# 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 7 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 subdivision at 8 Forest Road, Warriewood, NSW

**Report Date**: 7 October 2020 **Report Ref No**: 33371BMrpt1

**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-31 to 33, Amendment A, dated 6/2/2016)

~~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 Subdivision at 8 Forest Road, Warriewood, NSW

**Report Date**: 7 October 2020 **Report Ref No**: 33371BMrpt1

**Author**: Matthew Pearce

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

**Please mark appropriate box**

- [x] Comprehensive site mapping conducted 1 October 2020 (date)
- [x] Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- [ ] Subsurface investigation required
  - [x] No Justification: Sufficient previous investigation information to characterise subsurface conditions...
  - [ ] Yes Date conducted ……………………………………………
- [x] Geotechnical model developed and reported as an inferred subsurface type-section
- [x] Geotechnical hazards identified
  - [x] Above the site
  - [x] On the site
  - [x] Below the site
  - [x] Beside the site
- [x] Geotechnical hazards described and reported
- [x] Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - [x] Consequence analysis
  - [x] Frequency analysis
- [x] Risk calculation
- [x] Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- [x] 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.*
- [x] Design Life Adopted:
  - [x] 100 years
  - [ ] Other …………………………………………… specify
- [x] Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- [x] 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 | [signature] |
| Name | Daniel Bliss |
| Chartered Professional Status | MIEAust CPEng |
| Membership No. | 969495 |
| Company | *JK Geotechnics Pty Ltd.* |

REPORT TO

**WARRIEWOOD VALE PTY LTD**

ON

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

FOR

**PROPOSED RESIDENTIAL SUBDIVISION**

AT

**8 FOREST ROAD, WARRIEWOOD, NSW**

Date: 7 October 2020
Ref: 33371BMrpt1

**JKGeotechnics**
**www.jkgeotechnics.com.au**

**T: +61 2 9888 5000**
**JK Geotechnics Pty Ltd**
**ABN 17 003 550 801**

Report prepared by:

**Matthew Pearce**
Associate | Geotechnical Engineer

Report reviewed by:

**Daniel Bliss**
Principal | Geotechnical Engineer

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

## DOCUMENT REVISION RECORD

| Report Reference | Report Status | Report Date |
|---|---|---|
| 33371BMrpt1 | Final Report | 7 October 2020 |
| | | |
| | | |

# Table of Contents

# 1 INTRODUCTION

This report presents the results of our geotechnical risk assessment of the proposed residential subdivision 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 21 May 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.

Details of the proposed development are presented in Section 5 below. In summary however, it is proposed to subdivide the property into two main areas for staged development, comprising 18 residential allotments in the north-eastern corner and a residential apartment building to the west. The forested hillside portion of the site to the south and west will largely remain untouched, apart from along the edge for construction of a loop road. We also note the Riparian Zone along the northern edge of the site (25m out from the creek) will be transferred to council.

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 north-eastern portion of the site comprises the valley floor that slopes down to the north-east at about 3°. This portion of the site is about 110m (north-south) by 140m (east-west) in size. At the time of the walkover this portion of the site was unoccupied and grass covered. Where exposed, the surface material appeared to be silty sand and gravel fill.
- An unlined drainage culvert is located towards the eastern side of the site meandering northwards.
- To the south-west of the gently sloping valley floor 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 gently sloping portion of the site towards the above-mentioned culvert on the eastern side of the property, which then fell to the north.
- The southern and south-western portions of the site comprise hillsides sloping up at about 20° from the valley floor, flattening off to about 10° to 15° towards the crest near the southern boundary. The hills are covered in native forest with variably dense undergrowth and occasional outcrops of sandstone bedrock towards the crest.
- Along the northern boundary of the site 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 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. The test pits and boreholes encountered a nominal depth of topsoil or fill overlaying sandy soils and then generally natural sandy clay or clayey sand soils. Insitu testing was very limited. At one location there was a natural topsoil layer beneath colluvial (slope-wash) sandy soil. 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 with regular SPT tests within the now 8 Forest Road site, including three boreholes (BH1, BH2 and BH3) along the eastern side of the proposed residential lots and two boreholes (BH8 and BH9) within the proposed apartment site. Copies of the borehole logs are attached in Appendix C. In summary, the boreholes also encountered nominal depths of fill and/or topsoil overlying sand or silty sand of loose relative density and then generally alluvial clayey sand/sandy clay extending to at least the termination depth of the boreholes (6m). The relative density of the alluvial soils was generally loose or medium dense. In BH3 however, residual silty clay was encountered over sandstone at a depths of 1.5m. The sandstone was assessed to be of extremely low to very low strength to the termination depth of the borehole at 4.5m.

Groundwater seepage was encountered in most of the J&K boreholes at depths of about 4m to 4.5m.

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 lots (as per drawing DA-31) 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.

## 5 PROPOSED DEVELOPMENT

We understand from the provided architectural drawings by Jackson Teece (Project No 2019068, Drawing Nos DA-31 to 33, Amendment A, dated 6/2/2016), that the proposed development will comprise the following:

- Subdivision of 8 Forest Road to form two main areas for development, one being for a residential apartment development (subject of a separate DA) and one being for predominantly residential (house sized) lots and ancillary infrastructure.
- The southern portion of the existing property (currently forested hillside) will be subdivided as a "RU2 Residential Zone" and will be largely untouched, apart from the base of the hillside where 'ancillary' infrastructure will be required, such as access roads, stormwater drainage, etc.
- The riparian zone along the northern fringe of the site will be allocated for creek-line rehabilitation.
- The eastern area of the valley floor will be subdivided into 18 lots including:
    - Lot 1 as a communal park.
    - Lots 2 to 18 for residential houses, each of about 27m x 12m to 15m wide.
    - An accessway road extending north-south, linking to a new 'loop' access road at either end.
    - A detention basin beyond the looping access road to the north.
    - A substation offset from the south-western corner of Lot 8.
- Construction of a loop road off Jubilee Avenue on the north-eastern corner of the site surrounding the residential lots and the residential apartment building lot.
- Demolition of the derelict house beyond the south-western corner of the loop access road and conversion of this area into a community 'passive' recreational area
- Construction of a second detention basin in the north-western corner of the property.

The footprint and outline of the proposed development as described above is indicated on Figures 2 and 4.

## 6 GEOTECHNICAL ASSESSMENT

The property exhibited no signs of instability. The majority of the area that will be subdivided for future development has gentle slopes generally of about 2°. The proposed southern loop road, and the southern end of Lots 8, 9, 16 and 17 and the future apartment development areas will be on gentle to moderate slopes of up to about 10°. The hillside upslope from the proposed future development is about 18°, but due to several exposures of sandstone bedrock in this steeper portion of the hillside we infer relatively shallow soil cover in this area of the property.

The limited number of rock outcrops present greater than about 1m in height 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.

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 subdivisional development to be the following:

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

B Instability of the creek bank along the northern side of the site.

C Instability of the rock outcrops exposed on the hillside.

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 given below are for the proposed subdivisional works. A separate report is being prepared for the proposed residential apartment building, Ref: 33371BMrpt2, and that provides recommendations for design and construction of the apartment building.

7.1.2 The majority of the proposed residential lots will be underlain by some fill or topsoil, and predominantly alluvial soils. Detailed geotechnical investigation, including Site Classification in accordance with AS2870 (Residential Slabs and Footings) should be carried out for the lots to allow detailed design of the footings once the exact nature of the individual development is known. as a guide, shallow strip footings or raft slab footing systems are likely to be feasible for the majority of lots if not all of them, provided scour associated with creek flooding is not an issue. The footing designer should check with the Hydraulic/Civil Engineers regarding scour potential.

For any houses that need to be designed for occasional creek flooding events, consideration could be given to adoption of screw piles, where the piles are extended beyond the potential scour depth. Screw piles can also be used regardless of creek flooding, to found on higher density soils, where very loose or other problematic soils may be present. Traditional bored piles are unlikely to be suitable where cohesionless sands are present although if such sands are limited to the upper soil profile then they may be feasible with pier liners to prevent collapse.

7.1.3 A geotechnical investigation should also be carried out for the proposed roadways, including sampling and testing to assess the CBR value appropriate for design. As part of that investigation detailed recommendations on preparation of the pavement subgrade, placement of any fill required and construction of the road should be provided, but preliminary comments on these are given below.

7.1.4 Prior to construction of on grade slabs, including raft slabs, and pavements, appropriate subgrade preparation must be carried out. All topsoil or deleterious material should be stripped and set aside for landscaping or disposal.

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. Rolling for proof rolling and fill compaction should be carried out with care where in close proximity of existing houses. The distance should be assessed on a case by case basis but is likely to include all the lots on the eastern side of the site. The vibrations generated by the roller may need to be reduced or the rolling carried out in static mode only. The proof roll should be in the presence of an experienced geotechnical engineer engaged independently of the earthworks contractor to prevent conflicts of interest.

Any fill should be placed as engineered fill with compaction control. Provided it is just for residential lots or lightly loaded trafficable slabs, engineered fill may comprise sandy site won soil or ripped rock, free from deleterious inclusions. For roadways, hard durable imported gravel, such as crushed sandstone, should be used. 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).

7.1.5 No significant excavation is anticipated for the subdivisional works except perhaps minor cut and fill for the proposed southern loop road and perhaps the southern most residential lots. Excavation is likely to also be required for services.

All excavation should be in accordance with the current Safe Work Australia Code of Practice-Excavation Work.

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, if encountered, 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.

All surcharge and footing loads must be kept well clear of the excavation perimeter.

7.1.6 Where required, low height retaining walls of no more than 3m should be designed using the following parameters:

– For cantilever walls, adopt a triangular lateral earth pressure distribution and an 'active' earth pressure coefficient, $K_a$, of 0.3, for the retained height, assuming a horizontal backfill surface.
– A bulk unit weight of $20kN/m^3$ should be adopted for the soil profile.
– Any surcharge affecting the walls (e.g. sloping backfill, traffic loading, live loading, compaction stresses, etc) should be allowed in the design.
– The retaining walls should be provided with complete and permanent drainage of the ground behind the walls. The subsoil drains should incorporate a non-woven geotextile fabric (e.g. Bidim A34), to act as a filter against subsoil erosion.
– Toe resistance of the wall may be achieved by keying the footing into bedrock, if present. An allowable lateral stress of 200kPa may be adopted for design. Where only soils are present, adopt a passive earth pressure coefficient, Kp, of 3.0.

7.1.7 The guidelines for Hillside Construction given in Appendix B should also be considered, especially for the lots at the southern end of the site encroaching on the 10° slopes.

## 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.

### 7.3 Conditions Recommended During the Construction Period

7.3.1 The geotechnical engineer should witness the proof rolling of subgrade

7.3.2 The geotechnical engineer should inspect a representative portion of footing excavations prior to placing reinforcement or pouring the concrete.

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

7.3.4 Compaction density of any fill for the proposed road or backfill behind retaining walls must be checked by a NATA accredited laboratory to at least Level 2 in accordance with, and to the frequency outlined in, AS3798, and the results submitted to the geotechnical engineer.

7.3.5 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) that relate to retaining structures at the southern end of the site.

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 within the site 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 the southern or western fringes of the valley floor 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

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 |
|---|---|---|---|
| | Instability of Hillside Slopes Upslope of Proposed Access Road (maximum of about 18°) | Instability of Creek Bank along the Northern side of the Site | Instability of Rock Outcrops |
| Assessed Likelihood | Unlikely | Likely | Rare |
| Assessed Consequence | Minor | Insignificant | Insignificant |
| Risk | Low | Low | Very 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. | Unlikely to be any infrastructure adjacent to creek. If this is not the case, the creek banks could be lined and stabilised to further reduce the risk. | Detached/failed wedges or boulders would not tumble to the development areas on such moderate and gentle slopes. |

Estimated property price: $10,000,000

**TABLE B**
**SUMMARY OF RISK ASSESSMENT TO LIFE**

| POTENTIAL LANDSLIDE HAZARD | A | B | C |
|---|---|---|---|
| Assessed Likelihood | Unlikely | Likely | Rare |
| Indicative Annual Probability | $10^{-4}$ | $10^{-2}$ | $10^{-5}$ |
| Persons at risk | Persons walking on hillside or roadway | Persons walking beside creek | Persons walking within forested hillside |
| Duration of Use of area Affected (Temporal Annual Probability) | Say 5mins/day<br>= $3.5 \times 10^{-3}$ | Say 5mins/day<br>= $3.5 \times 10^{-3}$ | Say 10mins/month<br>= $2.3 \times 10^{-4}$ |
| Probability of not Evacuating Area Affected | 0.5 | 0.5 | 0.8 |
| Spatial Probability | 0.3 | 0.1 | 0.1 |
| Vulnerability to Life if Failure Occurs Whilst Person Present | 0.5 | 0.1 | 0.8 |
| Risk for Person Most at Risk | $2.6 \times 10^{-8}$ | $1.8 \times 10^{-7}$ | $1.5 \times 10^{-10}$ |
| Total Risk for Person Most at Risk | $2 \times 10^{-7}$ | | |

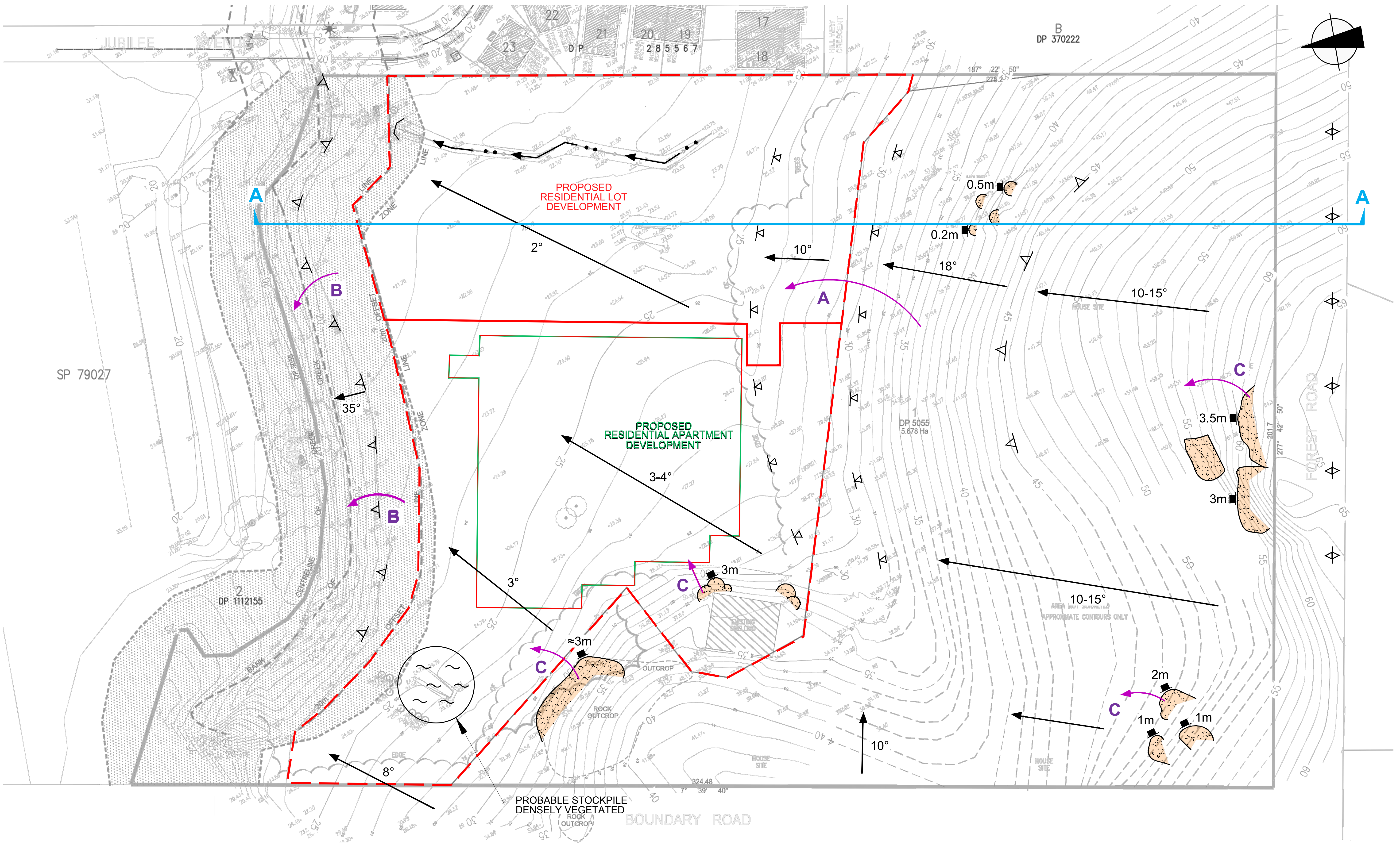

PLOT DATE: 7/10/2020 1:05:33 PM DWG FILE: Y:\33000's\33371BM WARRIEWOOD\CAD\33371BMRPT1.DWG

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: 33371BMrpt1 | Figure No: 1 |

JKGeotechnics




Legend

B Geotechnical Hazard

SCALE 1:1000 @A3 METRES

0 10 20 30 40 50

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

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

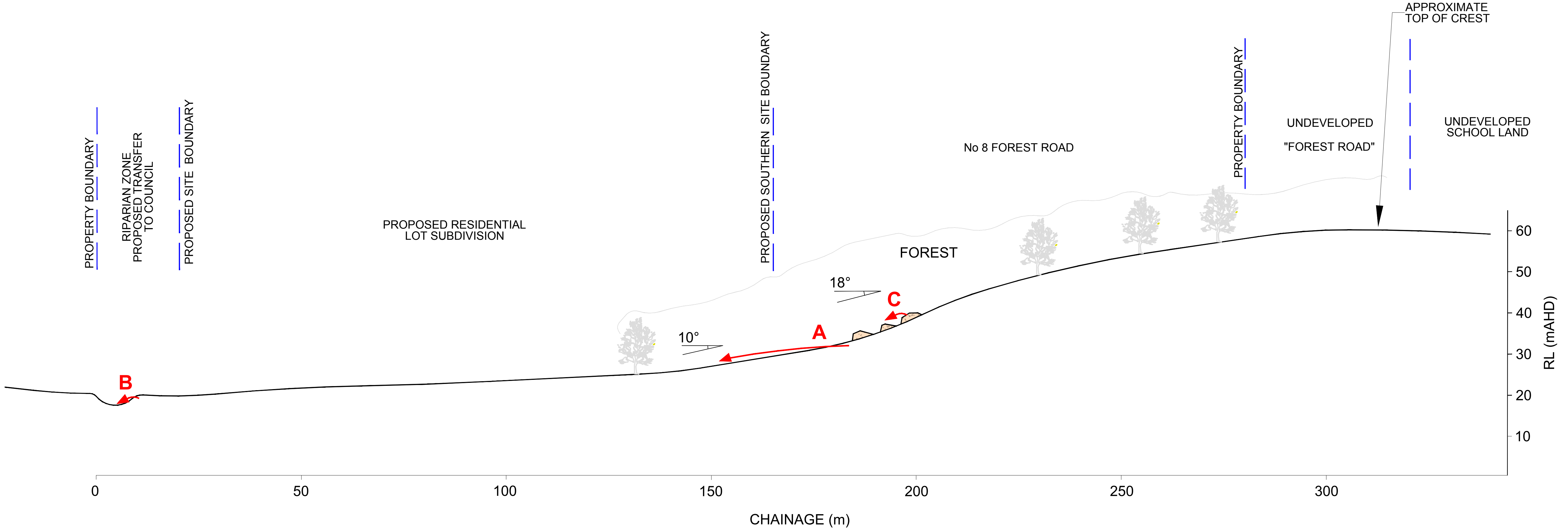
Location: 8 FOREST ROAD, WARRIEWOOD, NSW

Report No: 33371BMrpt1

Figure No: 2

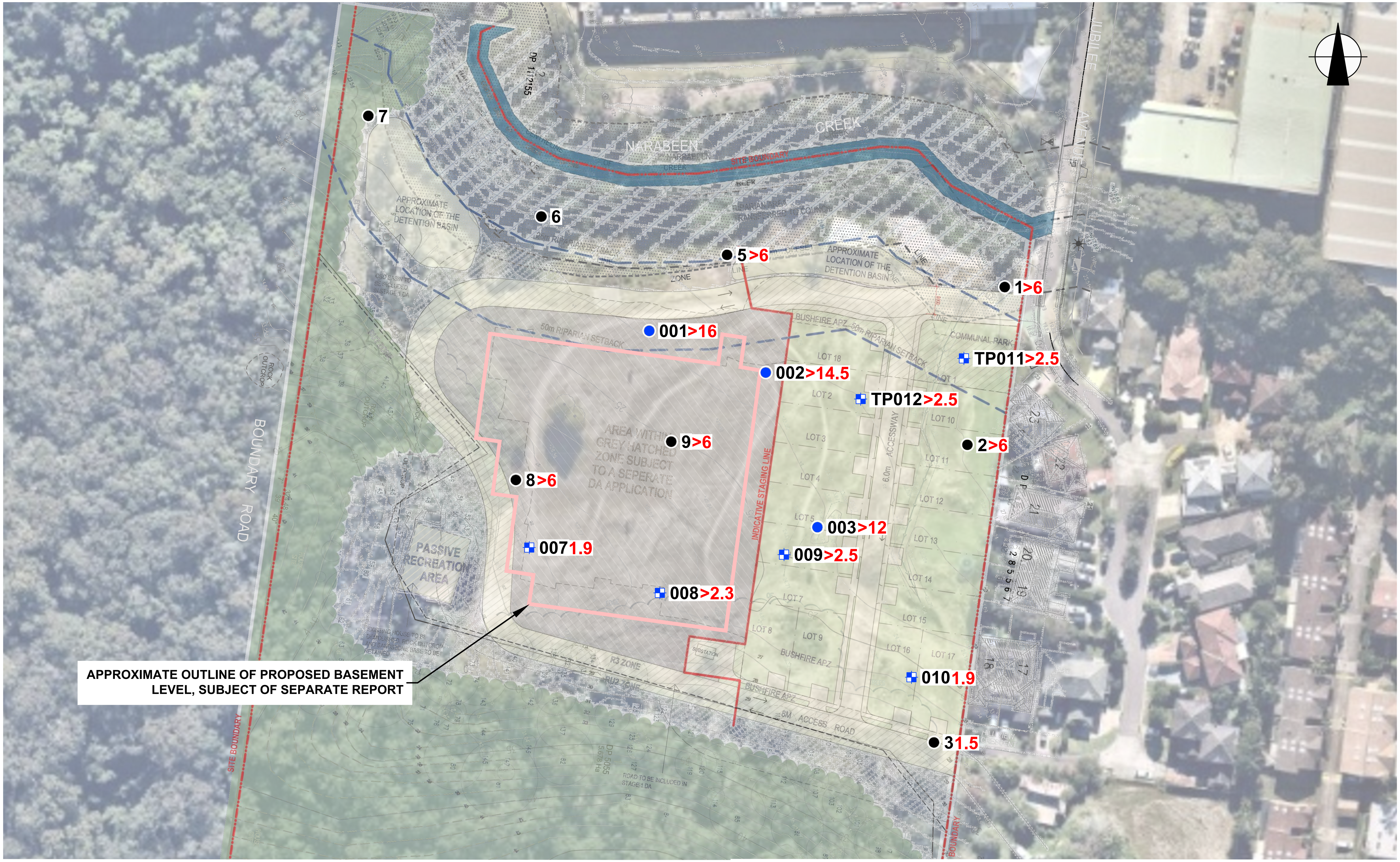
JKGeotechnics

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




| | |
|---|---|
| SCALE 1:1000 @A3 METRES (0, 10, 20, 30, 40, 50) | Title: **SECTIONAL SKETCH SHOWING POTENTIAL HAZARDS LOOKING EAST** |
| | Location: 8 FOREST ROAD, WARRIEWOOD, NSW |
| | Report No: 33371BMrpt1 — Figure No: 3 |
| This plan should be read in conjunction with the JK Geotechnics report. | JKGeotechnics |

PLOT DATE: 7/10/2020 1:09:20 PM DWG FILE: Y:\33000'S\33371BM WARRIEWOOD\CAD\33371BMRPT1.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 (approx.) LOCATION PLAN |
| Location: | 8 FOREST ROAD, WARRIEWOOD, NSW |
| Report No: | 33371BMrpt1 |
| Figure No: | 4 |

JKGeotechnics

PLOT DATE: 7/10/2020 1:07:07 PM DWG FILE: Y:\33000'S\33371BM WARRIEWOOD\CAD\33371BMRPT1.DWG

# TOPOGRAPHY

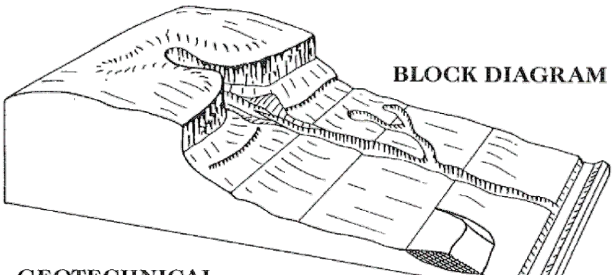
| *Symbol* | *Ground Profile* | | |
|---|---|---|---|
| | | convex | well defined or angular break of slope |
| | | concave | |
| | | convex | poorly defined or smooth change of slope |
| | | concave | |
| | breaks of slope | | convex and concave too close together to allow the use of separate symbols |
| | changes of slope | | |
| | sharp | | ridge crest |
| | rounded | | |
| 3 | Cliff or escarpment or sharp break 40° or more (estimated height in metres) | | |
| 15 | Uniform Slope | | Slope direction and angle (Degrees) |
| 10 | Concave Slope | | |
| 8 | Convex Slope | | |
| | Top | | Cut or fill slope, arrows pointing down slope |
| | Bottom | | |
| | Hummocky or irregular ground | | |

# OTHER FEATURES

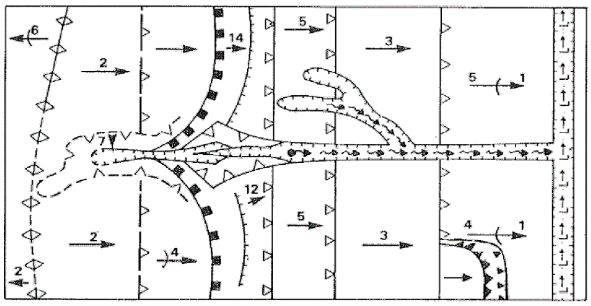
- Boulder
- Seepage/spring
- Swallow hole for runoff
- Natural water course
- Open drain, unlined
- Open drain, lined
- Fenceline
- Property boundary
- Dry Stone Wall
- J —— J 200 Major joint in rock face (opening in millimetres)
- – T – T – 10 Tension crack (opening in millimetres)
- Masonry or concrete wall
- Ponding water
- Boggy or swampy area

## EXAMPLE OF USE OF TOPOGRAPHIC SYMBOLS:

BLOCK DIAGRAM



GEOTECHNICAL PLAN



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

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

| | |
|---|---|
| Title: | GEOTECHNICAL MAPPING SYMBOLS |
| Location: | 8 FOREST ROAD, WARRIEWOOD, NSW |
| Report No: | 33371BMrpt1 |
| Figure No: | 5 |

JKGeotechnics

# 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.<br>These are two main interpretations:<br>(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.**

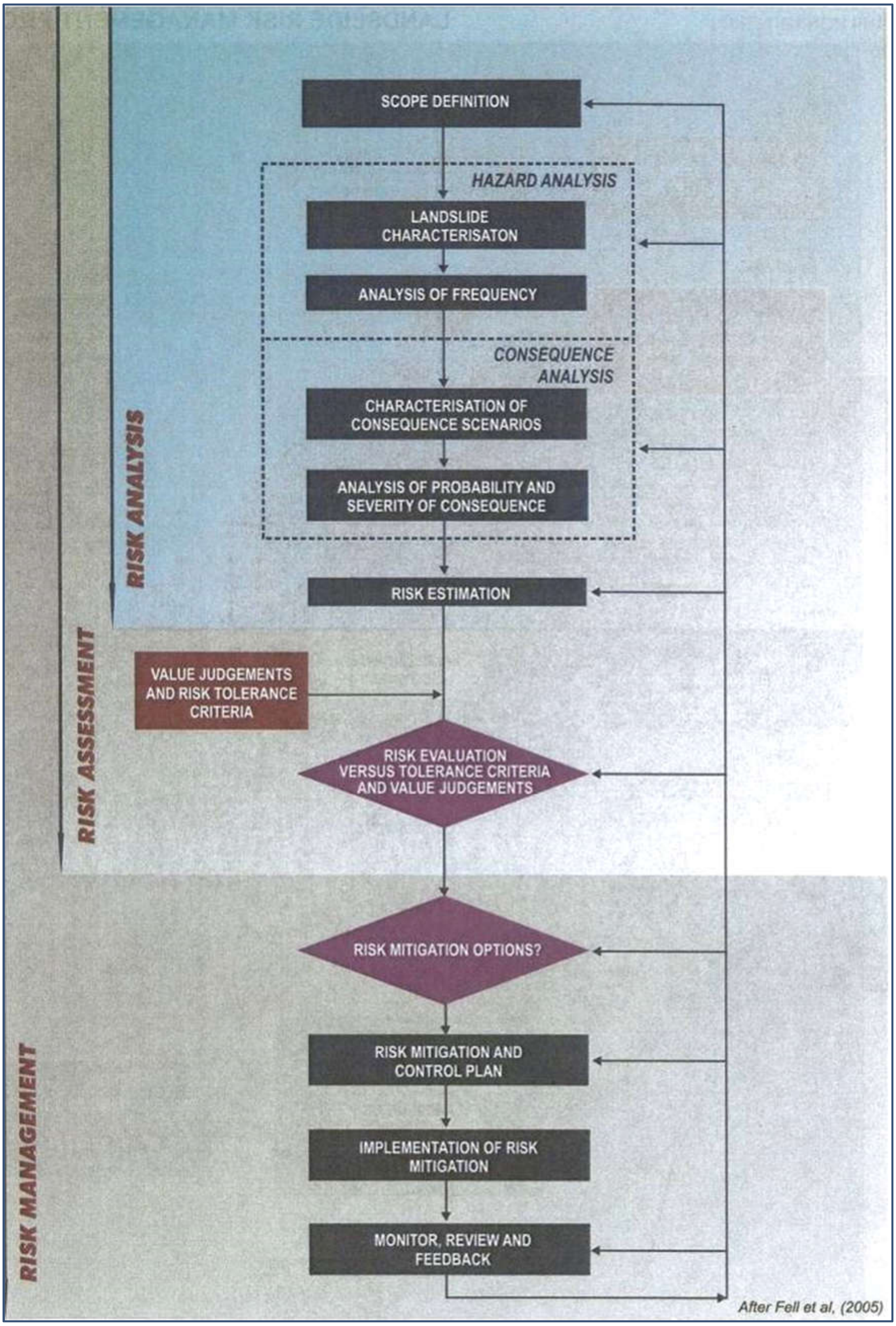



**FIGURE A1:** Flowchart for Landslide Risk Management.

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** | | | | | |
| $10^{-1}$ | $5\times10^{-2}$ | 10 years | 20 years | The event is expected to occur over the design life. | ALMOST CERTAIN | A |
| $10^{-2}$ | $5\times10^{-3}$ | 100 years | 200 years | The event will probably occur under adverse conditions over the design life. | LIKELY | B |
| $10^{-3}$ | $5\times10^{-4}$ | 1000 years | 2000 years | The event could occur under adverse conditions over the design life. | POSSIBLE | C |
| $10^{-4}$ | $5\times10^{-5}$ | 10,000 years | 20,000 years | The event might occur under very adverse circumstances over the design life. | UNLIKELY | D |
| $10^{-5}$ | $5\times10^{-2}$ | 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.

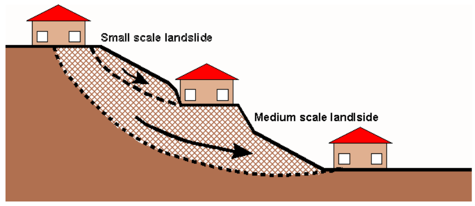


**Figure 1**

**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.

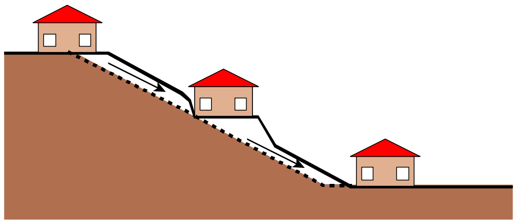


**Figure 2**

**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.

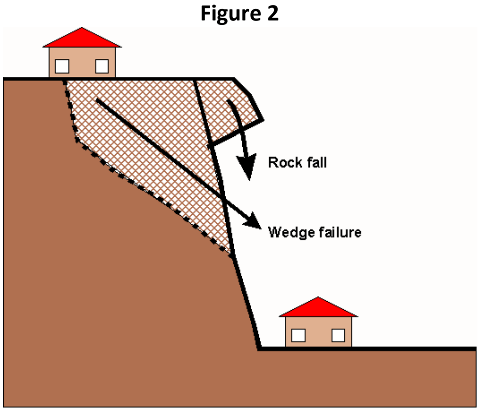


**Figure 3**

**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.

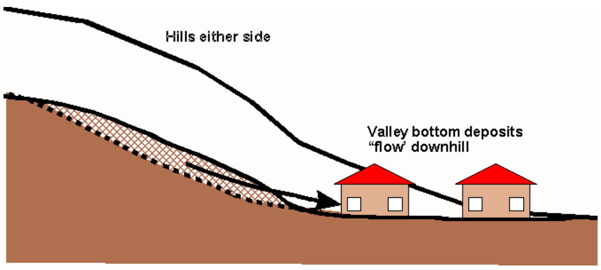


**Figure 4**

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

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

# AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

**Concept of Risk**

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

**Landslide Risk Assessment**

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

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

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

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

**Risk to Property**

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

**TABLE 2 – LIKELIHOOD**

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

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

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

**TABLE 1 – RISK TO PROPERTY**

| Qualitative Risk | | Significance - Geotechnical engineering requirements |
|---|---|---|
| Very high | VH | **Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property. |
| High | H | **Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property. |
| Moderate | M | **May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible. |
| Low | L | **Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required. |
| Very Low | VL | **Acceptable**. Manage by normal slope maintenance procedures. |

**Risk to Life**

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

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

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

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

**TABLE 3 – RISK TO LIFE**

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

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

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

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

# APPENDIX B

## SOME GUIDELINES

## FOR

## HILLSIDE CONSTRUCTION

# SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

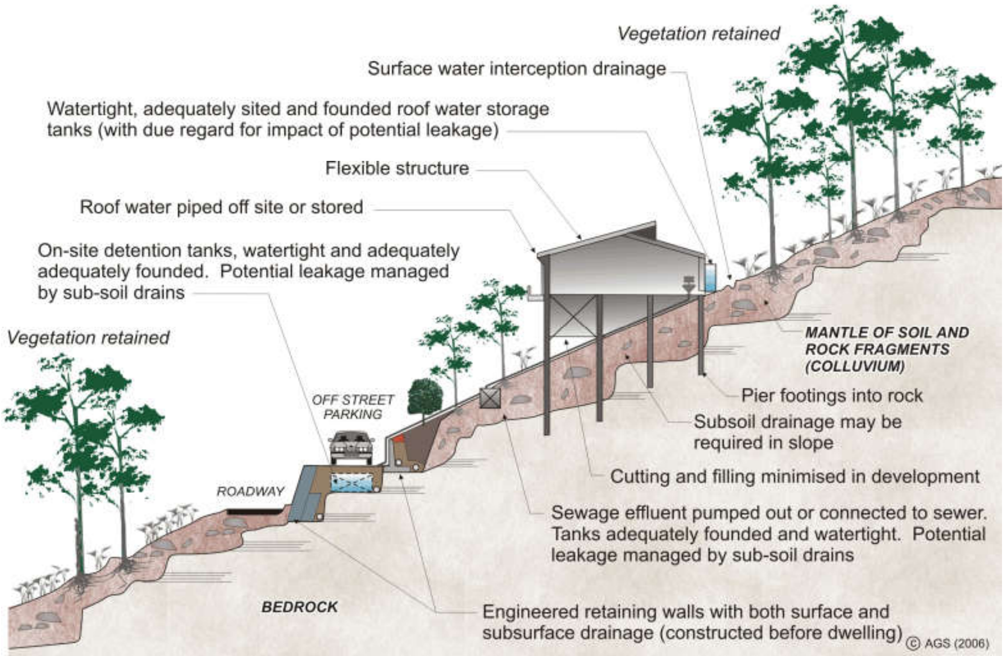
| | GOOD ENGINEERING PRACTICE | POOR ENGINEERING PRACTICE |
|---|---|---|
| **ADVICE** | | |
| GEOTECHNICAL ASSESSMENT | Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works. | Prepare detailed plan and start site works before geotechnical 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.<br>Support with engineered retaining walls or batter to appropriate slope.<br>Provide drainage measures and erosion control. | Large scale cuts and benching.<br>Unsupported cuts.<br>Ignore drainage requirements. |
| FILLS | Minimise height.<br>Strip vegetation and topsoil and key into natural slopes prior to filling.<br>Use clean fill materials and compact to engineering standards.<br>Batter to appropriate slope or support with engineered retaining wall.<br>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).<br>Block natural drainage lines.<br>Fill over existing vegetation and topsoil.<br>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.<br>Found on bedrock where practicable.<br>Provide subsurface drainage within wall backfill and surface drainage on slope above.<br>Construct wall as soon as possible after cut/fill operation. | Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork.<br>Lack of subsurface drains and weepholes. |
| FOOTINGS | Found within bedrock where practicable.<br>Use rows of piers or strip footings oriented up and down slope.<br>Design for lateral creep pressures if necessary.<br>Backfill footing excavations to exclude ingress of surface water. | Found on topsoil, loose fill, detached boulders or undercut cliffs. |
| SWIMMING POOLS | Engineer designed.<br>Support on piers to rock where practicable.<br>Provide with under-drainage and gravity drain outlet where practicable.<br>Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side. | |
| DRAINAGE<br>SURFACE | Provide at tops of cut and fill slopes.<br>Discharge to street drainage or natural water courses.<br>Provide generous falls to prevent blockage by siltation and incorporate silt traps.<br>Line to minimise infiltration and make flexible where possible.<br>Special structures to dissipate energy at changes of slope and/or direction. | Discharge at top of fills and cuts.<br>Allow water to pond bench areas. |
| SUBSURFACE | Provide filter around subsurface drain.<br>Provide drain behind retaining walls.<br>Use flexible pipelines with access for maintenance.<br>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.<br>Storage tanks should be water-tight and adequately founded. | Discharge sullage directly onto and into slopes.<br>Use of absorption trenches without consideration of landslide risk. |
| EROSION CONTROL & LANDSCAPING | Control erosion as this may lead to instability.<br>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.<br>Where structural distress is evident seek advice.<br>If seepage observed, determine cause or seek advice on consequences. | |

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

# AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

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

## EXAMPLES FOR GOOD HILLSIDE CONSTRUCTION PRACTICE




**WHY ARE THESE PRACTICES GOOD?**

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

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

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

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

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

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

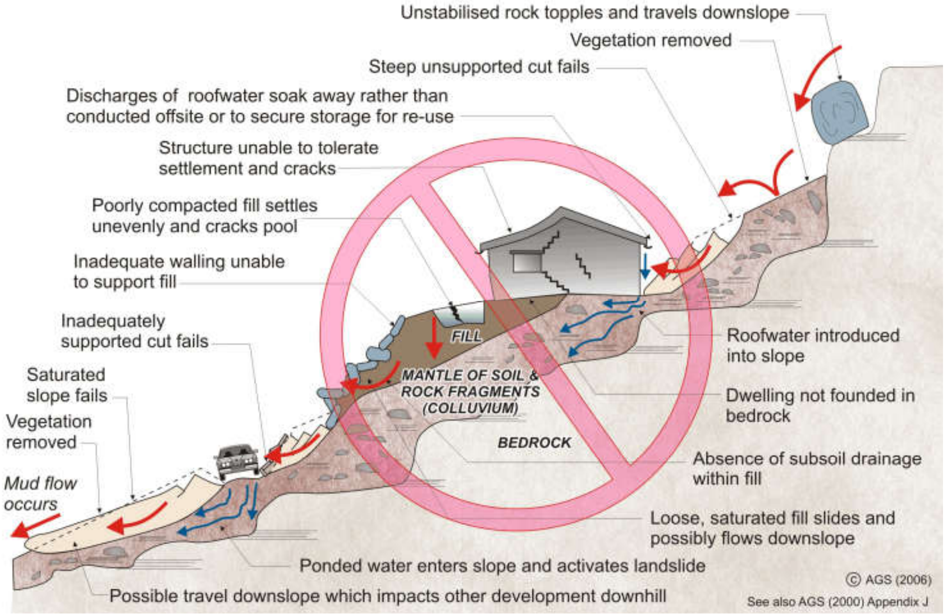
**Flexible structures -** have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

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

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

**ADOPT GOOD PRACTICE ON HILLSIDE SITES**

# EXAMPLES FOR **POOR** HILLSIDE CONSTRUCTION PRACTICE




**WHY ARE THESE PRACTICES POOR?**

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

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

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

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

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

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

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

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

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

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

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

# APPENDIX C

**Jeffery and Katauskas Pty Ltd**
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No. **1**
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
**Date:** 17-3-05
**Method:** SPIRAL AUGER JK550
**R.L. Surface:** ≈ 20.5m
**Datum:** AHD
**Logged/Checked by:** N.E.S./

| Field Tests | Depth (m) | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|
| | 0 | | FILL: Gravelly sand, fine to medium grained, grey brown, fine to coarse grained sandstone gravel. | D | | | GRASS COVER<br>APPEARS MODERATELY COMPACTED |
| N = 10<br>8,5,5 | | | | | | | |
| | 1 | SC | CLAYEY SAND: fine to medium grained, yellow brown. | M | L | | ALLUVIAL |
| N = 8<br>2,3,5 | | | | | | | |
| | 2 | | as above,<br>but orange brown mottled grey. | | MD | | |
| N = 26<br>8,12,14 | 3 | | | | | | |
| | 4 | | | W | L | | |
| N = 5<br>3,2,3 | 5 | | as above,<br>but grey. | | | | |
| | 6 | | END OF BOREHOLE AT 6.0m | | | | |
| | 7 | | | | | | |

# Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

# BOREHOLE LOG

Borehole No. **2**
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:** ≈ 21.6m
**Date:** 17-3-05 | **Datum:** AHD
**Logged/Checked by:** N.E.S./

| Groundwater Record | Samples (ES, U50, DB, DS) | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | | | TOPSOIL: Sand, fine to medium grained, dark grey, with rootlets. | D | | | GRASS COVER |
| | | N = 6 2,3,3 | | | SP | SAND: fine to medium grained, grey brown. | M | L | | ALLUVIAL |
| | | | 1 | | SC | CLAYEY SAND: fine to medium grained, orange brown and grey. | | | | |
| | | N = 10 3,3,7 | 2 | | | | | | | |
| | | | | | SC/CL | CLAYEY SAND/SANDY CLAY: fine to medium grained, medium plasticity, grey mottled orange brown. | M/ MC≈PL | MD/ H | | |
| | | N = 14 5,6,8 | 3 | | | | | | 420 450 510 | |
| | | | 4 | | SC | CLAYEY SAND: fine to medium grained, grey mottled orange brown. | M | MD | | |
| | | N = 11 5,5,6 | | | SC/CL | CLAYEY SAND/SANDY CLAY: fine to medium grained, medium plasticity, grey mottled orange brown. | W/ MC>PL | MD/ VSt | 210 280 230 | |
| | | | 5 | | | | | | | |
| | | | 6 | | | END OF BOREHOLE AT 6.0m | | | | |
| | | | 7 | | | | | | | |

# Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No. **3**

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:** ≈ 27.7m

**Date:** 17-3-05 **Datum:** AHD

**Logged/Checked by:** N.E.S./[signature]

| Groundwater Record | SAMPLES ES | U50 | DB | DS | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION | | | | | | 0 | | | TOPSOIL: Silty sand, fine to medium grained, dark grey, with rootlets. | D-M | | | GRASS COVER |
| | | | | | | | | SM | SILTY SAND: fine to medium grained, with fine to coarse grained sandstone gravel and cobbles. | D-M | (L) | | COLLUVIUM |
| | | | | | N = 11<br>3,4,7 | | | CH | SILTY CLAY: high plasticity, grey mottled orange brown. | MC>PL | H | 470<br>580<br>410 | |
| | | | | | | 1 | | SC | CLAYEY SAND: fine to medium grained, grey mottled red brown. | M | (L) | | RESIDUAL |
| | | | | | SPT<br>8/0mm<br>REFUSAL | | | - | SANDSTONE: fine to medium grained, light grey, with iron indurated bands and clay bands. | XW-DW | EL-L | | VERY LOW 'TC' BIT RESISTANCE WITH LOW BANDS |
| | | | | | | 2 | | | | | | | |
| | | | | | | 3 | | | | | | | |
| | | | | | | 4 | | | | | | | |
| | | | | | | | | | END OF BOREHOLE AT 4.5m | | | | |
| | | | | | | 5 | | | | | | | |
| | | | | | | 6 | | | | | | | |
| | | | | | | 7 | | | | | | | |

# 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
**Date:** 18-3-05
**Method:** SPIRAL AUGER JK550
**R.L. Surface:** ≈ 27.0m
**Datum:** AHD
**Logged/Checked by:** N.E.S./

| Groundwater Record | Samples (ES, U50, DB, DS) | Field Tests | Depth (m) | Graphic Log | Unified Classification | DESCRIPTION | Moisture Condition/ Weathering | Strength/ Rel. Density | Hand Penetrometer Readings (kPa.) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| DRY ON COMPLETION | 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 |
| | ES, DS | N > 22<br>2,9,<br>13/100mm<br>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<br>SOIL STRENGTH 'TC' RESISTANCE |
| | DS | N = 14<br>4,6,8 | 3 | | | | | | 440<br>520<br>480 | |
| | | | 4 | | CL | SANDY CLAY: medium plasticity, light grey, fine grained sand. | | VSt<br>-H | | |
| | DS | N = 19<br>5,8,11 | | | | | | | 430<br>370<br>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 LOG

Borehole No. **9**
1/1

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

**Job No.** 19312VB
**Date:** 18-3-05
**Method:** SPIRAL AUGER JK550
**R.L. Surface:** ≈ 25.0m
**Datum:** AHD
**Logged/Checked by:** N.E.S./

| Groundwater Record | Samples (ES, U50, DB, DS) | Field Tests | Depth (m) | Graphic Log | 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 |
| | | | | | SM | SILTY SAND: fine to medium grained, orange brown. | M | L | | ALLUVIAL |
| | | N = 5<br>2,2,3 | 1 | | | | | | | |
| | | | | | CL/SC | SANDY CLAY/CLAYEY SAND: medium plasticity, fine to medium grained, orange brown. | M/<br>MC>PL | MD/<br>VSt-<br>H | | |
| | | N = 20<br>5,8,12 | 2 | | | | | | 380<br>380<br>400<br>390 | |
| | | N = 27<br>7,14,13 | 3 | | | | | MD/<br>VSt | 330<br>260<br>250 | |
| | | | 4 | | | as above,<br>but grey mottled orange brown. | | | | |
| | | N = 13<br>4,6,7 | 5 | | | | | MD/H | 530<br>450<br>430 | |
| | | | 6 | | | END OF BOREHOLE AT 6.0m | | | | |
| | | | 7 | | | | | | | |