

REPORT TO WES MAAS

ON GEOTECHNICAL ASSESSMENT

FOR PROPOSED ALTERATIONS AND ADDITIONS

AT 44 BOWER STREET, MANLY, NSW

Date: 21 March 2025 Ref: 37452SMrpt

JKGeotechnics www.jkgeotechnics.com.au

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





Mlean,

Report prepared by:

Matthew Pearce Senior Associate | Geotechnical Engineer

Report reviewed by:

Paul Stubbs 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
37452SMrpt	Final Report	21 March 2025

© Document copyright of JK Geotechnics

This report (which includes all attachments and annexures) has been prepared by JK Geotechnics (JKG) for its Client, and is intended for the use only by that Client.

This Report has been prepared pursuant to a contract between JKG and its Client and is therefore subject to:

- a) JKG's proposal in respect of the work covered by the Report;
- b) The limitations defined in the Client's brief to JKG;
- c) The terms of contract between JKG and the Client, including terms limiting the liability of JKG.

If the Client, or any person, provides a copy of this Report to any third party, such third party must not rely on this Report, except with the express written consent of JKG which, if given, will be deemed to be upon the same terms, conditions, restrictions and limitations as apply by virtue of (a), (b), and (c) above.

Any third party who seeks to rely on this Report without the express written consent of JKG does so entirely at their own risk and to the fullest extent permitted by law, JKG accepts no liability whatsoever, in respect of any loss or damage suffered by any such third party.

At the Company's discretion, JKG may send a paper copy of this report for confirmation. In the event of any discrepancy between paper and electronic versions, the paper version is to take precedence. The USER shall ascertain the accuracy and the suitability of this information for the purpose intended; reasonable effort is made at the time of assembling this information to ensure its integrity. The recipient is not authorised to modify the content of the information supplied without the prior written consent of JKG.



Table of Contents

1	INTRODUCTION 1					
2	ASSESSMENT PROCEDURE					
	2.1	Walkover Survey and Stability Assessment	1			
	2.2	Subsurface Assessment	2			
3	RESU	LTS OF ASSESSMENT	2			
	3.1	Site Description	2			
	3.2	Geology and Subsurface Conditions	5			
4	SLOPI	E STABILITY RISK ASSESSMENT	7			
5	сомі	MENTS AND RECOMMENDATIONS	8			
	5.1	Dilapidation Surveys	8			
	5.2	Demolition	8			
	5.3	Excavation	8			
	5.4	Groundwater	9			
	5.5	Rock Cuts	10			
	5.6	Underpinning of Lower Overhanging Rock Shelf	10			
	5.7	Retaining Walls	10			
	5.8	Footings	10			
	5.9	Further Geotechnical Input	11			
6	GENERAL COMMENTS 11					

ATTACHMENTS

Table A: Summary of Risk to Property Assessment

- Table B: Summary of Risk to Life Assessment
- Figure 1: Site Location Plan
- Figure 2: Geotechnical Mapping and Potential Hazards Plan
- Figure 3: Sketch Section A
- Figure 4: Geotechnical Mapping Symbols
- Vibration Emission Design Goals
- **Report Explanation Notes**

APPENDIX A: Landslide Risk Management Terminology



1 INTRODUCTION

This report presents the results of a geotechnical assessment for proposed alterations and additions at 44 Bower Street, Manly, NSW. The location of the site is shown in Figure 1. The assessment was commissioned by the owner Mr Wes Maas in accordance with our proposal Ref P71273SM dated 3 March 2025.

From review of the architectural drawings by Utz Sanby, (Proj. No 2414) DA-01 to DA-11 and DA-14, all dated 18/2/2025, we understand the alterations and additions include the following:

- Construction of a store under the south-western corner of the existing house to extend the existing basement to the full footprint of the existing above ground footprint. This will require excavation to depths of about 3.6m from existing surface levels.
- Construction of a lower terrace level on the north side of the existing house, effectively lowering the garden/terrace/pool to match the basement level at RL23.54m. This will require demolition of the existing terrace pavements, pool and stairs and excavation to maximum depths of about 2.7m.
- The new pool will have a slightly different outline and new steps will be constructed from the western side of the proposed terrace, leading down to the garden.

In accordance with the requirements of the Manly DCP, the purpose of the geotechnical assessment is to assess the site for geotechnical stability hazards, and provide comments and recommendations on measures required to reduce the risk of landslip and subsidence of existing areas, where applicable. The purpose of the assessment was to utilise geotechnical information on the subsurface conditions from our previous inspections during excavation for the existing basement and footings, and to use this as a basis for providing comments and recommendations on seepage, excavation, new footings and further geotechnical input required at later development and construction stages.

2 ASSESSMENT PROCEDURE

2.1 Walkover Survey and Stability Assessment

The stability assessment is based upon a detailed inspection by our Associate Geotechnical Engineer, Matthew Pearce on 3 March 2025, of the topographic, surface drainage and geotechnical 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 flow chart illustrating the Risk Management Process based on the guidelines given in AGS 2007c (Reference 1).

The principal geotechnical features, which were measured using taped measurements and hand-held clinometer, are presented on Figure 2 using the existing survey by Peak Surveying Service Pty Ltd (Job. 24-2354, dated 3 December 2024) as a base plan. 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 4 defines the mapping symbols used.

2.2 Subsurface Assessment

To complement the observation of geotechnical features at the surface, we have reviewed our geotechnical inspections carried out in 2020 and 2021, during excavation and construction of the existing dwelling. Some of that information is included in Section 3.2 below.

3 RESULTS OF ASSESSMENT

3.1 Site Description

This site description should be read in conjunction with Figures 1, 2 and 3.

The site spans the stepping sandstone cliff lines from the seafront walkway (near Shelly Beach) to the start of gentle mid-slopes of the promontory which forms Sydney's North Head National Park.

No 44 Bower Street is a rectangular property 15m wide by 45m long with three distinct cliff lines over its northern (lower) half while the southern (upper) half is occupied by a large house with relatively flat surrounds. Surface reduced levels range from 27.7m at the southern street frontage to about RL6m at the northern property boundary, although the lower cliffs extend down to a narrow lawn beside the coastal walkway at about RL2m.



Photo 1- (looking south) View from coastal (Manly to Shelly Beach) walkway





House and Surrounds

The house comprises two above ground stories ('Ground Floor' and 'Level 1') over a partial basement ('Lower Ground Floor') with a garage off Bower Street. The ground floor level steps down from about RL27.13m to RL26.59m. There is a small garden set down less than 1m from street level and a side path around the western side of the house leading to a terrace and pool on the northern side of the house. On the eastern side of the house, steps lead down to a narrow side path at basement level providing access to the basement itself at RL23.54m.

The basement has been cut into the hillside with a saw-cut finished sandstone rock face on the eastern boundary, as shown in Photos 2 and 3. Above the rock face is a cement rendered brick wall (only a few courses high) and then a brush fence.



Photo 2 - looking north-eastwards



Photo 3 - looking south-eastwards

Other sides of the basement also comprise sandstone cuttings or shotcreted faces but from our inspection in 2021 the rock faces were of sound sandstone bedrock free of adversely inclined defects and only shotcreted to prevent future potential spalling. The basement was constructed with a void space between the rockface/shotcrete and internal walls. The basement extends under the majority of the house but not the south-western quadrant.

Cliff Line 1

On the northern side of the house, the hillside steps down to a lawn on the western side and pool on the eastern side. The lawn is set back about 1m to 2m from the crest of the first cliff line (Cliff Line 1) that runs across the site. The cliff is about 3m high and comprises a series of large rounded outcrops with vertical jointing that strikes north-south. The pool was built into the cliff line as shown in Photos 4 and 5 below. A weathered bedding parting on the western side of Cliff 1 was underpinned during construction but is now almost entirely hidden by vegetation.





Photo 4- (looking east) existing conditions



Photo 5- (extract from JKG Site Report 4, July 2021)

Cliff Line 2

At the toe of the pool structure is a natural terrace in the hillside which has been landscaped with a lawn to the edge of a rounded crest of a cliff ('Cliff Line 2'). The cliff is a about 4m to 5m high. As shown on Figure 2, and Photos 6 and 7, the cliff has an extensive but irregularly shaped overhang with a natural central column. Either side of the column of sandstone bedrock the overhang extends about 2m and 2.3m respectively. At the western side of Cliff 2, there is a lower overhanging unit of sandstone of only about 0.5m from base to ceiling, but extending back to a maximum of 1.3m from the cliff face. At the face there is a fig tree trunk. At the foot of the cliff is a deck accessible via steps that lead up through the eastern side of the cliff.



Photo 6- looking east- showing main overhanging outcrop

Cliff Line 3

About 1m north of the deck is a fence upon a wall which marks the limit of access to residents and was not safely accessible during our walkover. The fence sits upon a stone wall that appeared in reasonably good condition and was at least partially founded on sandstone bedrock. The sandstone outcrop marks the top of Cliff Line 3 which comprises a series of stepping rock faces ranging in height from about 0.5m to 4m with some sections of steep vegetation.



As can be seen in Photo 1, at least the lower rock face has been stabilised with rock bolts and shotcrete though it is not clear exactly where the property boundary is and whether any stabilisation works were carried out further up on the cliff line within the site.

Boundary Conditions

The neighbouring properties have many similarities with the subject site, also having 2 to 3 storey houses with set-backs of about 1m from the common boundaries. The landscaping profiles to the north of the houses are similar to that of the subject site due to the cliff lines extending across the site boundaries.

The house to the east of the site, No 42, is of brick construction and set back about 1m from the common boundary. It has a swimming pool between Cliff Lines 1 and 2. Between the southern end of the houses, existing surface levels are similar across the boundary which is marked by a combination of stone masonry walls, fencing, low height rendered walls and vegetation. The house at No 42 has a partial basement level cut into the hillside with an approximately 3.3m deep vertical cutting though sandstone bedrock located parallel to, and set back 0.8m from, the common boundary. The northern end of the ground floor level side path is suspended over a narrow passage between the basement wall and the rock face. The path has adown turn supported on the top of the rock on the common boundary.



Photo 7

To the west of the site, at No 46, a new house was constructed at a similar time to No 44. The building is set back about 1m from the common boundary. The side path at No 46 is about 2m to 3m lower than the side path at No 44. The common boundary is marked by a rendered wall of a garage and then a timber fence for the remainder of the upper portion of the site.

3.2 Geology and Subsurface Conditions

The Sydney 1:100,000 geological map indicates the site is underlain by Hawkesbury Sandstone.

The subsurface profile comprises a nominal depth of topsoil fill over sandstone bedrock. The sandstone bedrock was previously assessed during construction to be of at least medium strength with vertical jointing of the rock mass primarily oriented NNE to SSW. Photo 8 shows the exposed conditions following stripping of soil and Photo 9 shows conditions following detailed excavation. The bedrock had sub-horizontal beddings generally spaced greater than 2m.





Photo 8- (looking north) from November 2020, showing top of rock conditions on western side of site



Photo 9- (looking north), from July 2021, showing conditions on central and eastern side of site





4 SLOPE STABILITY RISK ASSESSMENT

Based on our site inspection we consider that the potential landslip hazards at the site are as follows:

- Hazard A: Failure of sandstone outcrops
- Hazard B: Broad scale failure of hillside
- Hazard C: Failure of landscape stone retaining walls
- Hazard D: Failure steep slope
- Hazard E: Failure of proposed rock faces and engineer designed retaining walls

The attached Tables A and B summarise our qualitative and semi-quantitative assessments of each potential hazard for the risk to property and the risk to life, respectively, based on the probability of instability occurring. The terminology adopted for this qualitative assessment is in accordance with Table A1 given in Appendix A. The qualitative assessments are based on judgements made in the field by the geotechnical engineer and in this regard are subjective and formed in part by the engineers' previous experiences.

The Management Concepts and Guidelines prepared by the Australian Geomechanics Society, Sub-Committee on Landslide Risk Management (Reference 1) recommend an acceptable risk for loss of life for the person most at risk of 1x10⁻⁵ for existing slopes/structures and 1x10⁻⁶ for new developments and this has been adopted for this risk assessment. For loss of property the acceptable risk should be determined by the owner, provided loss to property only affects the owners' property and does not impact on the property of others. In accordance with Reference 1 an acceptable risk of loss of property posed by existing slopes as 'Low' has been adopted for this risk assessment. Where risks posed by slope instability are considered unacceptable, remedial measures should be adopted to reduce the risk posed to an acceptable level.

As shown in Table A we assess the risks to property to be "Very Low" or "Low", which would be considered 'acceptable' in accordance with the criteria given in Reference 1. For Hazard A we have assumed that the lower overhang of Cliff 2 will be underpinned as discussed in Section 5.6 below, otherwise, if this was not carried out the consequence would be 'Minor' and risk increases to be "Low", which is still considered 'unacceptable'. As shown in Table B, our assessed risk to life for the person most at risk is about 10⁻⁷, which would also be considered 'acceptable' in accordance with Reference 1.

Provided our comments and recommendations given below are followed, the risk to both property and life for the person most a risk following the construction of the proposed alterations and additions will be acceptable provided our recommendations in Section 5 are adopted.

7



5 COMMENTS AND RECOMMENDATIONS

5.1 Dilapidation Surveys

Prior to demolition and excavation, detailed dilapidation surveys should be carried out on the adjoining properties to the west and east. The dilapidation surveys should comprise detailed inspections of the structures, both externally and internally, with all defects rigorously described, e.g. defect location, defect type, crack width, crack length, etc. The respective property owners should be provided with a copy of the dilapidation reports and be asked to confirm that they present a fair representation of the existing conditions.

Such reports can be used as a baseline against which to assess possible future claims for damage arising from the works and in this way can guard against opportunistic claims for damage that was present prior to the start of the works.

5.2 Demolition

Demolition must be carefully planned and carried out to reduce the risk of instability during localised demolition. We recommend that prior to the start of any demolition the structural engineer prepares a detailed demolition methodology/plan nominating the sequence of the demotion works and any propping required to provide support during demolition. The methodology must include appropriate structural engineer's inspections. The geotechnical engineer should also inspect any ground conditions where support to footings near crests of cuts or proposed cuts is to be removed. The methodology may need to be revised and updated during construction as conditions are exposed.

5.3 Excavation

Excavation for the proposed lower terrace and corner of the basement is expected to be required to maximum depths of about 3.6m though will generally be less.

Excavation to such depths will likely encounter a limited depth of topsoil fill and then sandstone bedrock. The sandstone is expected to be of medium to high strength with few defects.

The excavation equipment that can be used will be dictated by access considerations. We expected that only a small excavator of say 3 tonnes in size may be able to be used for the external works while excavation below the south-western corner will be limited to hand operated jackhammers.

Excavation of the sandstone bedrock will require assistance with rock excavation equipment, such as hydraulic rock hammers, ripping hooks, rotary grinders or rock saws.

Since the excavations will be carried out close to the portions of the existing house that will remain and the potentially vibration sensitive (cement rendered) neighbouring buildings, we recommend that low vibration emitting equipment be used, such as rock saws, ripping hooks, rotary grinders, and hand-held jack hammers.





Where hydraulic rock hammers are to be used, they should be limited in size and the excavation commenced away from likely critical areas (i.e. as far as possible from existing structures) to allow monitoring of transmitted vibrations prior to excavation close to the adjoining structures. The vibrations transmitted to the structures within the subject site and the adjoining sites must be quantitatively monitored at all times during rock hammer use. Vibration monitors should be solidly fixed to the existing walls, with the monitors attached to flashing warning lights, or other suitable warning systems, so that the operator is aware when acceptable limits have been reached at which point such excavation techniques should cease. It is possible that excavation using a rock hammer may not be possible while maintaining the transmitted vibrations within acceptable limits.

Vibrations, measured as Peak Vibration Velocity (PVV), should be limited to no higher than 5mm/sec. However, if any particularly sensitive structures or equipment are present in adjacent properties then a lower target limit may be appropriate. The appropriate limit should be assessed following review of the dilapidation reports.

If higher vibrations are recorded than the target limits, they should be assessed against the attached Vibration Emission Design Goals as higher vibrations may be feasible depending on the associated vibration frequency. However, any on site warning devices can only be set against the PVV and not the associated vibration frequency. If it is confirmed that transmitted vibrations are excessive, then it would be necessary to use smaller plant or alternative lower percussion techniques as discussed above.

We recommend use of excavation contractors experienced in such work and with a competent supervisor who is aware of vibration damage risks. The contractor should be provided with a full copy of this report and have all appropriate statutory and public liability insurances.

5.4 Groundwater

Given the ground profile is predominantly sandstone bedrock at shallow depths, on a hillside, and no groundwater was encountered during bulk excavation in 2020, groundwater is not expected to be a significant issue for the proposed alterations. Some small volumes of water may be perched on undulations on the rock surface and possibly in joints and seams in the rock. Such seepage from rock usually reduces following initial excavation, but should be expected to increase during and following rain. Such seepage is expected to be readily managed by gravity drainage and sump and pump techniques.

In the long term, drainage should be provided behind all retaining walls, and below the basement slab, to control and direct any seepage that does occur. The completed excavation should be inspected by the geotechnical and/or hydraulic engineers to confirm if the designed drainage system is adequate for the actual seepage flows.



5.5 Rock Cuts

Vertically cut rock must be progressively inspected by a geotechnical engineer at no more than 1.5m depth intervals to check for any adversely inclined joints or weak seams that require additional support. Any defects requiring stabilisation measures, such as rock bolts, shotcrete and mesh, or dental treatment of thin seams, may need be completed prior to further excavation. Given the strike (orientation in plan) of the vertical joints in the sandstone already identified on site, an allowance should be made for temporary rock bolting (assuming there is room to achieve this without encroaching on the boundary). If the orientation of jointing elsewhere is not adverse to stability, then the walls may be free standing.

Unless fully supported by a retaining structure, any weak seams should be grubbed out and dry packed with non-shrink grout, or shotcreted to prevent spalling in the long term and potential clogging up of the toe drainage. Drainage such as weepholes should be installed in the seams to prevent build-up of hydrostatic pressures. Exposed sandstone faces will also deteriorate and fret in the long term and allowance must be made for maintenance in the long term to clear any debris from the drains. Alternatively and advisedly, all sandstone cut faces could be covered with shotcrete to reduce such maintenance.

5.6 Underpinning of Lower Overhanging Rock Shelf

At the western end of Cliff Line 2, there is a lower overhang which extends for a length of about 6m and is up to about 1.3m back from the rock face. We recommend an underpin be constructed, behind the fig tree trunk. The underpin could comprise masonry or formed mass concrete, founded on sandstone bedrock scraped clear of any loose material. The underpin should be constructed to about 50mm shy of the underside of the rock and then once initial set has taken place, the void packed with non-shrink grout.

5.7 Retaining Walls

We are not aware of any soil retaining structures that will be required. If required we can be contacted for further advice.

5.8 Footings

All proposed footings must be founded in sandstone bedrock. The footings should be designed for an allowable bearing pressure of 1,000kPa, subject to inspection by a geotechnical engineer prior to pouring of concrete. Pad and strip footings will be appropriate.

At least the initial footings at a representative spread of locations across the site should be inspected by a geotechnical engineer. Footings must be dry and free of loose material prior to pouring concrete.

In addition, any footings above a line of 1V:1H drawn up from the toe of an excavation/cut rock face must be specifically inspected by a geotechnical engineer for the presence of adverse defects within its zone of influence. Ideally, footings will be set back at least 0.1m from the crest of a cut.





5.9 Further Geotechnical Input

The following is a summary of the further geotechnical input which is required and which has been detailed in the preceding sections of this report:

- Progressive inspection of existing and proposed rock faces.
- Inspection of seepage/drainage.
- Inspection of footing excavations.

6 GENERAL COMMENTS

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

Occasionally, the subsurface conditions may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

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

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

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

TABLE A: SUMMARY OF RISK ASSESSMENT TO PROPERTY							
POTENTIAL LANDSLIDE HAZARD	А	В	с	D	E		
	Localised Failure of Rock Outcrops	Broad Scale Failure of Hillside	Failure of Landscape Stone Retaining Walls	Failure of Steep Slope	Failure of Proposed Rock Faces and Engineer Designed Retaining Walls		
Assessed Likelihood	Unlikely	Barely Credible	Possible	Likely	Rare		
Assessed Consequence	Insignificant	Catastrophic	Insignificant	Insignificant	Minor		
Risk	Very Low	Low	Very Low	Low	Very Low		
Comments	Assumes outcrops are inspected by a geotechnical engineer and any recommended stabilisation or risk reduction measures are installed.	outcrops are inspected by a ical engineer and anyNo such known failures in Hawkesbury Sandstone. Assumes the site is not undermined by wavecut erosion, which will not happen in the design life.Assumes all structures (walls and the like) upslope are founded on 			Assumes: cut rock faces are inspected by a geotechnical engineer and any stabilisation measures recommended are installed; and retaining structures are well constructed		
Assumed property value: \$7.5M {source	: onthehouse.com.au}	TABLE B: SUMMARY OF R	ISK ASSESSMENT TO LIFE				
Potential Landslide Hazard	А	В	с	D	E		
Assessed Likelihood	Unlikely	Barely Credible	Possible	Likely	Rare		
Indicative Annual Probability	10 ⁻⁴	10 ⁻⁶	10 ⁻³	10-2	10 ⁻⁵		
Persons at risk	Residents on deck	Residents in house	Resident standing above	Resident on path above slope	Resident in basement, within 3m of sides		
Duration of Use of area Affected (Temporal Probability)	4 hrs /week, 2.4 x 10 ⁻²	0.5	Say 20mins per week 2.0 x 10 ⁻³	20 seconds / day 2.3 x 10 ⁻⁴	1 hr/day 4.2 x 10 ⁻²		
Probability of not Evacuating Area Affected	r of not Evacuating Area Failure likely to be sudden. But unlikely to be present during adverse weather when failure most likely to occur: 0.5 Likely to notice early signs of unlikely to occur, 0.1 Likely to notice early signs of instability, 0.1 Likely to notice early signs of instability and not be present during adverse weather when failure most likely to occur, 0.1 failure most likely to occur, 0.1		1				
Spatial Probability	0.5	1	0.3	0.5	0.1		
Vulnerability to Life if Failure Occurs Whilst Person Present	Possibly killed, 0.5	0.5	0.9	0.5	Likely to be afforded some protection from internal walls, the impact if failure being retained in the void space, 0.1		
Risk for Person most at Risk	3.0 x 10 ⁻⁷	2.5 x 10 ⁻⁸	5.4 x 10 ⁻⁸	5.8 x 10 ⁻¹⁰	4.2 x 10 ⁻⁹		
Total Risk for the Person Most at Risk			3.8 x 10 ⁻⁷				

Notes:

-To be read with reference to report, including definition of terms and stability risk assessment methodology in Appendix A based on 'Practice Note Guidelines for Landslide Risk Management' as presented in Australian Geomechanics, Vol 42, No 1, March 2007



JKGeotechnics



© JK GEOTECHNICS







A GEOTECHNICAL HAZARD

NOTE: REFER TO FIGURE 4 FOR GEOTECHNICAL MAPPING SYMBOLS.





© JK GEOTECHNICS



© JK GEOTECHNICS



VIBRATION EMISSION DESIGN GOALS

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

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

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

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

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

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

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



REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726:2017 *'Geotechnical Site Investigations'*. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached soil classification table qualified by the grading of other particles present (eg. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	< 0.002mm
Silt	0.002 to 0.075mm
Sand	0.075 to 2.36mm
Gravel	2.36 to 63mm
Cobbles	63 to 200mm
Boulders	> 200mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose (VL)	< 4
Loose (L)	4 to 10
Medium dense (MD)	10 to 30
Dense (D)	30 to 50
Very Dense (VD)	> 50

Cohesive soils are classified on the basis of strength (consistency) either by use of a hand penetrometer, vane shear, laboratory testing and/or tactile engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength (kPa)	Indicative Undrained Shear Strength (kPa)	
Very Soft (VS)	≤25	≤12	
Soft (S)	> 25 and \leq 50	> 12 and \leq 25	
Firm (F)	> 50 and \leq 100	> 25 and \leq 50	
Stiff (St)	> 100 and \leq 200	> 50 and \leq 100	
Very Stiff (VSt)	$>$ 200 and \leq 400	$>$ 100 and \leq 200	
Hard (Hd)	> 400	> 200	
Friable (Fr)	Strength not attainable – soil crumbles		

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'shale' is used to describe fissile mudstone, with a weakness parallel to bedding. Rocks with alternating inter-laminations of different grain size (eg. siltstone/claystone and siltstone/fine grained sandstone) is referred to as 'laminite'.

SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shrinkswell behaviour, strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.



INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All methods except test pits, hand auger drilling and portable Dynamic Cone Penetrometers require the use of a mechanical rig which is commonly mounted on a truck chassis or track base.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils and 'weaker' bedrock if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for a large excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Refusal of the hand auger can occur on a variety of materials such as obstructions within any fill, tree roots, hard clay, gravel or ironstone, cobbles and boulders, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of limited reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock cuttings. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be assessed from the cuttings, together with some information from "feel" and rate of penetration.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg. from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, NMLC or HQ triple tube core barrels, which give a core of about 50mm and 61mm diameter, respectively, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as NO CORE. The location of NO CORE recovery is determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the bottom of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils, as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289.6.3.1–2004 (R2016) '*Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – Standard Penetration Test (SPT)'.*

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63.5kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

• In the case where full penetration is obtained with successive blow counts for each 150mm of, say, 4, 6 and 7 blows, as

Ν	= 13	
4,	6, 7	

 In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

> N > 30 15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

A modification to the SPT is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as 'N_c' on the borehole logs, together with the number of blows per 150mm penetration.



Cone Penetrometer Testing (CPT) and Interpretation: The cone penetrometer is sometimes referred to as a Dutch Cone. The test is described in Australian Standard 1289.6.5.1–1999 (R2013) 'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Static Cone Penetration Resistance of a Soil – Field Test using a Mechanical and Electrical Cone or Friction-Cone Penetrometer'.

In the tests, a 35mm or 44mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm or 165mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck. The CPT does not provide soil sample recovery.

As penetration occurs (at a rate of approximately 20mm per second), the information is output as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa. There are two scales presented for the cone resistance. The lower scale has a range of 0 to 5MPa and the main scale has a range of 0 to 50MPa. For cone resistance values less than 5MPa, the plot will appear on both scales.
- Sleeve friction the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio the ratio of sleeve friction to cone resistance, expressed as a percentage.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between CPT and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of CPT values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable. There are limitations when using the CPT in that it may not penetrate obstructions within any fill, thick layers of hard clay and very dense sand, gravel and weathered bedrock. Normally a 'dummy' cone is pushed through fill to protect the equipment. No information is recorded by the 'dummy' probe.

Flat Dilatometer Test: The flat dilatometer (DMT), also known as the Marchetti Dilometer comprises a stainless steel blade having a flat, circular steel membrane mounted flush on one side.

The blade is connected to a control unit at ground surface by a pneumatic-electrical tube running through the insertion rods. A gas tank, connected to the control unit by a pneumatic cable, supplies the gas pressure required to expand the membrane. The control unit is equipped with a pressure regulator, pressure gauges, an audio-visual signal and vent valves.

The blade is advanced into the ground using our CPT rig or one of our drilling rigs, and can be driven into the ground using an SPT hammer. As soon as the blade is in place, the membrane is inflated, and the pressure required to lift the membrane (approximately 0.1mm) is recorded. The pressure then required to lift the centre of the membrane by an additional 1mm is recorded. The membrane is then deflated before pushing to the next depth increment, usually 200mm down. The pressure readings are corrected for membrane stiffness.

The DMT is used to measure material index (I_D), horizontal stress index (K_D), and dilatometer modulus (E_D). Using established correlations, the DMT results can also be used to assess the 'at rest' earth pressure coefficient (K_o), over-consolidation ratio (OCR), undrained shear strength (C_u), friction angle (ϕ), coefficient of consolidation (C_h), coefficient of permeability (K_h), unit weight (γ), and vertical drained constrained modulus (M).

The seismic dilatometer (SDMT) is the combination of the DMT with an add-on seismic module for the measurement of shear wave velocity (V_s). Using established correlations, the SDMT results can also be used to assess the small strain modulus (G_o).

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a 16mm diameter rod with a 20mm diameter cone end with a 9kg hammer dropping 510mm. The test is described in Australian Standard 1289.6.3.2–1997 (R2013) 'Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – 9kg Dynamic Cone Penetrometer Test'.

The results are used to assess the relative compaction of fill, the relative density of granular soils, and the strength of cohesive soils. Using established correlations, the DCP test results can also be used to assess California Bearing Ratio (CBR).

Refusal of the DCP can occur on a variety of materials such as obstructions within any fill, tree roots, hard clay, gravel or ironstone, cobbles and boulders, and does not necessarily indicate rock level.



Vane Shear Test: The vane shear test is used to measure the undrained shear strength (C_u) of typically very soft to firm fine grained cohesive soils. The vane shear is normally performed in the bottom of a borehole, but can be completed from surface level, the bottom and sides of test pits, and on recovered undisturbed tube samples (when using a hand vane).

The vane comprises four rectangular blades arranged in the form of a cross on the end of a thin rod, which is coupled to the bottom of a drill rod string when used in a borehole. The size of the vane is dependent on the strength of the fine grained cohesive soils; that is, larger vanes are normally used for very low strength soils. For borehole testing, the size of the vane can be limited by the size of the casing that is used.

For testing inside a borehole, a device is used at the top of the casing, which suspends the vane and rods so that they do not sink under selfweight into the 'soft' soils beyond the depth at which the test is to be carried out. A calibrated torque head is used to rotate the rods and vane and to measure the resistance of the vane to rotation.

With the vane in position, torque is applied to cause rotation of the vane at a constant rate. A rate of 6° per minute is the common rotation rate. Rotation is continued until the soil is sheared and the maximum torque has been recorded. This value is then used to calculate the undrained shear strength. The vane is then rotated rapidly a number of times and the operation repeated until a constant torque reading is obtained. This torque value is used to calculate the remoulded shear strength. Where appropriate, friction on the vane rods is measured and taken into account in the shear strength calculation.

LOGS

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

The terms and symbols used in preparation of the logs are defined in the following pages.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than 'straight line' variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

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

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if reliable water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after the groundwater level has stabilised at intervals ranging from several days to perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg. bricks, steel, etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably assess the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 '*Methods of Testing Soils for Engineering Purposes*' or appropriate NSW Government Roads & Maritime Services (RMS) test methods. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.



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

- Unexpected variations in ground conditions the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.
- Details of the development that the Company could not reasonably be expected to anticipate.

If these occur, the Company will be pleased to assist with investigation or advice to resolve any problems occurring.

SITE ANOMALIES

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

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

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

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. Licence to use the documents may be revoked without notice if the Client is in breach of any obligation to make a payment to us.

REVIEW OF DESIGN

Where major civil or structural developments are proposed <u>or</u> where only a limited investigation has been completed <u>or</u> where the geotechnical conditions/constraints are quite complex, it is prudent to have a joint design review which involves an experienced geotechnical engineer/engineering geologist.

SITE INSPECTION

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

- a site visit to confirm that conditions exposed are no worse than those interpreted, to
- a visit to assist the contractor or other site personnel in identifying various soil/rock types and appropriate footing or pile founding depths, or
- iii) full time engineering presence on site.



SYMBOL LEGENDS



CLASSIFICATION OF COARSE AND FINE GRAINED SOILS

Ma	jor Divisions	Group Symbol	Typical Names	Field Classification of Sand and Gravel	Laboratory Cl	assification
ianis	GRAVEL (more than half of coarse fraction is larger than 2.36mm	GW	Gravel and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	C _u >4 1 <c<sub>c<3</c<sub>
rsize fract		GP	Gravel and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Fails to comply with above
grained soil (more than 65% of soil excluding ove greater than 0.075mm)		GM	Gravel-silt mixtures and gravel- sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	Fines behave as silt
		GC	Gravel-clay mixtures and gravel- sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	Fines behave as clay
	SAND (more than half of coarse fraction is smaller than	SW	Sand and gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength	≤ 5% fines	Cu>6 1 <cc<3< td=""></cc<3<>
		fraction is smaller than	SP	Sand and gravel-sand mixtures, little or no fines	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength	≤ 5% fines
	2.36mm)	SM	Sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength	≥ 12% fines, fines are silty	
Coairs		SC	Sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength	≥ 12% fines, fines are clayey	N/A

Major Divisions		Group			Laboratory Classification					
		Symbol	Typical Names	Dry Strength	Dilatancy	Toughness	% < 0.075mm			
n 35% of sail excluding sethan 0.075mm)	SILT and CLAY (low to medium	ML	Inorganic silt and very fine sand, rock flour, silty or clayey fine sand or silt with low plasticity	None to low	Slow to rapid	Low	Below A line			
	plasticity)	plasticity)	plasticity)	plasticity)	CL, CI	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay	Medium to high	None to slow	Medium	Above A line
		OL	Organic silt	Low to medium	Slow	Low	Below A line			
bretha	SILT and CLAY (high plasticity)	MH	Inorganic silt	Low to medium	None to slow	Low to medium	Below A line			
oils (m e fracti		(high plasticity)	СН	Inorganic clay of high plasticity	High to very high	None	High	Above A line		
re grained: oversiz		OH	Organic clay of medium to high plasticity, organic silt	Medium to high	None to very slow	Low to medium	Below A line			
.=	Highly organic soil	Pt	Peat, highly organic soil	-	-	-	-			

Laboratory Classification Criteria

A well graded coarse grained soil is one for which the coefficient of uniformity Cu > 4 and the coefficient of curvature $1 < C_c < 3$. Otherwise, the soil is poorly graded. These coefficients are given by:

$$C_U = \frac{D_{60}}{D_{10}}$$
 and $C_C = \frac{(D_{30})^2}{D_{10} D_{60}}$

Where D_{10} , D_{30} and D_{60} are those grain sizes for which 10%, 30% and 60% of the soil grains, respectively, are smaller.

NOTES:

- 1 For a coarse grained soil with a fines content between 5% and 12%, the soil is given a dual classification comprising the two group symbols separated by a dash; for example, for a poorly graded gravel with between 5% and 12% silt fines, the classification is GP-GM.
- 3 Clay soils with liquid limits > 35% and ≤ 50% may be classified as being of medium plasticity.
- 4 The U line on the Modified Casagrande Chart is an approximate upper bound for most natural soils.





LOG SYMBOLS

Log Column	Symbol	Definition			
Groundwater Record		Standing water level. Time delay following completion of drilling/excavation may be shown.			
	<u> </u>	Extent of borehole/test pit collapse shortly after drilling/excavation.			
		Groundwater seepage into borehole or test pit noted during drilling or excavation.			
Samples	ES	Sample taken over depth indicated, for environmental analysis.			
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.			
	DR	Bulk disturbed sample taken over depth indicated.			
	ASB	Soil sample taken over depth indicated, for asbestos analysis.			
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.			
	SAL	Soil sample taken over depth indicated, for salinity analysis.			
Field Tests	N = 17	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual			
	4, 7, 10	figures show blows per 150mm penetration. 'Refusal' refers to apparent hammer refusal within the corresponding 150mm depth increment.			
	N _c = 5	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual			
	7	figures show blows per 150mm penetration for 60° solid cone driven by SPT hammer. 'R' reters to apparent hammer refusal within the corresponding 150mm depth increment.			
	3R				
	VNS = 25	Vane shear reading in kPa of undrained shear strength.			
	PID = 100	Photoionisation detector reading in ppm (soil sample headspace test).			
Moisture Condition	w > PL	Moisture content estimated to be greater than plastic limit.			
(Fine Grained Soils)	w≈PL	Moisture content estimated to be approximately equal to plastic limit.			
	W < PL	Moisture content estimated to be less than plastic limit.			
	w≈u w>LL	Moisture content estimated to be real liquid limit.			
(Coarse Grained Soils)	D	DRY – runs freelv through fingers.			
	M	MOIST – does not run freely but no free water visible on soil surface.			
	W	WET – free water visible on soil surface.			
Strength (Consistency)	VS	VERY SOFT $-$ unconfined compressive strength ≤ 25 kPa.			
Cohesive Soils	S	SOFT – unconfined compressive strength > 25kPa and \leq 50kPa.			
	F	FIRM – unconfined compressive strength > 50kPa and \leq 100kPa.			
	St Vs+	STIFF – unconfined compressive strength > 100 kPa and ≤ 200 kPa.			
	Hd	VERY STIFF – unconfined compressive strength > 200kPa and \leq 400kPa.			
	Fr	HAKD – UNCONTINED COMPLESSIVE SUPERIOUS AUDICE A.			
	()	Bracketed symbol indicates estimated consistency based on tactile examination or other			
		assessment.			
Density Index/ Relative Density		Density Index (I _D) SPT 'N' Value Range Range (%) (Blows/300mm)			
(Cohesionless Soils)	VL	VERY LOOSE ≤ 15 0-4			
	L	LOOSE > 15 and \leq 35 4 - 10			
	MD	MEDIUM DENSE > 35 and ≤ 65 10 - 30			
	D	DENSE > 65 and ≤ 85 30 - 50			
	VD	VERY DENSE > 85 > 50			
	()	Bracketed symbol indicates estimated density based on ease of drilling or other assessment.			
Hand Penetrometer Readings	300 250	Measures reading in kPa of unconfined compressive strength. Numbers indicate individual test results on representative undisturbed material unless noted otherwise.			

8

JKGeotechnics



Log Column	Symbol	Definition			
Remarks	'V' bit	Hardened steel 'V' shaped bit.			
	'TC' bit	Twin pronged tun	gsten carbide bit.		
	T_{60}	Penetration of au without rotation of	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.		
	Soil Origin	The geological ori	gin of the soil can generally be described as:		
		RESIDUAL	 soil formed directly from insitu weathering of the underlying rock. No visible structure or fabric of the parent rock. 		
		EXTREMELY WEATHERED	 soil formed directly from insitu weathering of the underlying rock. Material is of soil strength but retains the structure and/or fabric of the parent rock. 		
		ALLUVIAL	- soil deposited by creeks and rivers.		
		ESTUARINE	 soil deposited in coastal estuaries, including sediments caused by inflowing creeks and rivers, and tidal currents. 		
		MARINE	- soil deposited in a marine environment.		
		AEOLIAN	 soil carried and deposited by wind. 		
		COLLUVIAL	 soil and rock debris transported downslope by gravity, with or without the assistance of flowing water. Colluvium is usually a thick deposit formed from a landslide. The description 'slopewash' is used for thinner surficial deposits. 		
		LITTORAL	 beach deposited soil. 		



Classification of Material Weathering

Term		Abbreviation		Definition
Residual Soil		RS		Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely Weathered		xw		Material is weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are still visible.
Highly Weathered	Distinctly Weathered	HW	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately Weathered	(Note 1)	MW		The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.
Slightly Weathered		SW		Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh		FR		Rock shows no sign of decomposition of individual minerals or colour changes.

NOTE 1: The term 'Distinctly Weathered' is used where it is not practicable to distinguish between 'Highly Weathered' and 'Moderately Weathered' rock. 'Distinctly Weathered' is defined as follows: 'Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores'. There is some change in rock strength.

Rock Material Strength Classification

				Guide to Strength				
Term	Abbreviation	Uniaxial Compressive Strength (MPa)	Point Load Strength Index Is ₍₅₀₎ (MPa)	Field Assessment				
Very Low Strength	VL	0.6 to 2	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30mm thick can be broken by finger pressure.				
Low Strength	L	2 to 6	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.				
Medium Strength	М	6 to 20	0.3 to 1	Scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.				
High Strength	н	20 to 60	1 to 3	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.				
Very High Strength	VH	60 to 200	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.				
Extremely High Strength	EH	> 200	> 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.				



Abbreviations Used in Defect Description

Cored Borehole Log Column		Symbol Abbreviation	Description
Point Load Streng	gth Index	• 0.6	Axial point load strength index test result (MPa)
		x 0.6	Diametral point load strength index test result (MPa)
Defect Details	– Туре	Ве	Parting – bedding or cleavage
		CS	Clay seam
		Cr	Crushed/sheared seam or zone
		J	Joint
		Jh	Healed joint
		il	Incipient joint
		XWS	Extremely weathered seam
	– Orientation	Degrees	Defect orientation is measured relative to normal to the core axis (ie. relative to the horizontal for a vertical borehole)
	– Shape	Р	Planar
		с	Curved
		Un	Undulating
		St	Stepped
		lr	Irregular
	– Roughness	Vr	Very rough
		R	Rough
		S	Smooth
		Ро	Polished
		SI	Slickensided
	– Infill Material	Ca	Calcite
		Cb	Carbonaceous
		Clay	Clay
		Fe	Iron
		Qz	Quartz
		Ру	Pyrite
	– Coatings	Cn	Clean
		Sn	Stained – no visible coating, surface is discoloured
		Vn	Veneer – visible, too thin to measure, may be patchy
		Ct	Coating \leq 1mm thick
		Filled	Coating > 1mm thick
	– Thickness	mm.t	Defect thickness measured in millimetres



APPENDIX A

LANDSLIDE RISK MANAGEMENT TERMINOLOGY

LANDSLIDE RISK MANAGEMENT

Definition of Terms and Landslide Risk

Risk Terminology	Description
Acceptable Risk	A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
Annual Exceedance Probability (AEP)	The estimated probability that an event of specified magnitude will be exceeded in any year.
Consequence	The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.
Elements at Risk	The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.
Frequency	A measure of likelihood expressed as the number of occurrences of an event in a given time. See also 'Likelihood' and 'Probability'.
Hazard	A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.
Individual Risk to Life	The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
Landslide Activity	The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg. seasonal) or continuous (in which case the slide is 'active').
Landslide Intensity	A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, or kinetic energy per unit area.
Landslide Risk	The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.
Landslide Susceptibility	The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
Likelihood	Used as a qualitative description of probability or frequency.
Probability	A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.
	These are two main interpretations:
	 (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an 'objective' or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.



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

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

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

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



FIGURE A1: Flowchart for Landslide Risk Management.

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



TABLE A1: LANDSLIDE RISK ASSESSMENT QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability				Developing	_	1 1
Value	Notional Boundary	Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
10-1	boundary	10 years		The event is expected to occur over the design life.	ALMOST CERTAIN	A
10-2	5×10 ⁻²	100 years	20 years	The event will probably occur under adverse conditions over the design life.	LIKELY	В
10-3	5×10 ⁻³	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	С
10-4	5×10-5	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10-5	5×10-2	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10-6	5×10 ⁻²	1,000,000 years	200,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate cost of Damage				
Indicative	Notional	Description		Level
Value	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%	10/0	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

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

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

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

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



TABLE A1: LANDSLIDE RISK ASSESSMENT QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (continued)

QUALITATIVE RISK ANALYSIS MATRIX - LEVEL OF RISK TO PROPERTY

LIKELIHOOI	CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)					
	Indicative Value of	1: CATASTROPHIC	2: MAJOR	3: MEDIUM	4: MINOR	5: INSIGNIFICANT
	Approximate Annual	200%	60%	20%	5%	0.5%
	Probability					
A – ALMOST CERTAIN	10-1	VH	VH	VH	Н	M or L (5)
B - LIKELY	10-2	VH	VH	Н	М	L
C - POSSIBLE	10-3	VH	Н	М	М	VL
D - UNLIKELY	10-4	Н	М	L	L	VL
E - RARE	10-5	М	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.
н	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.
М	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 <u>www.ga.gov.au/urban/factsheets/landslide.jsp</u>. 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 <u>www.abcb.gov.au</u>.

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

JKGeotechnics

- 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. <u>Your local council is the first place to make enquiries if you are responsible for any sort of development</u> or own or occupy property on or near sloping land or a cliff.

	Slope	Maximum	
Appearance	Angle	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.

TABLE 1 – Slope Descriptions





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.

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 3



Figure 4

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.

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.



- 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.

Qualitative Ris	sk	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	н	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	М	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.

TABLE 1 – RISK TO PROPERTY



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.

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 <u>Australian Geomechanics Society</u>, 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.