It is recognised that, due to the many complex factors that can affect a site, the subjective nature of a risk analysis, and the imprecise nature of the science of geotechnical engineering, the risk of instability for a site and/or development cannot be completely removed. It is, however, essential that risk be reduced to at least that which could be reasonably anticipated by the community in everyday life and that landowners are made aware of reasonable and practical measures available to reduce risk as far as possible. Hence, where the policy requires that 'reasonable and practical measures have been identified to remove risk', it means that there has been an active process of reducing risk, but it does not require the geotechnical engineer to warrant that risk has been completely removed, only reduced, as removing risk is not currently scientifically achievable.

Similarly, the Pittwater Risk Management Policy requires that the design project life be taken as 100 years unless otherwise justified by the applicant. This requirement provides the context within which the geotechnical risk assessment should be made. The required 100 years baseline broadly reflects the expectations of the community for the anticipated life of a residential structure and hence the timeframe to be considered when undertaking the geotechnical risk assessment and making recommendations as to the appropriateness of a development, and its design and remedial measures that should be taken to control risk. It is recognised that in a 100 year period external factors that cannot reasonably be foreseen may affect the geotechnical risks associated with a site. Hence, the Policy does not seek the geotechnical engineer to warrant the development for a 100 year period, rather to provide a professional opinion that foreseeable geotechnical risks to which the development may be subjected in that timeframe have been reasonably considered.

Our assessment of the probability of failure of existing structural elements such as retaining walls (where applicable) is based upon a visual appraisal of their type and condition at the time of our inspection. Where existing structural elements such as retaining walls will not be replaced as part of the proposed development, where appropriate we identify the time period at which reassessment of their longevity seems warranted.
In preparing our recommendations given below we have adopted the above interpretations of the Risk Management Policy requirements. We have also assumed that no activities on surrounding land which may affect the risk on the subject site would be carried out. We have further assumed that all Council's buried services are, and will be regularly maintained to remain, in good condition.

We consider that our risk analysis has shown that the site and existing and proposed development can achieve the 'Acceptable Risk Management' criteria in the Pittwater Risk Management Policy provided that the recommendations given in Section 7 below are adopted. These recommendations form an integral part of the Landslide Risk Management Process.

7 COMMENTS AND RECOMMENDATIONS

We consider that the proposed development may proceed provided the following specific design, construction and maintenance recommendations are adopted to maintain and reduce the present risk of instability of the site and to control future risks. These recommendations address geotechnical issues only and other conditions may be required to address other aspects.

7.1 Conditions Recommended to Establish the Design Parameters

7.1.1 The comments and recommendations provided within this report are preliminary only based on the limited information available and may be used for preliminary planning and initial design of the development. More specific comments and recommendations must be provided as part of a detailed geotechnical investigation of the site to allow final design. The geotechnical investigation should involve the drilling of boreholes or completion of Cone Penetration Tests (CPT) depending on the footing system proposed for the building. If footings are to be founded within the rock then a significant number of boreholes would be required to profile the rock given its variable depth. The investigation is likely to be carried out in stages, with an initial wide spacing of boreholes to assess the general profile and then targeted boreholes between the previous boreholes to fully profile the rock. In order to optimise the bearing pressures within the rock the rock should be core drilled once encountered. Groundwater monitoring wells should be installed in some boreholes to assess the longer term groundwater level. CPTs would be appropriate if the building loads are not great and piles founded within the sandy soils are to be adopted.

7.1.2 **Excavation.** To achieve the basement level (currently proposed to range from 2.3m to 6.3m below existing ground surface levels) the excavations are expected to encounter fill and colluvial, residual and alluvial soils (comprising sand and clay), and some sandstone bedrock in the south-western corner. The soils and any extremely weathered rock will be able to be excavated using conventional earthmoving equipment such as tracked excavators or similar.

There is currently no information on rock strength, but rock of at least low strength will need to be excavated using hydraulic rock hammers, ripping hooks, rotary grinder or rock saws. The appropriate excavation equipment will need to be assessed as part of the detailed geotechnical investigation.

7.1.3 **Hydrogeological (Groundwater) Considerations.** Only limited information is available at present on groundwater, with groundwater encountered in some boreholes at about RL19m. This is below the proposed lowest basement level at RL21.4m and if this is the longer term groundwater level then it will be below the base of the excavation and groundwater will not be a significant issue. However, some seepage into the excavation may occur along the soil/rock interface and would increase during and following rainfall. As part of the detailed geotechnical investigation the groundwater level must be confirmed and further advice provided.

Drainage must be provided behind all retaining walls and may be required below the basement slab if seepage is encountered.

7.1.4 **Batters and Retention Systems.** Where excavations are shallow the use of temporary batters would be feasible, but for the deeper excavations shoring walls installed prior to the start of excavation are likely to be required. It may be more practical to install shoring walls around the entire basement perimeter to avoid removal of material from site and the importation of material for backfilling.

For cuts in soil of no more than 3m depth temporary batters may be formed at no steeper than 1 Vertical (V): 1.5 Horizontal (H) for sandy soils while permanent batters should be formed at no steeper than 1V:2.5H; however, for maintenance purposes it may be more practical to form permanent batters at 1V:3H or 1V:4H. All permanent batters should be protected from erosion by placement of topsoil and a deep rooted runner grass, or other suitable protection measures. Temporary batters through clayey soils of at least very stiff strength or weathered sandstone may be formed at 1V:1H, for cuts of up to 3m height. Steeper cuts through sandstone may be feasible, but will need to be assessed based on the results of the detailed geotechnical investigation and then confirmed by progressive inspections of the cut faces by a geotechnical engineer.

Where batters are not appropriate or are not preferred, full depth shoring system installed prior to the start of excavation may comprise contiguous or secant pile walls where sandy soils are encountered. Where clayey soils or weathered rock are present closely spaced soldier pile walls with shotcrete infill panels may suffice. The use of CFA piles would be required where sandy soils are present.

For walls retaining more than about 3m additional lateral support in the form or external anchors or internal props will be required, which must be installed progressively as each restraining point is uncovered.

Free-standing cantilevered contiguous or pile shoring walls may be provisionally be designed based on a triangular earth pressure distribution using an active earth pressure coefficient, K_a, of at least 0.35 and a bulk unit weight of 20kN/m^3. Where it is desired to limit horizontal surface movements due to the presence of movement sensitive structures, a higher lateral earth pressure coefficient of at least 0.55 should be adopted.

For propped or anchored shoring walls, a rectangular lateral earth pressure distribution of 4H kPa (where H is the retained height in metres) may be provisionally be adopted assuming no movement sensitive structures are present. Where movements are to be kept low, this distribution should be increased to 6HkPa.

The above coefficients and pressures assume horizontal backfill surfaces and any inclined backfill should be taken as a surcharge load. All surcharge loads should be allowed for in the design, plus full hydrostatic pressures unless measures are undertaken to provide complete and permanent drainage behind the wall.

Further advice on anchors can be provided as part of the detailed geotechnical investigation.

7.1.5 **Footings**. to reduce the risk of differential settlements and for the expected high column loads, the proposed building should be uniformly supported on footings founded within the rock. Where rock is encountered during excavation, shallow pad and strip footings will be feasible. Where the rock level drops off towards the creek, CFA piles will be required.

The allowable bearing pressure appropriate for the rock would start at 700kPa for extremely weathered rock, but would increase as better quality rock is encountered. We would expect that an allowable bearing pressure of at least 1000kPa would be appropriate for rock of at least very low strength. Rock of the Newport Formation is generally found to be of variable quality and higher bearing pressures may not be possible within the rock. However, the bearing pressure should be assessed from the results of cored boreholes drilled as part of the detailed geotechnical investigation and if good quality rock is encountered higher bearing pressures may be possible.

For piles, shaft adhesion of 10% of the above allowable bearing pressure may be used for the design of piles in compression, or 5% for tension loads, below a nominal socket of at least 0.3m. This assumes that the sides have achieved Class R2 roughness. R2 roughness is defined as Grooves of 1-4mm, width greater than 2mm at spacing of 50mm to 200mm.

If rock proves to be so deep at the northern end of the building that it is cost prohibitive to found the entire structure uniformly on rock, the designer could consider differential founding conditions if sufficient full height movement joints can be incorporated into the structures between portions founded on rock and portions of the structure founded in soil. Isolated piles in silty clay or sandy clay of at least very stiff strength can be provisionally designed for an allowable end bearing pressure of 400kPa and a shaft friction of 30kPa. Pile group reduction factors should be applied in accordance with engineering principals. Testing below the design pile toes level must be carried out to confirm the quality of the soils and to check for weak layers that may reduce the bearing capacity or potentially compressible layers that may cause long term settlement. If piles are to be founded within the soils investigation of the soils by CPTs should be carried out to profile the soil in detail.

7.1.6 **Basement Floor Slabs.** Any subgrade that is to support slabs or pavements should be prepared by proof rolling and replacement of any unstable areas detected during proof rolling with engineered fill. All fill should be placed as engineered fill with compaction control. Provided it is just for lightly loaded trafficable slabs, engineered fill may comprise sandy site won soil or ripped rock, free from deleterious inclusions. Such fill should be placed in 200mm loose thickness layers compacted to a density of at least 98% of Standard Maximum Dry Density (SMDD) and within 2% of Standard Optimum Moisture Content (SOMC).

The basement slab should be designed with a subbase layer of at least 100mm thickness of crushed rock to RMS QA specification 3051 unbound base material (or other approved good quality and durable fine crushed rock), which is compacted to at least 100% of Standard Maximum Dry Density (SMDD). This subbase layer will provide a separation between any sandstone subgrade areas and the slab and provide a uniform base for the slab.

Perimeter subsoil drains should be provided and will need to be connected to a sump and pump, or gravity drain with a non-return valve with respect to potential creek flood levels. If seepage is encountered then drainage may also need to be constructed below the basement slab, but this should initially be assessed once the groundwater levels are known and then confirmed by inspection of the completed excavation by the hydraulic consultant.

7.1.7 The guidelines for Hillside Construction given in Appendix B should also be adopted.

7.2 Conditions Recommended to the Detailed Design to be Undertaken for the Construction Certificate

7.2.1 All structural design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.2 All hydraulic design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.3 All landscape design drawings must be reviewed by the geotechnical engineer who should endorse that the recommendations contained in this report have been adopted in principle.

7.2.4 An excavation/retention methodology must be prepared prior to bulk excavation commencing. The methodology must include but not be limited to proposed excavation techniques, the proposed excavation equipment, excavation sequencing, geotechnical inspection intervals or hold points, vibration monitoring procedures, monitor locations, monitor types, contingency plans in case of exceedances.

7.2.5 The excavation/retention methodology must be reviewed and approved by the geotechnical engineer.

7.3 Conditions Recommended During the Construction Period

7.3.1 The geotechnical engineer must inspect all footing excavations prior to placing reinforcement or pouring the concrete.

7.3.2 The approved excavation/retention methodology must be followed.

7.3.3 Bulk excavations through rock must be progressively inspected by the geotechnical engineer as excavation proceeds. We recommend inspections at 1.5m vertical depth intervals and on completion.

7.3.4 Proposed material to be used for backfilling behind any retaining walls must be approved by the geotechnical engineer prior to placement.

7.3.5 Compaction density of the backfill material must be checked by a NATA registered laboratory to at least Level 2 in accordance with, and to the frequency outlined in, AS3798, and the results submitted to the geotechnical engineer.

7.3.6 The geotechnical engineer must inspect all subsurface drains prior to backfilling.

7.3.7 An 'as-built' drawing of all buried services at the site must be prepared (including all pipe diameters, pipe depths, pipe types, inlet pits, inspection pits, etc).

7.3.8 All rock anchors must be proof-tested to 1.3 times the working load. In addition, the anchors must be subjected to lift-off testing no sooner than 24 hours after locking off at the working load. The proof-testing and lift-off tests must be witnessed by the geotechnical engineer. The anchor contractor must provide the geotechnical engineer with all field records including anchor installation and testing records.

7.3.9 The geotechnical engineer must confirm that the proposed basement construction has been completed in accordance with the geotechnical reports.

7.3.10 Following demolition of the derelict house, the geotechnical engineer must reinspect the rock outcrops and any stabilisation measures that may be recommended must be installed.

We note that all above Conditions must be complied with. Where this has not been done, it may not be possible for Form 3, which is required for the Occupation Certificate to be signed.

7.4 Conditions Recommended for Ongoing Management of the Site/Structure(s)

The following recommendations have been included so that the current and future owners of the subject property are aware of their responsibilities:

7.4.1 All existing and proposed surface (including roof) and subsurface drains must be subject to ongoing and regular maintenance by the property owners.

7.4.2 The existing rock outcrops in the south-western corner must be inspected by an experienced engineer/engineering geologist at 10 yearly intervals; including provision of a written report confirming scope of work completed and identifying any required remedial measures.

7.4.3 No cut or fill in excess of 0.5m (e.g. for landscaping, buried pipes, retaining walls, etc), is to be carried out on site without prior consent from Northern Beaches Council.

7.4.4 Where the structural engineer has indicated a design life of less than 100 years then the structure and/or structural elements must be inspected by a structural engineer at the end of their design life; including a written report confirming scope of work completed and identifying the required remedial measures to extend the design life over the remaining 100 year period.

8 OVERVIEW

The main geotechnical issue for this site is the variable subsurface conditions, and in particular the variable depth of the rock. Rock is exposed close to the proposed building and was encountered on the southern side within the depth of the proposed excavation. However, with the majority of the building footprint the depth of the rock is not known, but is at depths of more than 16m towards the north-eastern corner based on the boreholes drilled to date.

Excavation for the basement level, to maximum depths of about 6.3m (in the south-western corner) will encounter sandstone bedrock. Elsewhere at basement level we expect that sandy clay and clayey sand subgrade of very stiff to hard strength or perhaps loose relative density closest to the creek, will be exposed. Therefore, part of the structure will be supported on footings founded within rock and to prevent potential differential settlement issues preferably the entire building should be founded on rock. Shallow footings may be appropriate where rock is encountered, but piles will be required where rock is not exposed. We understand that column loads of 2,000kN are expected and for such loads piles founded within the rock would also be required as the soils would be of limited bearing capacity. The depth of the piles will be quite significant given the depth to rock of more than 16m and large capacity piling rigs will be required. Conventional bored piers are unlikely to be feasible due to the sandy soils and expected groundwater and auger, grout injected (CFA) piles will be required.

While the proposed basement excavation is far enough away from other structures to accommodate short term batters, such batters would only be appropriate where the excavations are shallow. For the deeper excavation, shoring walls will be required and it may be more efficient to install shoring walls around the entire basement perimeter to prevent double handling of material by either stockpiling excavated material for use as backfill or removing excavated material from site and importing backfill. The installation of shoring walls will also increase the space available for other site activities.

In order to assess these issues in more detail a detailed geotechnical investigation of the site must be carried out. The comments and recommendations provided within this report are preliminary only based on the limited information available and may be used for preliminary planning and initial design of the development.

More specific comments and recommendations must be provided as part of the detailed geotechnical investigation to allow final design.

It is possible that the subsurface soil, rock or groundwater conditions encountered during construction may be found to be different (or may be interpreted to be different) from those inferred from our surface observations in preparing this report. Also, we have not had the opportunity to observe surface run-off patterns during heavy rainfall and cannot comment directly on this aspect. If conditions appear to be at variance or cause concern for any reason, then we recommend that you immediately contact this office.

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.

Reference 2: MacGregor, P, Walker, B, Fell, R, and Leventhal, A (2007) *'Assessment of Landslide Likelihood in the Pittwater Local Government Area'*, Australian Geomechanics, Vol 42, No 1, March 2007, pp183-196.

TABLE A
SUMMARY OF RISK ASSESSMENT TO PROPERTY

POTENTIAL LANDSLIDE HAZARD	A	B	C	D
	Instability of Hillside Slopes Upslope of Proposed Access Road (maximum of about 18°)	Instability of Creek Bank on the northern Side of the Access Road	Instability of Rock Outcrops	Instability of the Proposed Basement Retaining Walls
Assessed Likelihood	Unlikely	Likely	Rare	Rare
Assessed Consequence	Minor	Insignificant	Insignificant	Medium
Risk	Low	Low	Very Low	Low
Comments	Soils are likely to be of limited depth over a stepped rock profile. Any instability is unlikely to extend beyond the proposed access road and impact the apartment building.	Instability unlikely to impact apartment building.	Detached/failed wedges or boulders would not tumble to the apartment development area on such moderate and gentle slopes.	Assumes walls are engineer designed and well-constructed.

Estimated property price: $10,000,000 (Undeveloped)

TABLE B
SUMMARY OF RISK ASSESSMENT TO LIFE

POTENTIAL LANDSLIDE HAZARD	A	B	C	D
Assessed Likelihood	Unlikely	Likely	Rare	Rare
Indicative Annual Probability	10^{-4}	10^{-2}	10^{-5}	10^{-5}
Persons at risk	Persons walking on hillside or roadway	Persons walking beside creek	Persons clambering on rocks	Persons in building
Duration of Use of area Affected (Temporal Annual Probability)	Say 5mins/day $= 3.5 \times 10^{-3}$	Say 5mins/day $= 3.5 \times 10^{-3}$	Say 10mins/month $= 2.3 \times 10^{-4}$	Say 12 hours/day = 0.5
Probability of not Evacuating Area Affected	0.5	0.5	0.8	0.5 (warning in the form of cracking likely)
Spatial Probability	0.3	0.1	0.1	0.05
Vulnerability to Life if Failure Occurs Whilst Person Present	0.5	0.1	0.8	0.5 (full building collapse unlikely)
Risk for Person Most at Risk	2.6×10^{-8}	1.8×10^{-7}	1.5×10^{-10}	6.3×10^{-8}
Total Risk for Person Most at Risk	2.7×10^{-7}			

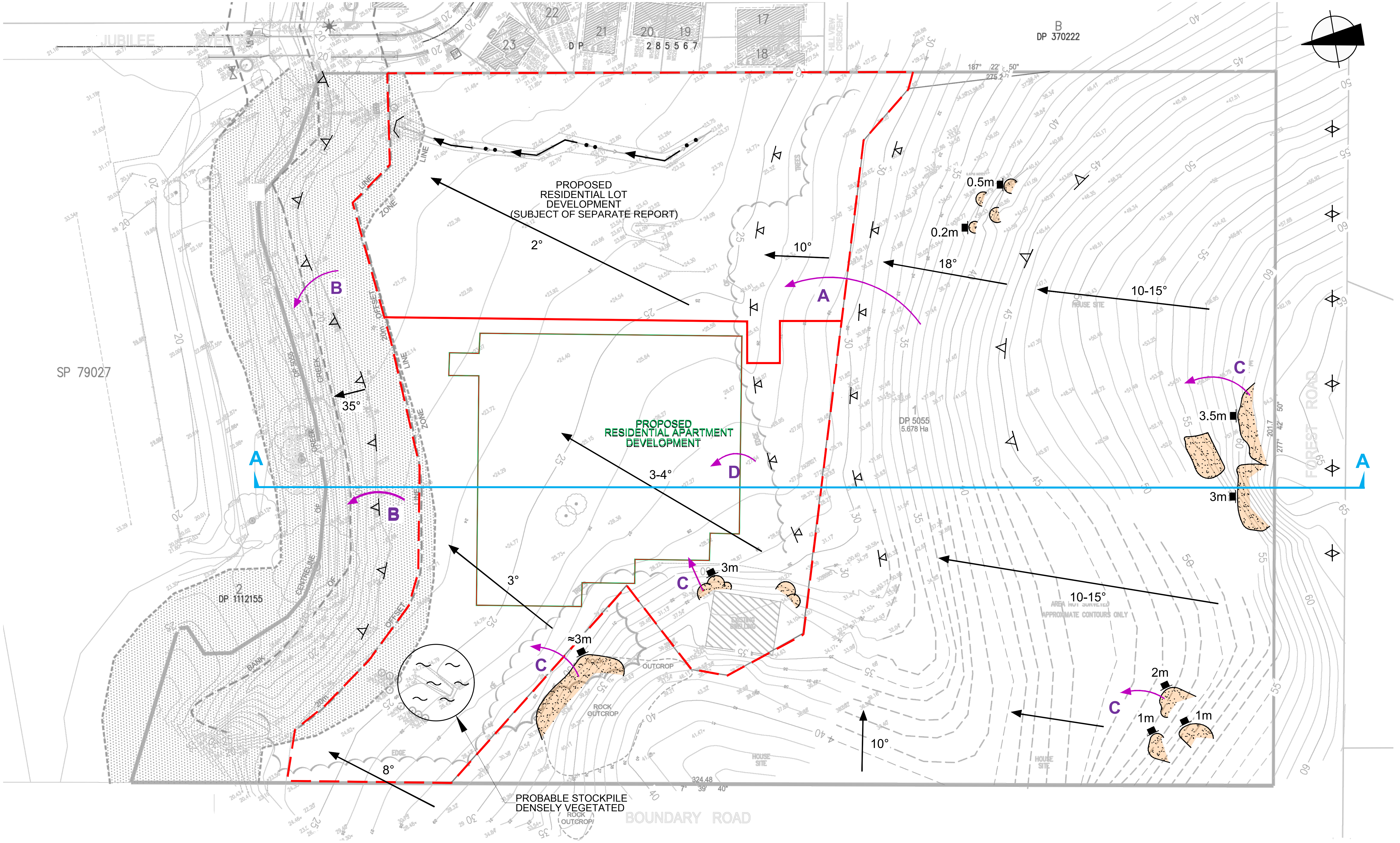
AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

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

Title:	SITE LOCATION PLAN
Location:	8 FOREST ROAD, WARRIEWOOD, NSW
Report No: 33371BMrpt2	Figure No: 1

JKGeotechnics

PLOT DATE: 7/10/2020 1:44:07 PM DWG FILE: Y:\33000's\33371BM WARRIEWOOD\CAD\33371BMRPT2.DWG



Legend

B Geotechnical Hazard

0 10 20 30 40 50
SCALE 1:1000 @A3 METRES

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

Title: **GEOTECHNICAL MAPPING SKETCH SHOWING POTENTIAL HAZARDS**

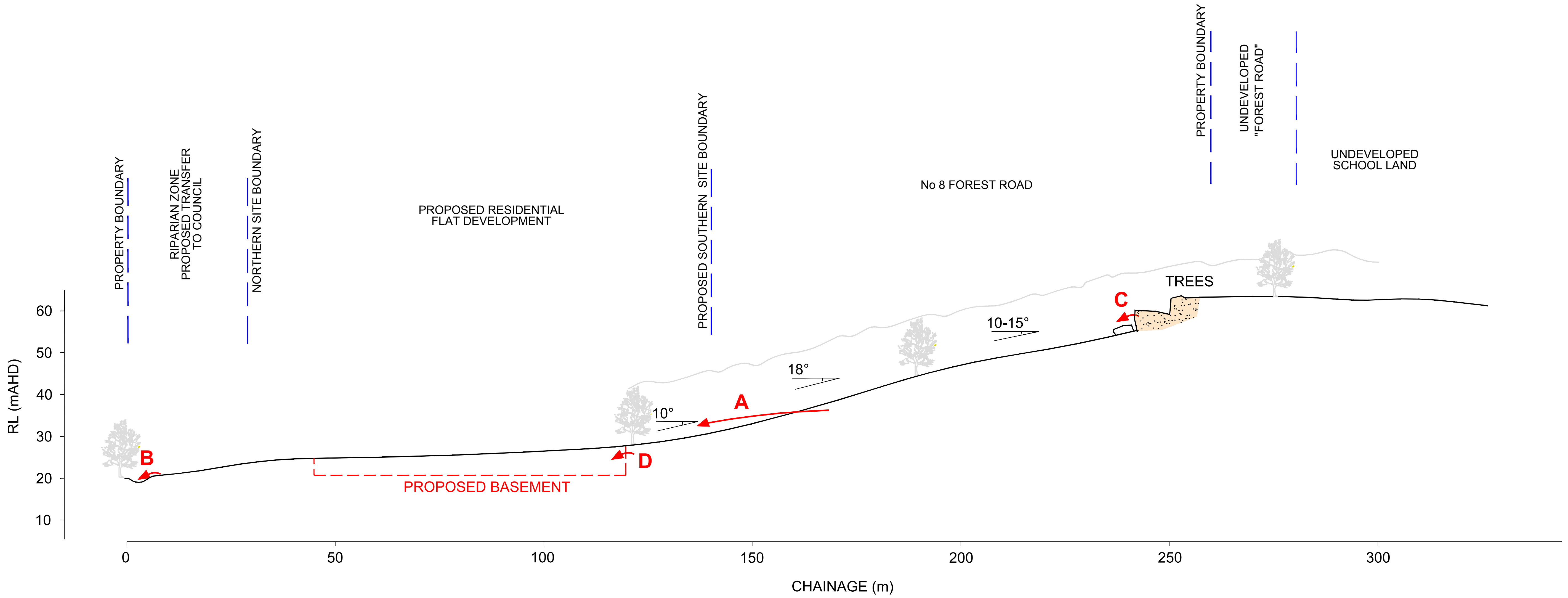
Location: 8 FOREST ROAD, WARRIEWOOD, NSW

Report No: 33371BMrpt2

Figure No: 2

JKGeotechnics

PLOT DATE: 7/10/2020 1:05:58 PM DWG FILE: Y:\33000's\33371BM WARRIEWOOD\CAD\33371BMRPT1.DWG



0 10 20 30 40 50 SCALE 1:1000 @A3 METRES	Title: **SECTION A-A LOOKING EASTWARDS**	
	Location: 8 FOREST ROAD, WARRIEWOOD, NSW	
	Report No: 33371BMrpt2	Figure No: 3
This plan should be read in conjunction with the JK Geotechnics report.	JKGeotechnics	

PLOT DATE: 7/10/2020 1:45:04 PM DWG FILE: Y:\33000'S\33371BM WARRIEWOOD\CAD\33371BMRPT2.DWG

LEGEND

- BOREHOLE (JK GEOTECHNICS, 2005)
- BOREHOLE (CARDNO, 2015)
- TEST PIT (CARDINO 2015)
- >2.3 DEPTH TO ROCK (m)

AERIAL IMAGE SOURCE: MAPS.AU.NEARMAP.COM

0 10 20 30 40 50
SCALE 1:1000 @A3 METRES

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

Title:	PREVIOUS INVESTIGATION LOCATION PLAN
Location:	8 FOREST ROAD, WARRIEWOOD, NSW
Report No: 33371BMrpt2	Figure No: 4

JKGeotechnics

PLOT DATE: 7/10/2020 1:45:45 PM DWG FILE: Y:\33000'S\33371BM WARRIEWOOD\CAD\33371BMRPT2.DWG

TOPOGRAPHY

Symbol *Ground Profile*

convex
concave
} well defined or angular break of slope

convex
concave
} poorly defined or smooth change of slope

breaks of slope
changes of slope
} convex and concave too close together to allow the use of separate symbols

sharp
rounded
} ridge crest

3 Cliff or escarpment or sharp break 40° or more (estimated height in metres)

15 Uniform Slope
10 Concave Slope
8 Convex Slope
} Slope direction and angle (Degrees)

Top
Bottom
} Cut or fill slope, arrows pointing down slope

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

J —— J Major joint in rock face
200 (opening in millimetres)

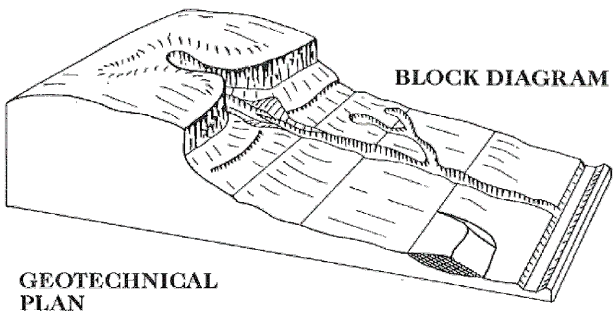
– T – T – Tension crack
10 (opening in millimetres)

Masonry or concrete wall

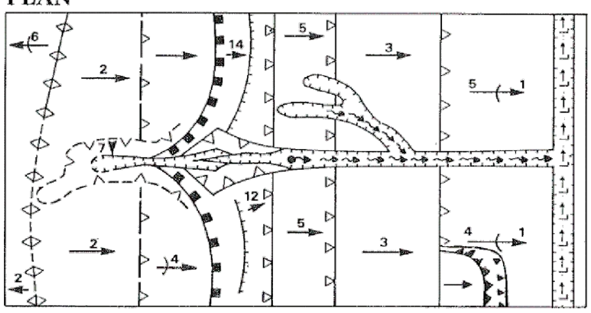
Ponding water

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:	8 FOREST ROAD, WARRIEWOOD, NSW	
Report No: 33371BMrpt2		Figure No: 5

JKGeotechnics

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

PLOT DATE: 7/10/2020 1:45:57 PM DWG FILE: Y:\33000's\33371BM WARRIEWOOD\CAD\33371BMRPT2.DWG

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	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. These are two main interpretations: (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.

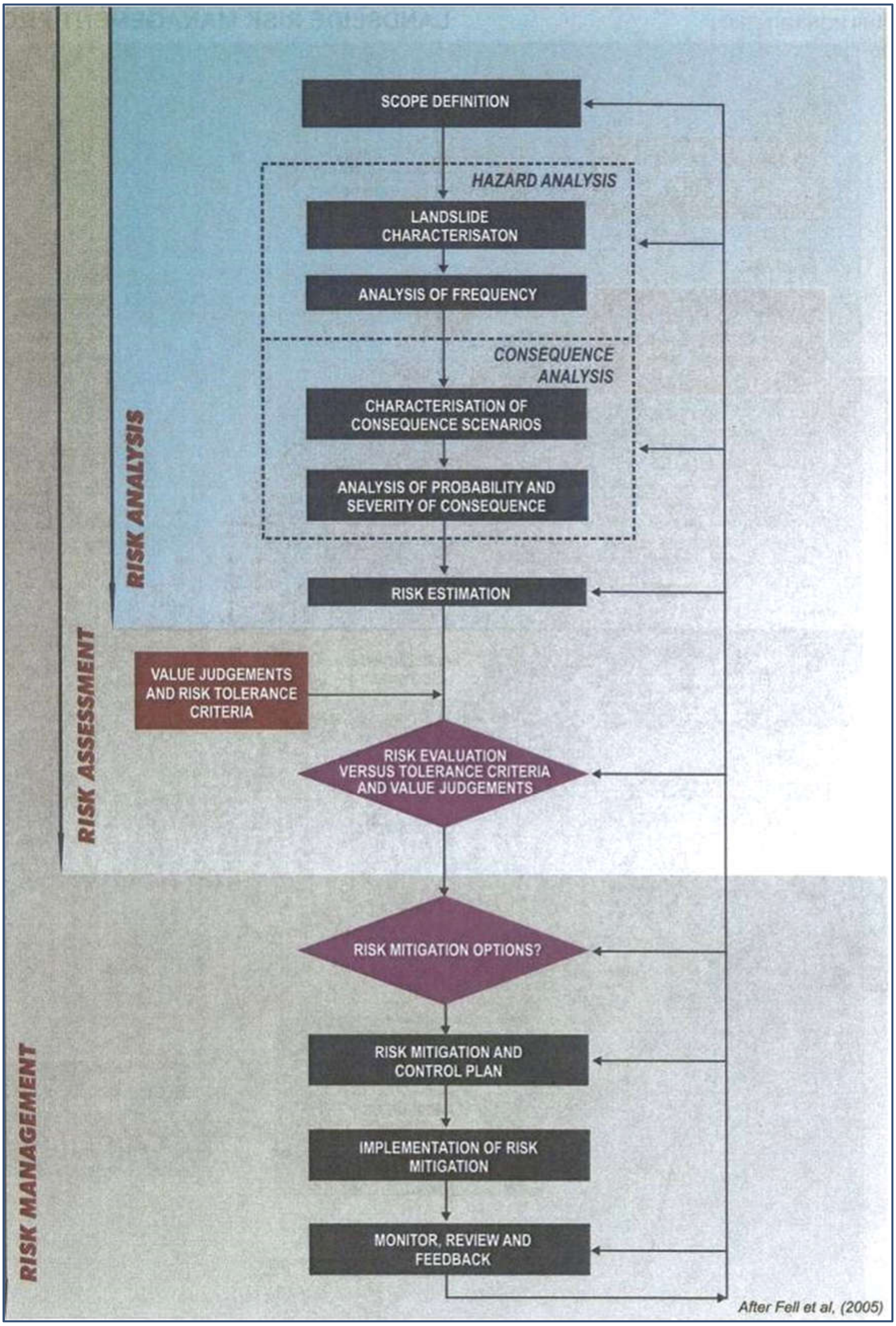


FIGURE A1: Flowchart for Landslide Risk Management.

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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. The 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 series 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.

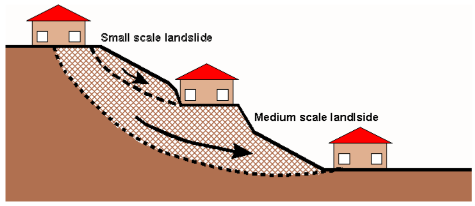


Figure 1

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.

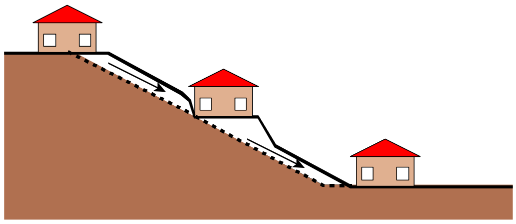


Figure 2

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.

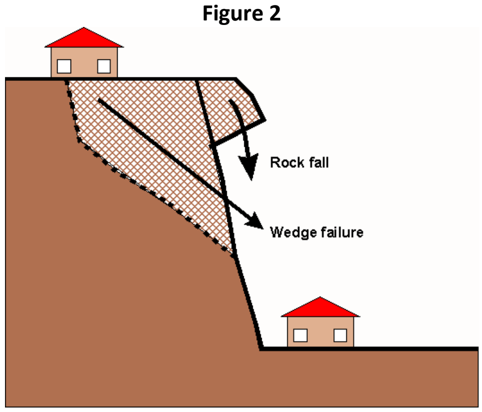


Figure 3

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.

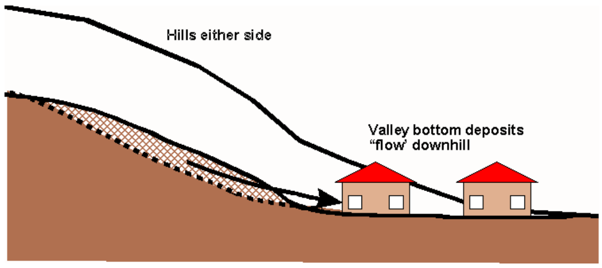


Figure 4

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
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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

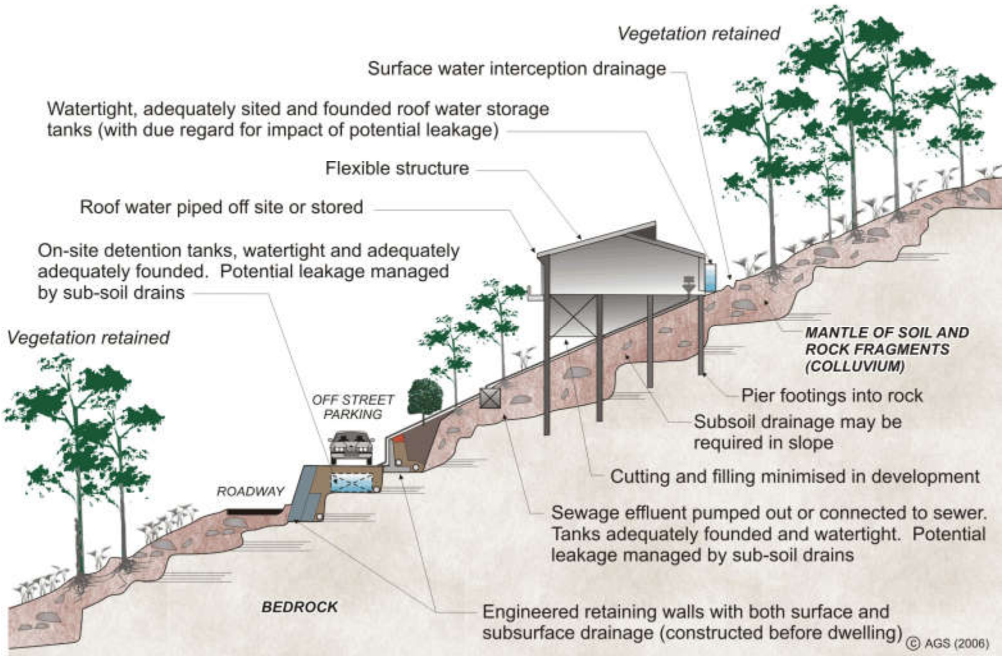
	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having 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.

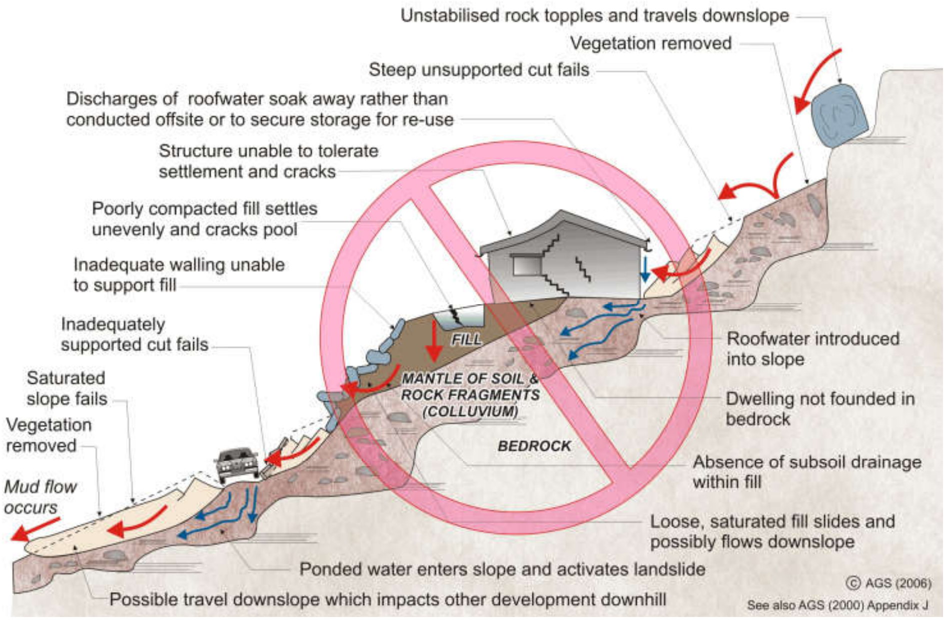
Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

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- GeoGuide LR3 - Soil Slopes
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APPENDIX C

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No. **8**
1/1

Client: [redacted]
Project: SECTOR 5, WARRIEWOOD VALLEY URBAN LAND RELEASE
Location: JUBILEE AVENUE AND FOREST ROAD, WARRIEWOOD, NSW

Job No. 19312VB **Method:** SPIRAL AUGER JK550 **R.L. Surface:** ≈ 27.0m
Date: 18-3-05 **Datum:** AHD
Logged/Checked by: N.E.S./

Groundwater Record	Samples (ES, U50, DB, DS)	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLET-ION	ES		0		TOPSOIL: Silty sand, fine to medium grained, dark grey, with rootlets.	M			GRASS COVER
				SP	SAND: fine to medium grained, light grey.	M	(L)		COLLUVIUM
	DS	N > 22 2,9, 13/100mm REFUSAL		SC	CLAYEY SAND: fine to medium grained, orange brown mottled grey, with XW sandstone gravel.	M	(MD)		
	DS		1	-	SANDSTONE BOULDER: fine to coarse grained, light grey mottled orange brown.	DW	VL-L		MODERATE 'TC' BIT RESISTANCE WITH LOW BANDS
			2	CL	SILTY CLAY: medium plasticity, light grey, with fine grained sand.	MC>PL	H		COLLUVIUM SOIL STRENGTH 'TC' RESISTANCE
	DS	N = 14 4,6,8	3					440 520 480	
			4	CL	SANDY CLAY: medium plasticity, light grey, fine grained sand.		VSt -H		
	DS	N = 19 5,8,11						430 370 480	
	DS		5		as above, but orange brown mottled light grey.				
			6		END OF BOREHOLE AT 6.0m				
			7						

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No.
9
1/1

BOREHOLE LOG

Client: [redacted]
Project: SECTOR 5, WARRIEWOOD VALLEY URBAN LAND RELEASE
Location: JUBILEE AVENUE AND FOREST ROAD, WARRIEWOOD, NSW

Job No. 19312VB **Method:** SPIRAL AUGER JK550 **R.L. Surface:** ≈ 25.0m
Date: 18-3-05 **Datum:** AHD
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Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0		TOPSOIL/FILL: Silty sand, fine to medium grained, grey, with rootlets.	M			RUBBLE ON SURFACE
	N = 5 2,2,3		SM	SILTY SAND: fine to medium grained, orange brown.	M	L		ALLUVIAL
	N = 20 5,8,12	1	CL/SC	SANDY CLAY/CLAYEY SAND: medium plasticity, fine to medium grained, orange brown.	M/ MC>PL	MD/ VSt-H	380 380 400 390	
	N = 27 7,14,13	3				MD/ VSt	330 260 250	
		4		as above, but grey mottled orange brown.				
	N = 13 4,6,7					MD/H	530 450 430	
		6		END OF BOREHOLE AT 6.0m				
		7						