

31 July 2018
5QS Ref: 7605



Mr E & Mrs M Burke
PO Box 136
CHURCH POINT NSW 2105

Dear Mr & Mrs Burke,

RE: Limited Geotechnical Investigation
Proposed Residence
No 131 Thompson Street, Scotland Island

1. Introduction

As requested, 5QS Consulting Group North [5QS] has prepared this report with comments on slope instability risk for the above property. Proposed development of the property is understood to involve the construction of a new pole framed dwelling.

The purpose of this report is to provide information on subsurface conditions and comments on:

- The assessed risk of slope instability on the property, in accordance with the methodology set out in guidelines prepared by the Australian Geomechanics Society Sub-committee on Landslide Risk Management, in 'Australian Geomechanics', Vol 37 No 2 (Ref 1); and
- Geotechnical engineering guidelines for site development.

For the purpose of this investigation, the client provided 5QS with a set of architectural plans by Ezy Homes (Australia) Pty Ltd, in 7 sheets dated 18 July 2018, showing the layout and extent of the proposed residence.

The scope of this investigation included a desktop review of available published information, field work and preparation of this report.

For the purpose of a qualitative assessment of the risk of slope instability on the site, this report makes reference to the terms defined in the Australian Geomechanics Society Landslide Taskforce paper, *Practice note guidelines for landslide risk management*, in 'Australian Geomechanics' Vol 42 No 1 (Ref 2).

This report should be read in conjunction with the attached 'General Notes'.

2. Site Description

The property, identified as Lot 166 in DP 12749, [the site] occupies a trapezoidal shaped allotment approximately 1 185 m² in area situated on the south-western side of Thompson Street, Scotland Island. The site is bounded by existing residential development to the north and south-west, by Hilda Avenue to the south-east and by Thompson Street to the north-east.

At the time of the investigation, the site was undeveloped.

The site is situated on the south-west facing mid-slopes of a prominent peak forming Scotland Island. Ground slopes fall towards the south-west at average grade of about 25 % (slope angle approximately 14°). Minor sandstone outcrop was observed within the property, and in the road cuttings along Hilda Avenue and Thompson Street. Vegetation consists of partially cleared tall native forest with some areas of moderately dense scrub.

The site layout and location of the proposed development can be seen on attached drawing 7605/G1 Revision A. Various views of the site are given in Photographs P1 to P3.



Photograph P1 – View towards south-west, taken from Thompson Street; location of proposed residence in centre of frame



Photograph P2 – View south-west through north, taken from intersection of Hilda Avenue and Thompson Street



Photograph P3 – View north-west through south-east,
taken from near south-western boundary

3. Background Information from Desktop Review

3.1 Geological Setting

Reference to the 'Sydney 1:100 000 geological series sheet 9130, Edition 1', published by the NSW Department of Mineral Resources, (Ref 3), indicates that the site lies near an inferred geological boundary between the Newport and Garie Formations and the Hawkesbury Sandstone of Middle Triassic age.

The Newport and Garie Formations typically include interbedded laminite, shale and quartz to quartz lithic sandstone with clay pellet sandstone to the south of the Hawkesbury River.

Rock types within the Hawkesbury Sandstone typically include medium to coarse grained quartz sandstone with minor shale and laminite lenses.

3.2 Soil Landscape

The site lies near an inferred boundary between the Hawkesbury and Watagan colluvial soil landscapes as identified on the 'Sydney 1:100 000 soil landscape series sheet 9130, Fourth Edition', published by the NSW Department of Environment, Climate Change and Water (Ref 4).

The Hawkesbury colluvial landscape is characterised by rugged, rolling to very steep hills on Hawkesbury sandstone. Local relief is 40 m to 200 m with ground slopes of greater than 25 %. Landforms include narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders and greater than 50 % rock outcrop. Limitations of the Hawkesbury colluvial landscape include extreme soil erosion hazard, rock fall hazard, steep slopes, rock outcrop, shallow, highly permeable soils and soils of low fertility.

The Watagan colluvial landscape is characterised by rolling to very steep hills on fine-grained Narrabeen Group sediments. Local relief is in the order of 50 m to 220 m with ground slopes greater than 25 %. Landforms comprise narrow, convex crests and ridges, and steep colluvial sideslopes with occasional boulders and benches.

Limitations of the Watagan landscape include mass movement hazard, steep slopes, severe soil erosion hazard and occasional rock outcrop.

4. Field Work

4.1 Methods

The field work was undertaken on 12 April 2017 and consisted of:

- A walkover assessment of the site and surrounding area by an experienced engineer from 5QS;
- Three dynamic cone penetrometer [DCP] tests;
- Excavation of one borehole by hand auger methods; and
- Observation of existing sandstone outcrop in cuttings and other features on and in the area local to the site.

4.2 Results

The subsurface profile encountered in borehole BH1 comprised sand to 0.55 m depth, overlying sandy clay and clayey sand to hand auger refusal at a depth of 1.6 m.

The DCP tests DCP1, DCP2 and DCP3 were driven to refusal at depths of 1.4 m, 0.55 m and 1.85 m, respectively.

No surface water seepage was observed on the site during the walkover assessment. No signs of overall slope instability were observed on site.

Logs of the DCP probe tests and an engineering log of the borehole are given in the attachment section of this report.

5. Assessment of Slope Instability Risk

5.1 General

An assessment of the risk to both property and life due to failure mechanisms on the site has been undertaken with reference to the Australian Geomechanics Society Landslide Taskforce paper, 'Practice note guidelines for landslide risk management' (Ref 2).

Risk analysis can be broken up into four components, namely:

- Hazard identification;
- Frequency analysis, or estimation of likelihood of occurrence;
- Consequence analysis; and
- Risk estimation.

The following sections give comments on analysis of risk to property and loss of life.

5.2 Slope Hazard Identification

Based on the observed site conditions, the following hazards relating to potential instability have been identified for Lot 166 in DP 12749;

- Hazard 1 – Creep of surface soils;
- Hazard 2 – Rock topple of surface boulders from slopes on and above the site;
- Hazard 3 – Minor rotational landslide; and
- Hazard 4 – Large scale rotational landslide / deep seated instability.

No overt signs of deep seated instability on the site were observed at the time of this investigation.

5.3 Risk to Property

A summary of the results of the site assessment by 5QS is presented in Table 1, together with a qualitative assessment of the likelihood of occurrence of mass ground movements following construction and its consequence and risk to post construction structures on the site and neighbouring lots.

Table 1 – Assessment of Risk to Property

	Hazard	Likelihood	Consequence to Development	Risk to Development
1	Creep failure of surficial soils	Possible	Insignificant	Very Low
2	Toppling / dislodgment of blocks or boulders	Unlikely	Medium	Low
3	Minor rotational landslide	Unlikely	Medium	Low
4	Large scale rotational landslide / deep seated instability	Rare	Major	Low

Hazard 1 has been assessed as having a likelihood category of 'Possible' associated with the extent of loose surficial soils and ground slopes present on the site. Creep failure on site was assessed as having an 'Insignificant' consequence for the proposed development; hence, a risk rating of 'Very Low' applies to this hazard.

Hazard 2 has been assessed as having a likelihood category of 'Unlikely' associated with the extent of surficial boulders on and upslope of the site, and the likelihood of their disturbance during the design life of the proposed residence. Rock topple was assessed as having a 'Medium' consequence on the proposed development and downslope properties; hence, a risk rating of 'Low' applies to this hazard.

Hazard 3 has been assessed as having a likelihood category of 'Unlikely' owing to the ground slopes, the inferred bedrock profile and the extent of surficial soils observed within the site. Minor rotational failure was assessed as having a 'Medium' consequence for the proposed development and neighbouring properties; hence, a risk rating of 'Low' applies to this hazard.

Hazard 4 has been assessed as having a likelihood category of 'Rare' on the basis of the following:

- Interpreted presence of bedrock within two metres of the existing ground surface;
- The absence of unfavourable and unfavourably oriented strata; and
- The lack of observable groundwater seepage or groundwater.

Deep seated slope instability would be expected to impact on the proposed development with a consequence level of 'Major'; hence a risk rating of 'Low' applies to this hazard.

Reference to the 'Geotechnical Risk Management Policy for Pittwater – 2009' indicates that sites which have been deemed to have a risk level of 'Low' are an acceptable risk level for new development.

5.4 Assessment of Risk to Life

Ref 2 also provides a framework for landslide risk management, guidance on risk analysis methods and information on acceptable or tolerable risks for loss of life.

For the loss of life, the individual risk can be calculated using:

$$R_{LOL} = P_H \times P_{S:H} \times P_{T:S} \times V_{D:T}$$

Where,

- R_{LOL} is the risk, or annual probability of death of an individual
- P_H is the annual probability of the hazardous event
- $P_{S:H}$ is the probability of spatial impact by the hazard given the event
- $P_{T:S}$ is the temporal probability given the spatial impact, and
- $V_{D:T}$ is the vulnerability of the individual

A summary of the results of the assessment undertaken in relation to risk to life of the hazards identified at this site is presented in Table 2.

Table 2 – Assessment of Risk to Life

	Hazard	$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk $R_{(LOL)}$
1	Creep failure of surficial soils	1×10^{-3}	1	1×10^{-3} ⁽¹⁾	0.1 ⁽²⁾	1×10^{-7}
2	Boulder topple	1×10^{-4}	0.05	0.7	0.3 ⁽³⁾	1×10^{-6}
3	Minor rotational landslide	1×10^{-4}	0.5	0.5	0.05 ⁽⁴⁾	1×10^{-6}
4	Large scale landslide	1×10^{-5}	1	0.7	0.1 ⁽⁴⁾	7×10^{-7}

Notes to Table 2:

- 1 Evacuation possible
- 2 Person not buried by debris
- 3 Person inside building struck by rock fall
- 4 Building not inundated by debris

Reference to the 'Geotechnical Risk Management Policy for Pittwater – 2009' indicates that sites which have been deemed to have a risk level to loss of life of 10^{-6} per annum are acceptable for new development.

5.5 Geotechnical Risk Management Policy for Pittwater - 2009

The proposed development at this site is suitable for the site conditions and can achieve Acceptable Risk Management as defined in the 'Geotechnical Risk Management Policy for Pittwater – 2009', provided adherence to the development guidelines set out in Section 6 of this report is observed.

6. Geotechnical Guidelines for Site Development

6.1 General

Effective risk management on the site would be achieved by including in the proposed development design features which either reduce the likelihood of occurrence of a potential slope movement hazard or ameliorate the consequences of a landslide event.

Examples of such risk management measures are given in the following sections.

6.2 Footings

All proposed footing systems should be designed in accordance with AS2870–2011 (Ref 5) or engineering principles.

Consideration will need to be given to the required extent of excavation and filling of the site, including removal of any existing trees and site regrading, when selecting and designing the footing system.

Based on the results of the fieldwork, it is anticipated that footing excavations in the north eastern portion of the proposed dwelling will encounter weathered sandstone. On this basis, and to prevent dissimilar settlement due to variable founding conditions and soil creep, it is advised that all footings be founded at least 100 mm within the underlying weathered sandstone at depths in the order of 0.5 m to 2 m below existing ground surface levels.

Footings founded within weathered sandstone may be proportioned for a maximum allowable end bearing capacity of 400 kPa.

Footings near proposed or existing excavations should be founded below or behind the zone of influence of the base of the excavation.

Footing excavation works should be inspected by a suitably qualified engineer to confirm the founding conditions assumed for design.

6.3 Excavations

All permanent excavations in soil to depths in excess of 0.6 m without battering on this site must be supported by an engineer-designed retaining wall.

Permanent unsupported cuts in loose surface sands must be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 2.5H:1V and must be protected from erosion.

Permanent unsupported cuts in medium to high strength sandstone must be battered in accordance with the requirements of the Building Code of Australia, but should in no case be steeper than 1H:10V and must be protected from erosion.

Tiered batter slopes must be separated by a minimum distance of 1.5 m. Separation distances must not contain grades greater than 20H:1V.

Where applicable, the excavation design should incorporate surcharge loads from slopes, retaining walls, structures and other improvements within the vicinity of the excavation.

Drainage measures should be implemented above and behind all excavations to intercept both surface and subsurface water movement.

6.4 Filling

All fill to be placed on site to heights greater than 0.6 m without battering must be supported by an engineer-designed retaining wall. Note that Council's planning guidelines may impose other restrictions.

All unsupported filling should be battered in accordance with the requirements of the BCA Volume 2, but in no case should be either greater than 1 m in height or steeper than a grade of 2.5H:1V. All fill batters must be protected from erosion.

Fill materials should be placed and compacted in layers of thickness and required degree of compaction to be determined in line with engineering design of proposed structures on the site.

6.5 Earthworks in General

Council's development guidelines should be reviewed during site planning as these may impose height limitations or support requirements on site cuts and fills.

6.6 Retaining Walls

All retaining walls on this site should be engineer-designed in accordance with the requirements of AS 4678–2002, 'Earth-retaining structures' (Ref 6). Retaining walls supporting soil cuttings on this site shall be designed using a design friction angle of 23° and a soil unit weight of 1.7 t/m³.

All retaining structures should be designed to support, where appropriate, surcharge loading due to any sloping ground surface above the retaining walls. All retaining walls should be constructed with adequate surface and subsurface drainage to the Engineer's and Council's requirements.

6.7 Site Drainage

The effective drainage from the site of surface and subsurface water is important to ensure the stability of the surface soil and the long term performance of footing systems and retaining walls.

The property should be developed and maintained in accordance with the guidelines set out in Section 3 of the BCA and Appendix B of AS 2870–2011 (Ref 5).

In particular the following measures are recommended:

- Catch/dish drains formed at the top and dish and rubble drains installed at the toe of all batters and subsoil drains installed behind new retaining walls;
- Cut areas sloped to fall away from proposed building areas and water not be allowed to pond around buildings;
- Surface stormwater and subsoil water collected and disposed of in accordance with Council's requirements; and
- Erosion control measures to be undertaken during construction to Council's requirements.

6.8 Land Clearing

The site lies within an area of bush fire prone land, as identified on Pittwater Councils Bush Fire Prone Land Map.

It is anticipated that the clearing of vegetation to create an asset protection zone on the property will not adversely impact on slope stability on this site.

7. Report Limitations

5QS Consulting Group North [5QS] has prepared this report on a limited geotechnical investigation for a proposed dwelling at No 131 Thompson Street, Scotland Island in accordance with the 5QS proposals by email of 30 March 2017 and 25 July 2018.

The following is a guide as to the intended scope and use of this report.

- This report is provided for the exclusive use of Mr E & Mrs M Burke for the purposes as described in the report. It may not be used or relied upon for other purposes or by a third party. 5QS can accept no responsibility for loss or damage arising out of the use of this report beyond its purpose as stated above, or incurred by any third party relying on the report without the express written consent of 5QS. In preparing this report 5QShas necessarily relied upon information provided by the client and/or their agents.
- The extent of testing associated with this assessment is limited to the DCP test probe and borehole locations and variations in ground conditions may occur. The data from the test locations have been used to provide an interpretation of the likely subsurface profile at the site of the proposed development. 5QS should be contacted immediately if subsurface conditions are subsequently encountered that differ from those described in this report so that we can review and re-interpret the geotechnical model on the basis of the additional data.
- The scope of this investigation does not include any comment on the potential excavatability of the subsurface materials on site.
- Neither this report, nor sections from this report, should be used as part of a specification for a project without review and agreement by 5QS. This is because this report has been written as advice and opinion rather than instructions for construction.

- This report must be read in conjunction with all of the attachments.
- The recommendations provided in this report represent a summary of our technical advice. Please discuss the recommendations with the undersigned if you require any clarification.

For and on Behalf of

5QS Consulting Group North



Adam Hawkes
Professional Engineer

Reviewed



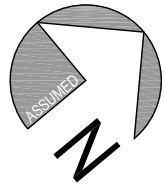
Peter Fennell
Principal

8. References

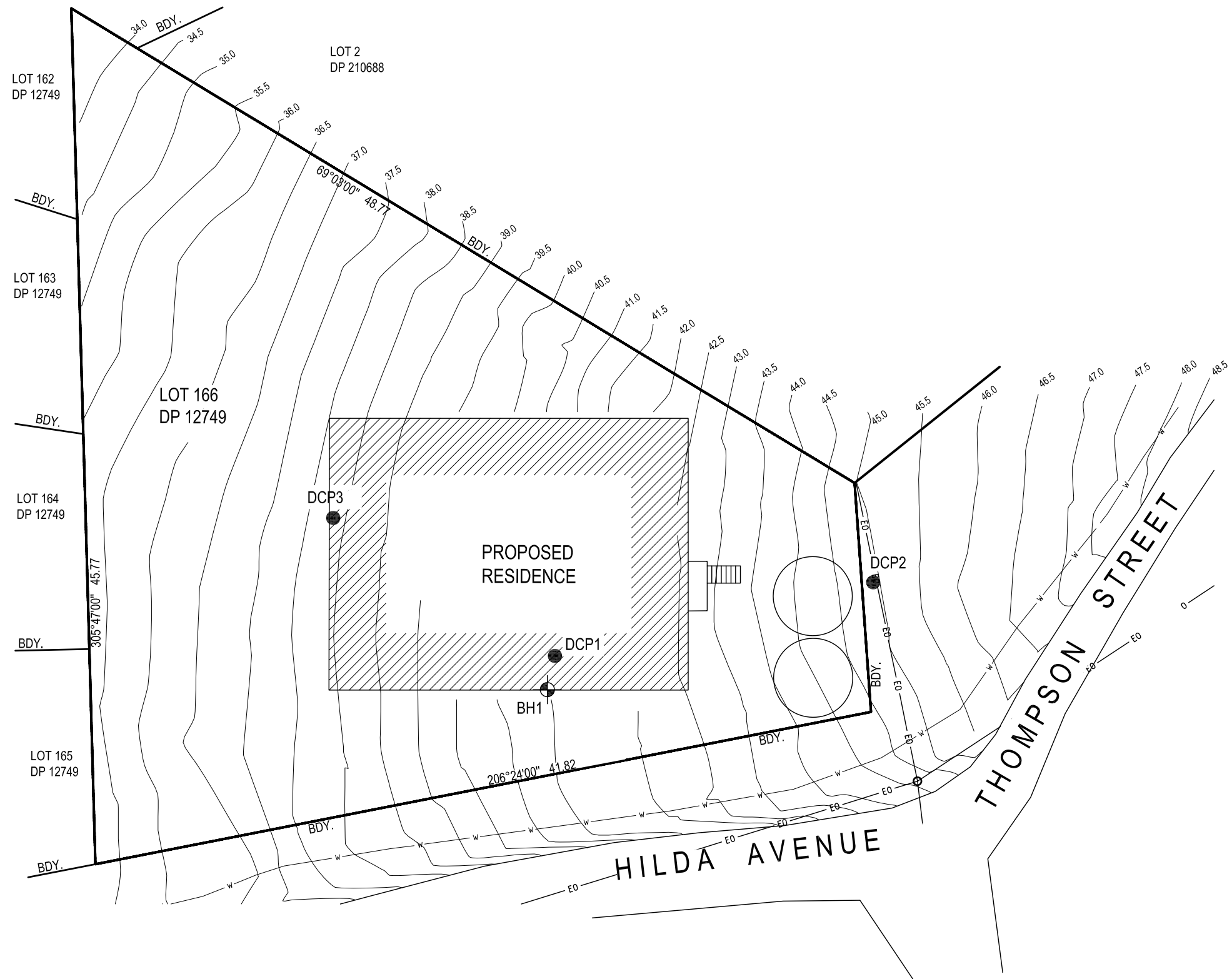
1. Landslide risk management concepts and guidelines, in 'Australian Geomechanics', Vol 37 No 2 (May 2002)
2. Practice note guidelines for landslide risk management, in 'Australian Geomechanics', Vol 42, No 1 (March 2007)
3. 'Sydney 1:100 000 geological series sheet 9130, Edition 1, NSW Department of Mineral Resources (1983)
4. 'Sydney 1:100 000 soil landscape series sheet 9130 (Fourth Edition)' and associated report, NSW Department of Environment, Climate Change and Water (2009)
5. Australian Standard AS 2870–2011, 'Residential slabs and footings', Standards Australia (January 2011)
6. Australian Standard AS 4678–2002, 'Earth-retaining structures', Standards Australia (February 2002)

Attachments:

1. Drawings 7605/G1 Revision A
2. Dynamic Cone Penetrometer logs
3. Engineering log
4. General Notes
5. Australian Geoguides LR7 (Landslide Risk) and LR8 (Hillside Construction Practice)



TEST LOCATION PLAN DEVELOPED FROM SITE PLAN BY
EZY HOMES AUSTRALIA, (DATED 18 July 2018)



TEST LOCATION PLAN
SCALE 1:250

LEGEND

- DCP APPROXIMATE LOCATION OF DYNAMIC CONE PENETROMETER TEST
- ⊕ BH APPROXIMATE LOCATION OF BORE HOLE
- EO ELECTRICITY OVERHEAD
- W WATER

Approved:



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TEST LOCATION PLAN
PROPOSED RESIDENCE
131 THOMPSON STREET, SCOTLAND ISLAND
E. & M. BURKE

Drawing: 7605

Sheet: G1 Revision: A

Original Sheet Size: A3

REV.	DATE	ISSUE DESCRIPTION	DESIGN	DRAWN	CHECKED
A	5.02.18	Development Layout Amended	-	AWH	PAF
-	26.04.17	Report Issue	-	JT	AWH

Dynamic Cone Penetrometer log



Location: 131 Thompson Street, Scotland Island
Client: E & M Burke
Position: See test location plan - 7605/G1
GroundWater: Nil encountered

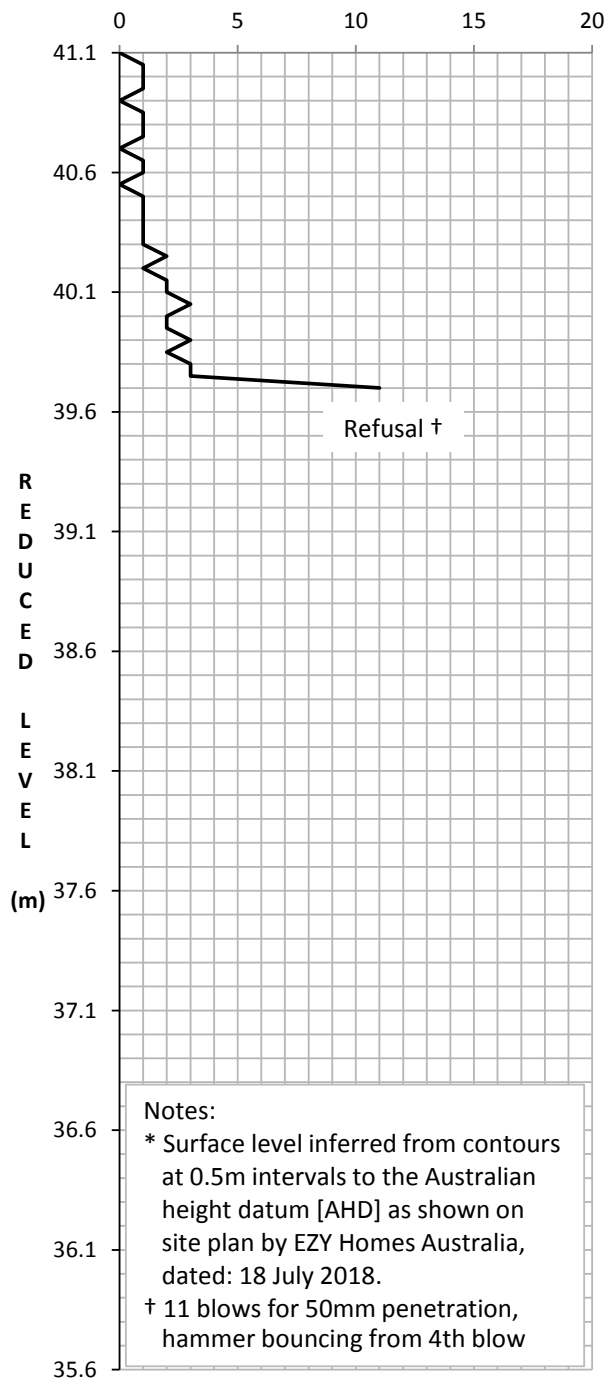
5QS Ref: 7605
Date: 12-Apr-17
Logged By: AWH / JT

* Surface RL: 41.1 AHD

* Surface RL: 45.2 AHD

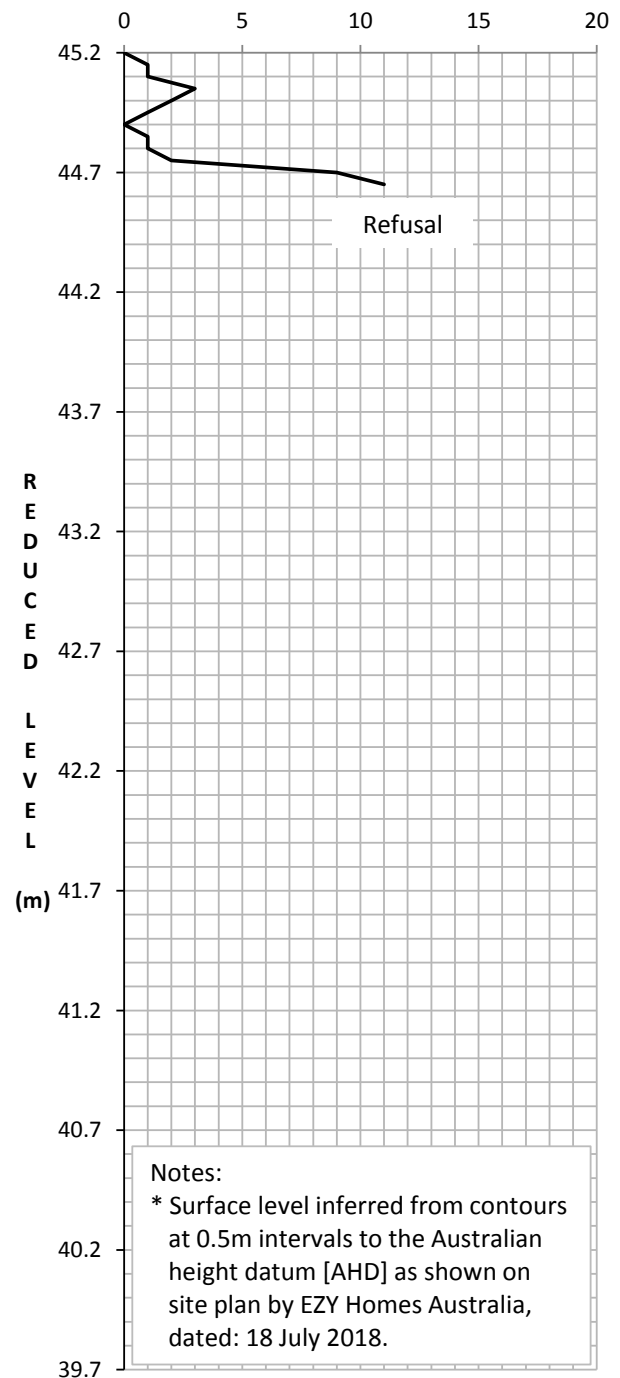
DCP1

NUMBER OF BLOWS TO PENETRATE 50mm



DCP2

NUMBER OF BLOWS TO PENETRATE 50mm



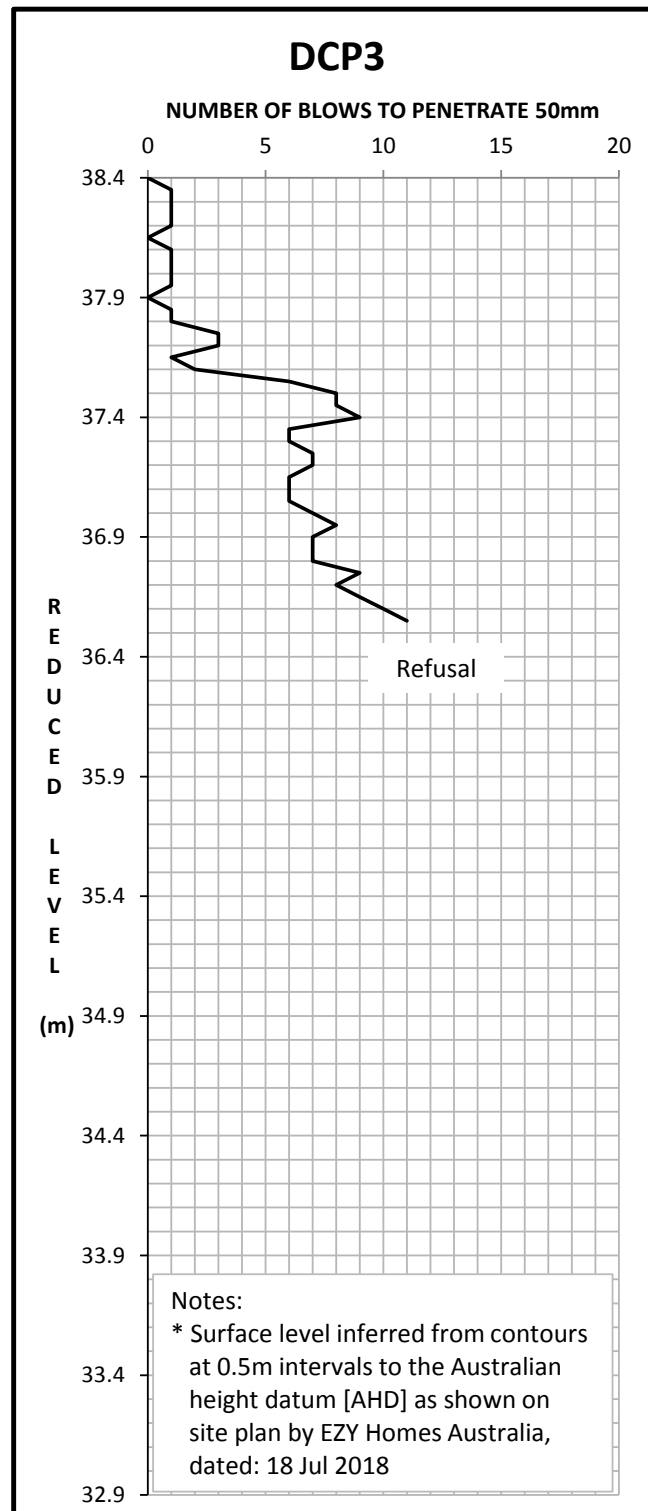
Dynamic Cone Penetrometer log



Location: 131 Thompson Street, Scotland Island
Client: E & M Burke
Position: See test location plan - 7605/G1
GroundWater: Nil encountered

5QS Ref: 7605
Date: 12-Apr-17
Logged By: AWH / JT

* **Surface RL:** 38.4 AHD



Borehole No: BH1
Equipment: Hand Augers[†]
Logged By: AWH/JT
Job No: 7605
Date: 12/04/2017

Drilling Information			Sampling Data		Profile Description													Structure and Additional Comments						
Depth in metres	Progress	Water	Sample Type	Graphic Log	USCS	Material/Strata						Consistency Rel. Density			Moisture				Plasticity					
						VS	Fb	S	VL	L	M	St	D	VS	H	VD	D	SM		M	W			
					SP	TOPSOIL - Sand with a trace of fines, dark brown, fine sand																		
					SP	SAND with a trace of fines, brown, fine sand																		
0.5			NIL		CL	Sandy CLAY - red, brown and orange mottle, trace of rounded gravel to 5mm, M < Wp																M		
					SC	Clayey SAND - orange, yellow and grey, some bands of red, brown and orange sandy clay																		
1						Band of CLAY from 1.25 m to 1.35 m depth - pale grey, estimated stiff to very stiff, some nodules of pale grey sand, M < Wp																M		
1.5						Refusal of hand auger at 1.6m depth, limit of investigation.																		
2																								
Key						USCS Summary						Comments												
Water						Moisture						† 160mm diameter clay cutter to 0.3m depth												
						D dry						GP GRAVEL, poorly graded												
						M moist						GM Silty GRAVEL												
						W wet						GC Clayey GRAVEL												
						Sampling Data						SW SAND, well graded												
						U50 undisturbed sample						SP SAND, poorly graded												
						50mm diameter						SM Silty SAND												
						D disturbed sample						SC Clayey SAND												
						NC cone penetrometer						ML Low plasticity SILT												
						B bulk sample						CL Low plasticity CLAY												
Plasticity						Consistency						MH High plasticity SILT												
NP Non Plastic						Relative Density						CH High plasticity CLAY												
L Low						VS very soft						OL, OH, Pt Organic soils												
M Medium						S soft																		
H High						F firm																		
						VL very loose																		
						L loose																		
						St stiff																		
						M medium dense																		
						VSt very stiff																		
						D dense																		
						H hard																		
						VSt very dense																		

Refer to explanation sheet for description of terms and symbols used

TERMS & SYMBOLS



Unified Soil Classification System (UCS)

COARSE-GRAINED SOILS More than half the material (by weight) is individual grains visible to the naked eye	GRAVELLY SOIL More than half of the coarse fraction is larger than 4.75mm	CLEAN GRAVEL Will not leave a stain on wet palm	Substantial amounts of all grain particle sizes		GW		
			Predominantly one size or range of sizes with some intermediate sizes missing		GP		
		DIRTY GRAVEL Will leave stain on wet palm	Non-plastic fines (to identify, see ML below)		GM		
			Plastic fines (to identify, see CL below)		GC		
	SANDY SOIL More than half of the coarse fraction is smaller than 4.75mm	CLEAN SAND Will not leave not leave a stain on wet palm	Wide range in grain size and substantial amounts of all grain particle sizes		SW		
			Predominantly one size or range of sizes with some intermediate sizes missing		SP		
		DIRTY SAND Will leave stain on wet palm	Non-plastic fines (to identify, see ML below)		SM		
			Plastic fines (to identify, see CL below)		SC		
FINE-GRAINED SOILS More than half the material (by weight) is individual grains not visible to the naked eye (< 0.074mm)	Ribbon	Liquid Limit	Dry crushing strength	Dilatancy reaction	Toughness	Stickiness	
	None	<50	None to slight	Rapid	Low	None	ML
	Weak	<50	Medium to high	None to very slow	Medium to High	Medium	CL
	Strong	>50	Slight to medium	Slow to medium	Medium	Low	MH
	Very Strong	>50	High to very high	None	High	Very high	CH
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture						OL, OH, Pt

Description and classification of soils and rock in accordance with AS1726 'Geotechnical Site Investigations'

<u>Plasticity A2.4(b)</u>			<u>Consistency terms - Cohesive soils TA4</u>		
Symbol	Descriptive term	Liquid limit (%)	Term	USS (kPa)	Field guide to consistency
NP	Non plastic	-	Very soft	< = 12	Exudes between fingers when squeezed in hand
L	of low plasticity	< = 35	Soft	12 - 25	Can be moulded by light finger pressure
M	of medium plasticity	> 35 < = 50	Firm	25 - 50	Can be moulded by strong finger pressure
H	of high plastic	> 50	Stiff	50 - 100	Cannot be moulded by fingers, can be indented by thumb
<u>Moisture Condition A2.5(a)</u>			Vary stiff	100 - 200	Can be indented by thumb nail
'Dry' (D)	Cohesive soils; hard and friable or powdery, well dry of plastic limit. Granular soils; cohesionless and free-running		Hard	> 200	Can be indented with difficulty by thumbnail
'Moist' (M)	Soil feels cool, darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.		<u>Consistency terms - Non-Cohesive soils TA5</u>		
'Wet' (W)	Soil feels cool, darkened in colour. Cohesive soils usually weakened and free water forms on hand when handling. Granular soils tend to cohere.		Term	Density Index (%)	
			Very loose	< = 15	
			Loose	15 - 35	
			Medium dense	35 - 65	
			Dense	65 - 85	
			Very Dense	> 85	

TERMS & SYMBOLS



Symbols

Soil



Asphaltic Concrete or Hotmix



Concrete



Topsoil



Fill



Peat, Organic Clays and Silts (Pt, OL, OH)



Clay (CL, CH)



Silt (ML, MH)



Sandy Clay (CL, CH)



Silty Clay (CL, CH)



Gravelly Clay (CL, CH)



Sandy Silt (ML)



Clayey Sand (SC)



Silty Sand (SM)



Sand (SP, SW)



Clayey Gravel (GC)



Silty Gravel (GM)



Gravel (GP, GW)



Loam

Inclusions



Rock Fragments



Organic Material



Ironstone Gravel, Laterite



Shale Breccia in Sandstone

Rock



Claystone (massive)



Siltstone (massive)



Shale (laminated)



Sandstone (undifferentiated)



Sandstone, fine grained



Sandstone, coarse grained



Conglomerate



Limestone



Coal



Dolerite, Basalt



Tuff



Porphyry



Granite



Pegmatite



Schist



Gneiss



Quartzite



Talus



Alluvium

Seams



Seam >0.1m thick



Seam 0.01m to 0.1m thick

General Notes

Introduction

These notes are supplied with all geotechnical reports from **5QS Consulting Group** and therefore may contain information not necessarily relevant to this report.

The purpose of the report is set out in the introduction section of this report. It should not be used by any other party, or for any other purpose, as it may not contain adequate or appropriate information in these events.

Engineering Reports

5QS Consulting Group engineering reports are prepared by qualified personnel and are based on information obtained, and on modern engineering standards of interpretation and analysis of that information. Where the report has been prepared for a specific design proposal the information and interpretation may not be relevant if the design proposal is changed. If the design proposal or construction methods do change, **5QS Consulting Group** request that it be notified and will be pleased to review the report and the sufficiency of the investigation work.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, the report must be regarded as interpretative, rather than a factual document, limited, to some extent, by the scope of information on which it relies.

***5QS Consulting Group** cannot accept responsibility for problems which may develop if it is not consulted after factors considered in the report's development have changed.*

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, **5QS Consulting Group** cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency.
- The actions of contractors responding to commercial pressures.

If these occur, **5QS Consulting Group** will be pleased to assist with investigation or advice to resolve the matter.

A Geotechnical Engineering Report May Be Subject To Misinterpretation

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a geotechnical engineering report. To help avoid these problems, **5QS Consulting Group** should be retained to review the adequacy of plans and specifications relative to geotechnical issues.

Engineering Logs Should Not Be Separated From The Engineering Report.

Final engineering logs are developed by the Geotechnical Engineer based upon interpretation of field logs and laboratory evaluation of field samples. Only final engineering logs are included in geotechnical engineering reports. To minimize the likelihood of engineering log misinterpretation, *give contractors ready access to the complete geotechnical engineering report.*

Site Inspection

5QS Consulting Group will always be pleased to provide inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit, to full time engineering presence on site.

Change In Conditions

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions, which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.*

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and thus, the continuing adequacy of a geotechnical report. **5QS Consulting Group** should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

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, **5QS Consulting Group** requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed during construction, than at some later stage, well after the event.

Ground Water

Unless otherwise indicated the water levels given on the engineering logs are levels of free water or seepage in the test hole recorded at the given time of measuring. This may not accurately represent actual ground water levels, due to one or more of the following:

- In low permeability soils, ground water although present 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 prior weather changes. They may not be the same at the time of construction as indicated at the time of investigation.

Accurate confirmation of levels can only be made by appropriate instrumentation techniques and monitoring programs.

General Notes – Continued

Foundation Depth

Where referred to in the report, the recommended depth of any foundation, (piles, caissons, footings etc) is an engineering estimate of the depth to which they should be constructed. The estimate is influenced and perhaps limited by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications based upon this report should provide for variations in the final depth depending upon the ground conditions at each point of support.

Engineering Logs

Engineering logs presented in the report 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 provide the most reliable assessment, but this is not always practicable, or possible to justify economically. In any case, the boreholes or test pits represent only a very small sample of the subsurface profile.

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

Drilling Methods

The following is a summary of drilling methods currently used by **5QS Consulting Group**, and some comments on their use and application.

Continuous Sample Drilling: The soil sample is obtained by screwing a 75 or 100mm auger into the ground and withdrawing it periodically to remove the soil. This is the most reliable method of drilling in soils as the moisture content is unchanged and soil structure, strength, appearance etc. is only partially affected.

Test Pits: These are excavated using a backhoe or tracked excavator, allowing close examination of insitu soil if it is safe to descend into the pit. The depth of digging is limited to about 3 metres for a backhoe, and about 5 metres for an excavator. A potential disadvantage is the disturbance of the site caused by the excavation.

Hand Auger: The soil sample is obtained by screwing a 75mm Auger into the ground. This method is usually restricted to approximately 1.5 to 2 metres in depth, and the soil structure and strength is significantly disturbed.

Continuous Spiral Flight Augers: The soil sample is obtained by using a 90 – 115mm diameter continuous spiral flight auger which is withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays, and in sands above the water table. Samples, returned to the surface, are very disturbed and may be contaminated. Information from the drilling is of relatively lower reliability. SPT's or undisturbed sampling may be combined with this method of drilling for reasonably satisfactory sampling.

Hand Penetrometers

Hand Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and recording the number of blows for successive 50mm increments of penetration.

Two, relatively similar tests are used:

1. Perth Sand Penetrometer (AS 1289.5.3.3) – A 16mm flat ended rod is driven with a 9kg hammer, dropping 600mm. This test was developed for testing the density of sands and is mainly used in granular soils and loose fill.
2. Cone Penetrometer/Scala Penetrometer (AS 1289.5.3.2) – A 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm. The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio (CBR) have been published by various road authorities.

Sampling

Sampling is carried out during drilling to allow engineering examination, and laboratory testing of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending on the amount of disturbance during drilling, some information on strength and structure.

Undisturbed samples are taken by pushing a thin walled sample tube into the soils and withdrawing this with a sample of soil in a relatively undisturbed state contained inside. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils. Details of the type and method of sampling are given in the report.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 series, Methods of Testing Soils for Engineering Purposes. Details of the test procedure used are given on the individual report forms.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

LANDSLIDE RISK

Concept of Risk

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

Landslide Risk Assessment

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

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

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

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a

landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

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

TABLE 2: LIKELIHOOD

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

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

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

TABLE 1: RISK TO PROPERTY

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

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

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

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

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

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly

developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

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

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

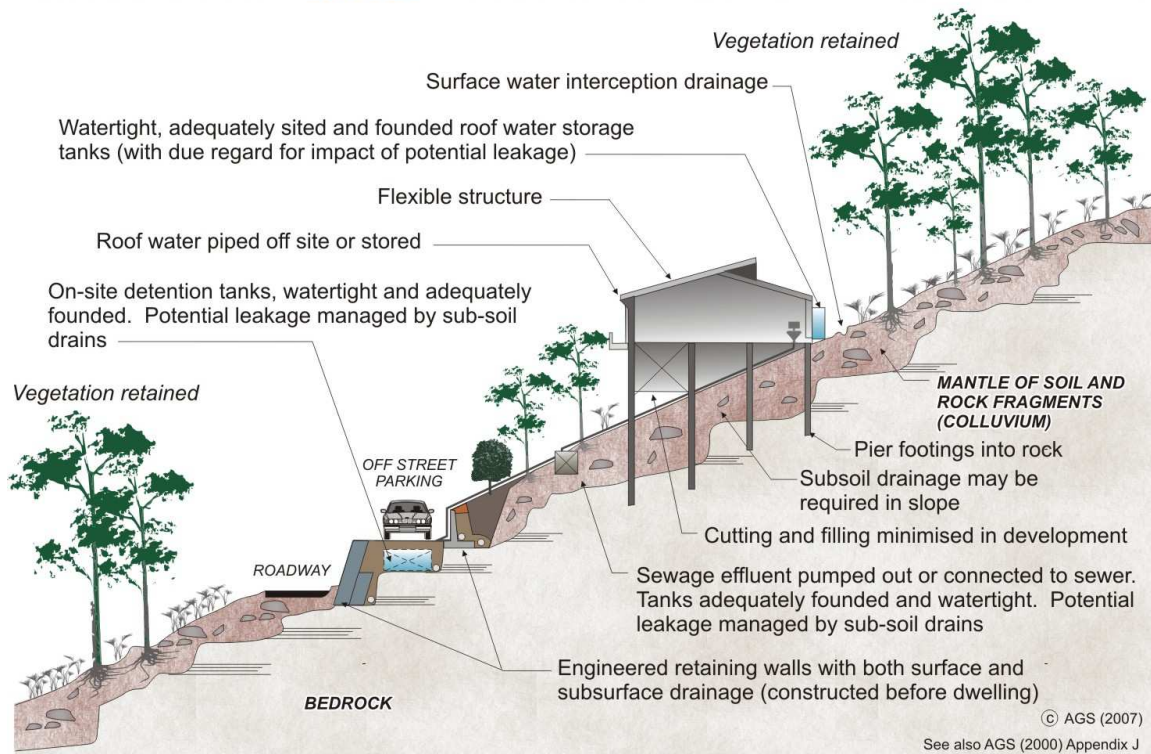
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to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

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

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

EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

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

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

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

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

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

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

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

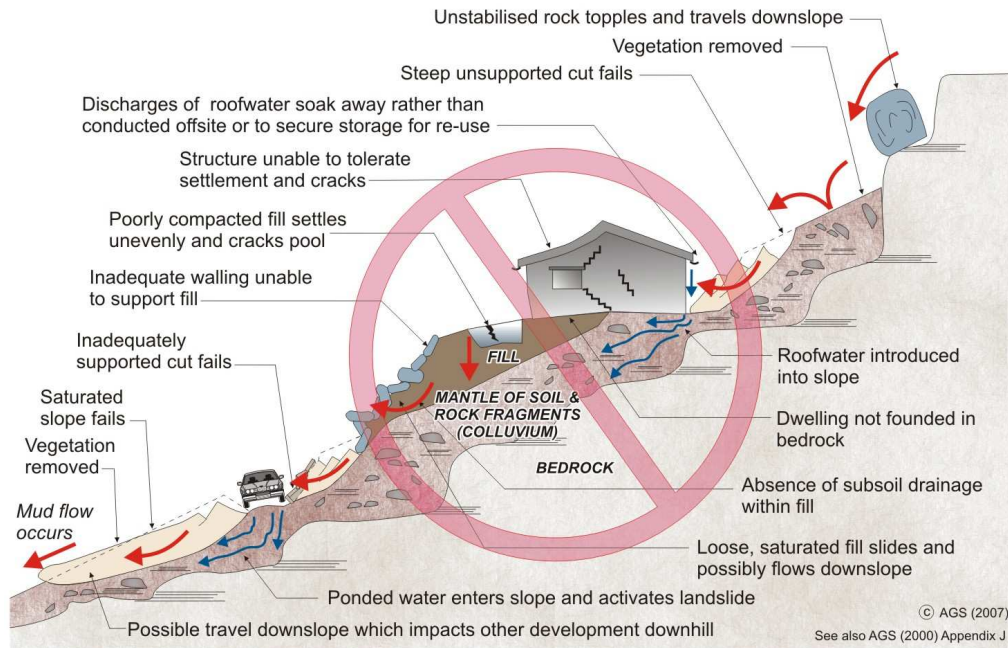
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

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

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

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

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

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

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

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

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

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|-------------------------------------|--|
| • GeoGuide LR1 - Introduction | • GeoGuide LR6 - Retaining Walls |
| • GeoGuide LR2 - Landslides | • GeoGuide LR7 - Landslide Risk |
| • GeoGuide LR3 - Landslides in Soil | • GeoGuide LR9 - Effluent & Surface Water Disposal |
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