APPENDIX 8 GEOTECHNICAL REPORT

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KEIGHRAN GEOTECHNICS
Geotechnical • Pavements • Materials • Consulting Engineers

Principal
G.D. Keighran BE MIE(Aust)

Date: 20th April 2020 | Your Ref: | Our Ref: 19091/GK/1

AWJ Civil Pty Ltd
155 Newton Road
WETHERILL PARK NSW 2164

Attention: Mr M. O'Connell

Dear Sir,

Re: Geotechnical Land Use Stability Assessment
Lot 1 DP 1130700 , Lot 1 Section 60 DP 758855, Lot 1 DP 922029, Lot 1 DP 9223398 and Lot 1 DP 115461
No. 2 and No.23 Williwa Street – Portland

1.0 Introduction

At your request, our principal engineer, Mr G. Keighran, on the 1st November 2019 has undertaken an inspection and investigation of the subsurface conditions across the subject property comprising Lot 1 DP 1130700 , Lot 1 Section 60 DP 758855, Lot 1 DP 922029, Lot 1 DP 9223398 and Lot 1 DP 115461 (No. 2 and 23) Williwa Street at Portland. The properties are known as the Portland Cement Works which had been in operation since 1863 and was decommissioned in 1998.

A development concept plan was developed for the new Owners AWJ Civil Pty Ltd by Compliance Health & Environmental Consulting Pty Ltd in February 2019 and is indicated in Drawing CH1060 Figure No.2.

2. Method Of Investigation

Upon review of a series of historical geotechnical and environmental site investigation reports, it was identified by the client and Lithgow City Council that there are several areas that required some further investigation and guidance to ascertain whether further development was feasible within the. Typically, the concerns were slope stability and the anecdotal uncontrolled filling. Conventional earthworks and lot classifications are expected for the balance of the zones. This included:-

- R1 Residential Zone - Existing Hot Water Dam
- R5 Residential Zone - Northern Side
- R5 Residential Zone - North Eastern Corner

The subsurface conditions within the property were assessed on 1st November 2019 using a 5 tonne excavator supplied by AWJ Civil Pty Ltd under the supervision of our principal geotechnical engineer.

A series of thirteen (13) test pits were excavated within the R5 zone within the Hot Water Dam and three (3) test pits within the R2 Residential Zone (North) and Inspection of the exposures due to shallow bedrock on R5 Zone on the north eastern corner of the properties.

The test pits were logged by our principal engineer who provided the test pits logs presented in Appendix A. The method of soil classification adopted is explained in Appendix B and the location of the boreholes are shown on Drawing No. 19091/1A.

3. Local Geology and Subsurface conditions

The Bathurst 1,250,000 Geological Sheet indicates that the Portland Cement Works site is underlain by Smt – Tanawarra Shale from the Mumbil Group (East) which was laid down during the Silurian Geological Period. The Tanawarra Shale comprise mudstone, siltstone, limestone , lithic sandstone and volcanic clast conglomerate.

Our inspection of the exposures across the subject property including the expose mudstone, conglomerate, sandstone and limestone bedrock.

Conglomerate and mudstone in the Escarpment in NE Corner

Limestone Exposed in Access Road on centre north

The subsurface conditions encountered during the investigation are summarised below and the full test pit5s logs are provided in Appendix A.

R1 Zone - Hot water Dam

A total of thirteen (13) test pits were excavated across the Hot Water Dam floor which encountered the following subsurface conditions:-

FILL (1): Limestone gravel and clayey sand, cream colour, dry to moist and loose. Encountered in TP 1 to TP 4 and TP 10 to depths ranging from 0.5 metres in TP 1 to a maximum 1.2 metres in TP 3.

FILL (2): ash, fine grained trace some concrete gravel, dark grey and grey in colour, dry to wet with depth and loose to medium dense with depth. Encountered below FILL (1) in the above detailed test pits and from the surface in TP 5 to TP 9 and TP 11 to TP 13 to depths ranging from 1.0 metres in TP 10 and TP 11 to 3.6 metres in TP 1 and TP 2. The eastern corner around TP 1 and TP 2 was the deepest and the southern side around TP 10 and TP 11 was the shallowest with about 1.7 to 2.0 metres across the western and northern sides. .

RESIDUAL: sandy clay, medium plasticity, yellow orange in colour and in a moist and stiff condition. Encountered below the FILL (2) in all thirteen (13) test pits.

No free groundwater was encountered, however, wet FILL (2) were encountered in the test pits with FILL (2) at the surface.

TP 2

TP 7

R5 Zone north – Overburden Stockpile

Three (3) test pits were excavated to a maximum depth of 0.5 metres before encountering refusal in the large dimensioned FILL materials-:

FILL: limestone / conglomerate cobbles in sandy matrix, cream to yellow grey, dry and loose to medium dense. Encountered from the surface to well over 0.5 metres where refusal of the 5 tonne excavator occurred in TP 14 to TP 16.

Based on the previous Contamination Report by Compliance Health & Environmental Consulting Pty Ltd the R5 Zone North–R5-1 to R5-7 contained deep Overburden FILL materials overlying natural sandy and silty clays and shale / limestone bedrock. The exact depth of overburden FILL was not determined in our investigation or the Compliance Health & Environmental Consulting Pty Ltd and is expected to be in excess of 10 metres.

TP 16

TP 15

R5 Zone – NE Corner

This area was visually inspected by our principal geotechnical engineer and no test pits were undertaken due to the shallow exposure of parent bedrock present in the exposures within 0.5 metres of the surface.

The exposures from the Dam below up to the north eastern corner boundary exposed shallow conglomerate and mudstone bedrock to the crest of the R5 Zone.

4. Site Stability and Suitability for Residential and Industrial Development

The site stability and suitability for residential and industrial development was undertaken by assessing the subsurface conditions and slope of the land surface adopting the Classification of Risk Slope Instability ranging from Very Low to Very High as detailed in Appendix D.

R1 Zone – Hot water Dam

The Hot Water Dam is located in the central section of the property on generally level ground between the water filled quarries. The hot water dam is about 2 metres below the level of the Portland Cement Plant and is expected to be backfilled and graded to a level below the level of the existing plant in the south eastern corner of the site.

The slope stability risk is there for VERY LOW , however the presence of the uncontrolled ash and limestone gravel fill materials provide a High Risk of differential settlements across any proposed building platform and will require significant bulk earthworks to create a stable Very Low Risk building platform suitable for the proposed R2 Residential Development including dwellings, roads , services

The recommended bulk earthworks treatment is to win suitable FILL materials from elsewhere on the property and strip back the existing uncontrolled FILL materials to the RESIDUAL sandy clays. The uncontrolled FILL materials may be stockpiled and blended where suitably uncontaminated and be blended with the site won materials before being placed and compacted on a Level 1 basis (AS 3798-2007) to provide a 98% Standard Compaction compacted fill to a suitable design level.

R5 Zone north – Overburden Stockpile

The R5 Zone North is considered to be the overburden stockpile for the Portland Cement works and comprises as far as we can determine from the shallow test pitting substantial reserve of natural materials won from the Quarry construction during the century long operation of the Portland Cement Works. This area is considered to be likely source of FILL materials for the Hot Water Dam bulk earthworks.

The current access roadway to the east of the overburden stockpile exposes natural soil and rock materials on the surface which present and VERY LOW risk of Instability, However, the Western Side of the R5 Zone North is elevated by up to 10 metres with stockpiled overburden materials removed from the Quarries on the property. This area is considered to be a MEDIUM Risk of Instability which can be reduced to a LOW RISK with significant bulk earthworks to remove the existing uncontrolled overburden materials which can them be replaced and reshaped into a suitable R5 Residential subdivision.

The existing slopes are currently less that 1V:2H which is considered to be a stable for the long term, however, the presence of the uncontrolled fill materials presents the MEDIUM RISK of instability and as indicated earlier will require significant bulk earthworks to be suitable for Residual subdivision development. .

R5 Zone – NE Corner

The R5 Zone in the North Eastern Corner is located on shallow residual soils with limited if any uncontrolled FILL materials overlying the parent bedrock at depth up to 0.5 metres The presence of the shallow bedrock provides a VERY LOW Risk of instability from both a slope stability point of view and Site Classification to AS 2870 – 2011.

We consider that the R5 Zone in the North Eastern Corner of the property is suitable for residential subdivision at the present time with no significant bulk earthworks other that standard subdivision construction operations.

6. Development Recommendations

6.1 Subdivision Construction

The location of the proposed roadways is considered to be appropriate in that they minimise the extent of cutting and filling required and follow the existing grades of the quarry slopes. The narrower the permissible road formation and the greater the permissible grades, the less significant will be the earthworks involved.

The incidence of deep cuts should be minimised and maximum batter slopes of 1V:2H should be designed unless retained by a suitable retaining wall.

Prior to filling, existing areas containing uncontrolled FILL areas are to be stripped to expose competent natural ground. Where the natural ground slope is in excess of 10% the stripped subgrade should be benched in horizontal terraces so that the fill can be compacted in horizontal layers to reduce the risk of sliding of the fill mass along the inclined plane of the fill/natural ground interface. Placement and compaction of fill should be undertaken under engineering guidance and to the relevant Council specifications.

6.2 Residential Dwelling Construction

The following constraints are intended as general guidelines for development and should be read in conjunction with Appendix E 'GeoGuide LR08 for Hillside Construction'. Development of each lot will require specific assessment prior to commencing construction and the constraints will vary depending on the proposed building site. In some cases, further subsurface investigation is considered appropriate, however, further subsurface information will become available during the road construction.

6.2.1 Low to Very Low Risk Areas

* dwelling construction should follow Standard Council guidelines for residential development after the completion and sign off of any bulk earthworks undertaken as recommended in the R2 – Hot Water Dam location and in the R5 Zone North Overburden Stockpile.

6.2.2 Medium Risk Areas

* further investigation and/or assessment will be likely on most lots, depending on the type and position of proposed development

* restrictions on the type of houses may be appropriate for some of the steeper lots. In general, proposed dwellings should be designed to step down the slope to reduce the need to cut and fill. The use of suspended floors will be preferable to slab-on-ground construction. Elevated timber pole houses will be well suited to many of these sites

* footings for all residential structures, retaining walls etc. should be socketted into the weathered parent bedrock mass. Depending on the type of structure, piered footings may be sufficient, but in general footings will need to comprise rigid, stepped, pier wall type footings, aligned down the slope. Footings across the slope should be avoided to prevent lateral soil pressures (from soil creep) developing on the footings

* strict limits on the extent of cutting and filling will apply. Maximum depths of the order of 1m are anticipated, but reduced depths may apply in some cases. Proposals to excavate to greater depths may be permissible but will require specific geotechnical assessment. Proposals to fill to depths significantly greater than 1m are unlikely to be permissible. All fill and cut batters must be appropriately graded or permanently retained

* all roof and run-off water is to be directed in closed pipes to the interallotment stormwater system. No liquid wastes should be disposed on site. Restrictions may apply to garden irrigation systems.

6.2.3 High Risk Areas

* further and detailed investigation will be necessary to further define subsurface conditions in these areas. Development may not be considered advisable or feasible

* if development is feasible, restrictions on the type of structure which can be constructed will almost certainly apply

* cutting or filling of the land will be significantly restricted

* strict drainage and site maintenance procedures will need to be observed.

6.2.4 Prior to Development : All Lots

Prior to subdivision development, all development proposals should be reviewed by the appointed geotechnical engineer to allow assessment of whether such development is appropriate to the Zone. In many cases this may require further subsurface investigation to confirm the suitability or otherwise and to allow the optimum footing system to be adopted.

Continued geotechnical guidance and inspection during subdivision construction is likely to necessary on some lots and essential on others. Inspections of bulk earthworks, footing and cutting excavations will be required.

Yours faithfully,
KEIGHRAN GEOTECHNICS
per:

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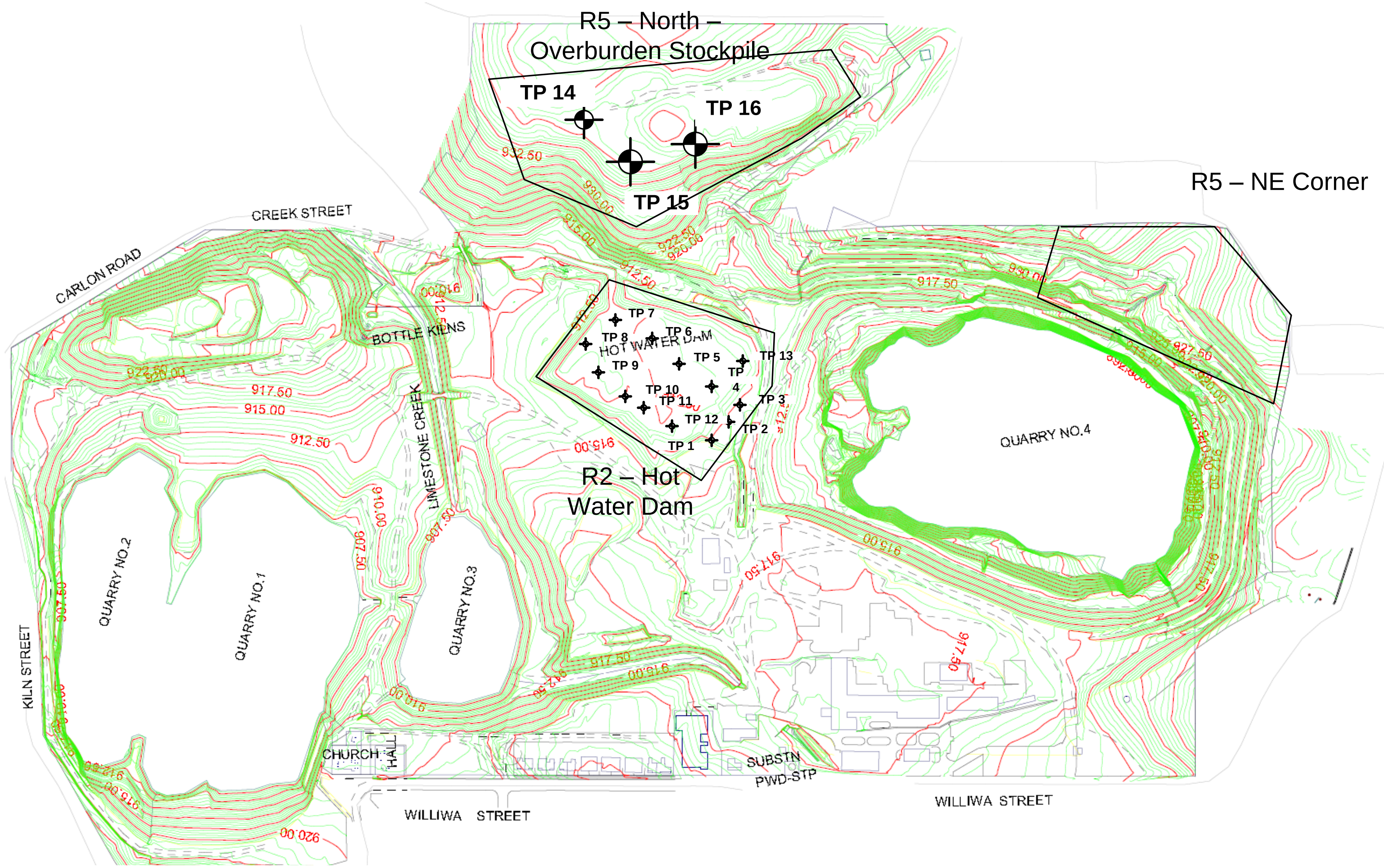
G. D. KEIGHRAN BE MIE(Aust)
Director - Principal Engineer

Attachments
Drawing No. 19091/1A - Test Pit Locations
Drawing No. 19091/1B - Risk Assessment Summary
Appendix A Engineering Test Pit Logs
Appendix B Method of Soil Classification
Appendix C Engineering Classification of Sedimentary Rocks in the Sydney Area
Appendix D Important Information About Your Stability Assessment Report
Appendix E GeoGuide LR08 Hillside Construction



TEST PIT LOCATIONS

GEOTECHNICAL INVESTIGATION

GDK
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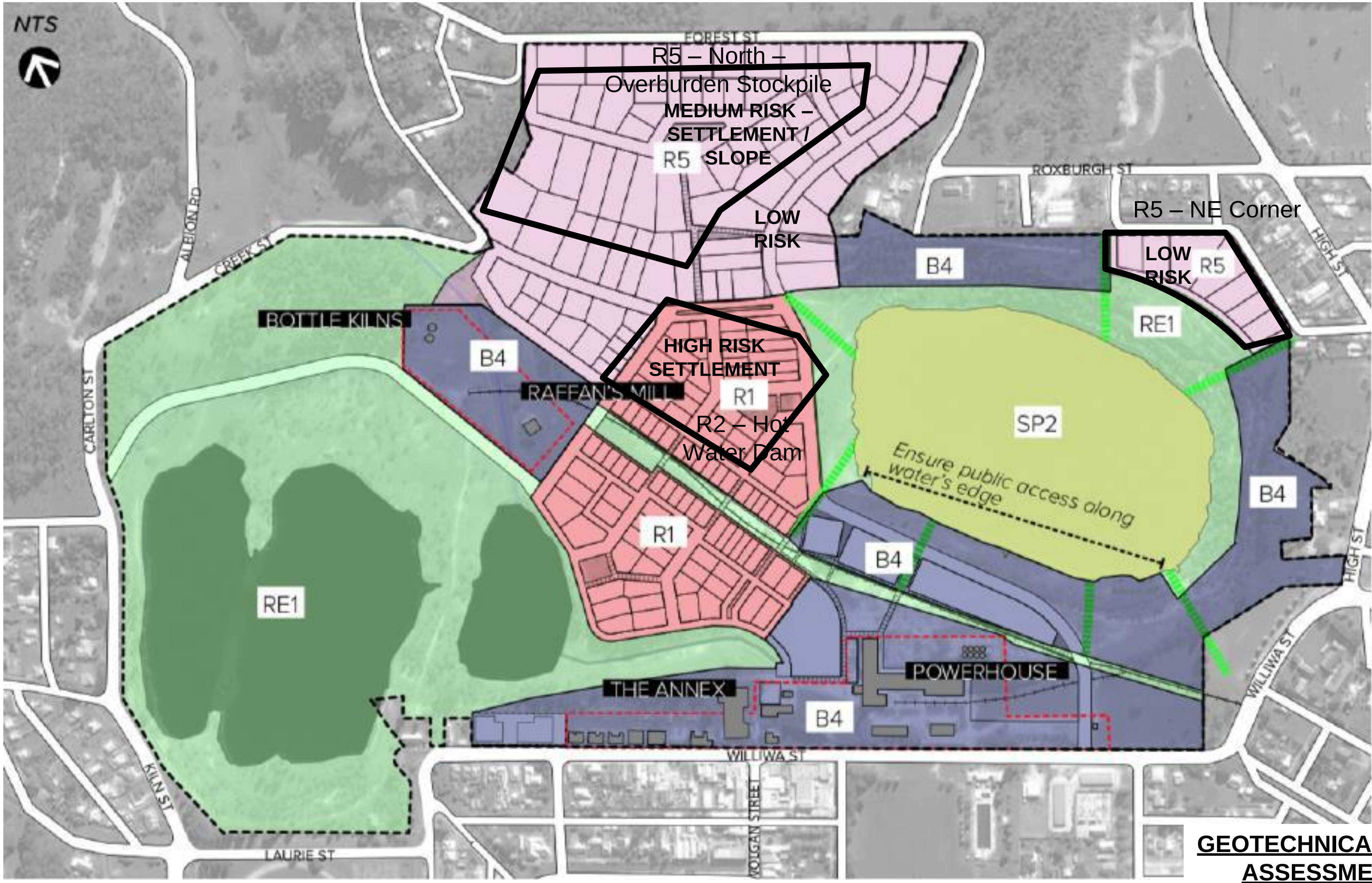
Scale Plan	
Section	
Drawn	
Checked	

AWJ CIVIL PTY LTD
GEOTECHNICAL LAND USE STABILITY ASSESSMENT
No. 2 and No 23 WILLIWA STREET PORTLAND

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
0	ISSUED TO CLIENT IN REPORT	26 MAR 2010	

Drawing No.
19091/1A



GEOTECHNICAL RISK ASSESSMENT

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Scale	
Plan	
Section	
Drawn	
Checked	

AWJ CIVIL PTY LTD
GEOTECHNICAL LAND USE STABILITY ASSESSMENT
No. 2 and No 23 WILLIWA STREET PORTLAND

REVISIONS

REV	DESCRIPTION	DATE	APPROVED
0	ISSUED TO CLIENT IN REPORT	20 APR 2020	

Drawing No.

19091/1B

DATE SAMPLED: 01/11/2019 **OUR REF: 19091/ GK / 1** **APPENDIX: A**

DEPTH (m) From	**To**		**MATERIAL DESCRIPTION**	**SAMPLING DATA Depth (m)**	**Type**
TP 1					
0	0.5	TOPSOIL:	ash and silty sand, vegetation Grey brown, dry to moist=t and loose		
0.5	3.6	FILL:	ash, fine grained Dark grey and grey Dry to moist and loose		
3.6	3.8	RESIDUAL:	sandy clay, medium plasticity Yellow , Moist and stiff		
3.8		Discontinued			
TP 2					
0	0.8	FILL:	Limestone gravel and clayey sand cream, dry to moist and loose		
0.8	3.6	FILL:	ash, fine grained, trace concrete gravel Dark grey and grey Dry to moist and loose		
3.6	3.8	RESIDUAL:	sandy clay, medium plasticity Yellow and grey , moist and stiff		
3.8		Discontinued			
TP 3					
0	1.2	FILL:	Limestone gravel and clayey sand cream, dry to moist and loose		
1.2	2.5	FILL:	ash, fine grained, trace concrete gravel Dark grey and grey Dry to moist and loose		
2.5	2.8	RESIDUAL:	sandy clay, medium plasticity Yellow , Moist and stiff		
2.8		Discontinued			

DATE SAMPLED: 01/11/2019 **OUR REF: 19091/ GK / 1** **APPENDIX: A**

DEPTH (m) From	To		MATERIAL DESCRIPTION	SAMPLING DATA Depth (m)	Type
TP 4					
0	0.7	FILL:	Limestone gravel and clayey sand cream, dry to moist and loose		
0.7	1.7	FILL:	ash, fine grained, trace concrete gravel Dark grey and grey Dry to moist and loose		
1.7	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow , Moist and stiff		
2.0		Discontinued			
TP 5					
0.0	1.7	FILL:	ash, fine grained, trace concrete gravel Dark grey and grey Moist to wet and loose		
1.7	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 6					
0.0	1.8	FILL:	ash, fine grained Dark grey and grey Moist to wet and loose		
1.8	2.3	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.3		Discontinued			
TP 7					
0.0	1.1	FILL:	ash, fine grained, Dark grey and grey Moist to wet and loose		
1.1	1.2	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
1.2		Discontinued			

DATE SAMPLED: 01/11/2019 **OUR REF: 19091/ GK / 1** **APPENDIX: A**

DEPTH (m) From	To		MATERIAL DESCRIPTION	SAMPLING DATA Depth (m)	Type
TP 8					
0.0	1.5	FILL:	ash, fine grained, Dark grey and grey Moist to wet and loose		
1.5	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 9					
0.0	1.4	FILL:	ash, fine grained Dark grey and grey Moist to wet and loose		
1.4	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 10					
0.0	0.6	FILL:	Limestone gravel and clay Grey and yellow dry to moist and loose		
0.6	1.0	FILL:	ash, fine grained, Dark grey and grey Moist to wet and loose		
1.5	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 11					
0.0	1.0	FILL:	ash, fine grained Dark grey and grey Moist to wet and loose		
1.0	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			

DATE SAMPLED: 01/11/2019 **OUR REF: 19091/ GK / 1** **APPENDIX: A**

DEPTH (m) From	**To**		**MATERIAL DESCRIPTION**	**SAMPLING DATA Depth (m)**	**Type**
TP 12					
0.0	1.1	FILL:	ash, fine grained Dark grey and grey Moist to wet and loose		
1.1	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 13					
0.0	1.2	FILL:	ash, fine grained Dark grey and grey Moist to wet and loose		
1.2	2.0	RESIDUAL:	sandy clay, medium plasticity Yellow orange, Moist and stiff		
2.0		Discontinued			
TP 14					
0.0	0.5	FILL:	sandstone gravel to 200 mm in sandy matrix Yellow orange and grey Dry and uncompacted		
0.5		Discontinued			
TP 15					
0.0	0.5	FILL:	sandstone gravel to 200 mm in sandy matrix Yellow orange and grey Dry and uncompacted		
0.5		Discontinued			
TP 16					
0.0	0.5	FILL:	sandstone gravel to 200 mm in sandy matrix Yellow orange and grey Dry and uncompacted		
0.5		Discontinued			

The method of soil classification adopted is based on that presented in AS1726. Unless specific detailed testing has been undertaken, the soil descriptions in this report are based on visual assessment and are hence subjective interpretations.

1. **PRIMARY CLASSIFICATION** (based on the predominant particle size within the soil mass)

A. **Coarse Grained Soils**. ie. more than half the soil has particles larger than 0.075mm.

GRAVELS : more than half the coarse fraction is larger than 2.36mm. Gravels are further subdivided into fine (2.36 to 6mm), medium (6 to 20mm) and coarse (20 to 63mm). Particles larger than 63mm minimum dimension are called COBBLES and larger than 200mm are called BOULDERS.

SANDS : more than half of the coarse fraction is smaller than 2.36mm. Sands are further subdivided into fine (0.075 to 0.2mm), medium (0.2mm to 0.6mm) and coarse (0.6 to 2.36mm).

B. **Fine Grained Soils**. ie. more than half the soil has particles smaller than 0.075mm.

SILTS : particles range from 0.075mm to 0.002mm particles can be felt but not seen.

CLAYS : particles smaller than 0.002mm, which can be neither felt nor seen.

2. **SECONDARY CLASSIFICATION**

A. **Coarse Grained Soils** are described as either **Well Graded** (having good representation of all particles sizes), **Poorly Graded** (one or more intermediate sizes poorly represented or absent) or **Uniform** (particles all of one size).

In addition gravels and sands may have a proportion of their composition comprising clays and/or silts. When this occurs, the "trace" denotes less than 5 per cent of the total soil, "with clay/silt" denotes 5 to 12 percent of the total soil and the use of the prefix "silty" or "clayey" (as applicable) denotes greater than 12 per cent of the soil mass.

B. **Fine Grained Soils**: The plasticity of fine grained soils is denoted and defined as follows:-

low plasticity	liquid limit less than 35 percent
intermediate or medium plasticity	liquid limit from 35 to 50 percent
high plasticity	liquid limit greater than 50 percent

In addition, clays and silts may have proportion of sands or gravels in their composition. "Trace" denotes less than 15 percent coarse fraction and "with sand / gravel" denotes 15 to 30 percent coarse fraction. When the coarse fraction exceeds 30 percent, "sandy" or "gravelly" are used as a prefix.

3. **CONDITION OF SOIL :** the condition of the soil may be described in the following terms:-

Moisture condition : is described by the appearance and feel of the soil using one of the following terms:

'Dry' - looks and feels dry; cohesive soils usually hard, powdery or friable, granular soils run freely through the hands.

'Moist' - soil feels cool, darker in colour, granular soils tend to cohere, cohesive soils usually weakened by remoulding

'Wet' - as for moist but free water form on hands when handling.

Consistency of cohesive soils

Term	Undrained Shear Strength	General Guide To Consistency
Very soft	less than 12 kPa	Exudes between the fingers when squeezed in hand
Soft	12 to 25 kPa	Can be moulded by light finger pressure
Firm	25 to 50 kPa	Can be moulded by strong finger pressure
Stiff	50 to 100 kPa	Cannot be moulded by fingers and indented by thumb
Very Stiff	100 to 200 kPa	Can be indented by thumb nail
Hard	greater than 200 kPa	Can be indented with difficulty by thumb nail

Relative Density of cohesionless soils: The consistency of an essentially cohesionless soil is described in terms of the density index, as defined in AS 1289.A1 which requires some form of test on an undisturbed or in situ sample. Normally a penetration test (SPT, Scala or Dutch Cone) is used in conjunction with published correlation tables.

Term	Density Index	Field Guide To Consistency
Very loose	less than 15%	Ravels
Loose	15 to 35%	Shovels easily
Moderately Dense	36 to 65%	Shovelling difficult
Dense	66 to 85%	Pick required
Very dense	greater than 85%	Picking difficult

4. **STRUCTURE OF SOIL** : the following aspects of structure may be noted:-

a) Zoning : A soil may consist of separate zones of different properties. A 'Layer' is a continuous zone across an exposure. A 'Lens' is a discontinuous layer of different material, with lenticular shape. A 'Pocket' is an irregular inclusion of different material. The boundaries of the zones are described as 'sharp regular', 'sharp irregular' or 'gradual'.

b) Defects: Such as fissures or surfaces along which the soil breaks easily, root holes etc.

c) Cementing : Coarse grained soils or defects within soils may be cemented together by various agencies. If the cementing agent allows the particle aggregation to be easily fractured by hand when the soil is saturated it is described as 'weakly cemented'. If the cementing agent prevents fracturing by hand of the particle aggregations when saturated, the soil has assumed rock properties which are described according to the system adopted for classification of rocks.

5. **ORIGIN**

An attempt is made, where possible, to assess origin (fill, alluvial, residual, colluvial etc.) since this assists in the judgement of probable engineering behaviour. This assessment is generally restricted to field logging activities. An interpretation of landform is a useful guide to the origin of transported soils (eg. talus, slide debris, slope wash, alluvial, lacustrine, estuarine, aeolian and littoral deposits) while local geology and remnant fabric will assist identification of residual soils.

ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS IN THE SYDNEY AREA APPENDIX C

(from Australian Geomechanics Journal 1975)

This classification system provides a standardised terminology for the engineering description of the sandstone and shales in the Sydney Area, but the terms and definitions may be used elsewhere when applicable. Under this system rocks are classified by rock type, degree of weathering, strength, stratification spacing, and degree of fracturing. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc.) where these are relevant.

ROCK TYPE DEFINITIONS

Rock Type	Definition
Conglomerate	More than 50% of the rock consists of gravel sized (greater than 2mm) fragments.
Sandstone	More than 50% of the rock consists of sand sized (.06 to 2mm) grains.
Siltstone	More than 50% of the rock consists of silt-sized (less than .06mm) granular particles and the rock is not laminated.
Claystone	More than 50% of the rock consists of clay or scricitic material and the rock is not laminated.
Shale	More than 50% of the rock consists of silt or clay sized particles and the rock is laminated.

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

DEGREE OF WEATHERING

Term	Symbol	Definition
Extremely Weathered	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System but the texture of the original is still evident.
Highly Weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of weathered substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered	SW	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh recognisable.
Fresh	Fr	Rock substance unaffected by weathering.

DEGREE OF FRACTURING

The classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Type	Description
Fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter.
Highly fractured	Core lengths are generally less than 20mm - 40mm with occasional fragments.
Fractured	Core lengths are mainly 30mm - 100mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300mm - 1000mm with occasional longer sections and occasional sections 100mm - 300mm.
Unbroken	The core does not contain any fracture.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics (1972).

Term	IS(50) MPa
Extremely weak	
	0.03
Very Weak	
	0.1
Weak	
	0.3
Medium Strong	
	1.0
Strong	
	3.0
Very Strong	
	10.0
Extremely strong	

Stratification Spacing Term	Separation of Stratification Planes
Thinly laminated	<6mm
Laminated	6mm to 20mm
Very thinly bedded	20mm to 60mm
Thinly bedded	60mm to 0.2m
Medium bedded	0.2m to 0.6m
Thickly bedded	0.6m to 2m
Very thickly bedded	2m

1. Introduction.

In the Sydney Basin, which includes Wollongong to Newcastle and inland to Lithgow, there are many naturally occurring slopes which are often the result of weathering and downslope transport of a mantle of soil and rock fragments. These may be unstable or potentially unstable, which may have a significant effect upon hillside development. Natural factors that effect the stability geology, nature and extent of the mantle of soil and rock fragments, groundwater, slope gradient and topography and vegetation. Further, the stability of these sites are often affected by both subdivision and individual lot development, where the impact of cutting, filling and drainage can be substantial.

2. Assessment Procedure

The risk of slope instability should be assessed by an experienced geotechnical engineer and has been based upon:-

* study of geological and topographic maps supplemented by the consultant's experience in the areas
* consideration of information made available by the client about the site and its surrounding areas (including previous instability, building distress and drainage problems) and development proposals.
* visual appraisal of the site and surrounding area including signs of instability, soil and rock exposures, seepage and vegetation.
* collection of basic geological measurements from the site to produce a geological sketch model.
* consideration of possible effects of high rainfall.

The assessment applies to the site at the time of the Inspection.

Although the assessment is predominantly deductive and incorporates judgement based on experience, in most very low to medium risk sites it will be sufficient to enable development to proceed. However, on very high and some medium risk sites geotechnical investigation will be required to confirm the assessment and define development options. The scope of such investigation depends upon the risk of instability and the proposed development and will involve subsurface investigations and possibly soil testing to improve the geotechnical consultant's understanding of the site.

3. Development

Whilst some sites may be unsuitable for economic development.Building techniques are available to enable development of many higher risk sites. Inappropriate development on the site and neighbouring properties can cause slope failure and serious damage. Inappropriate development includes:

* unsupported excavation or placement of fill.
* excessive clearing of vegetation.
* introduction of water to the slope.
* surface footings founded on the mantle of soil and rock fragments.

The owner's decision to develop the site involves an acceptance of a level of risk following development as assessed by the consultant. Even with suitable hillside construction techniques some minor cracking may occur. Other engineering constraints unrelated to slope instability may apply.

4. Classification of Risk Slope Instability

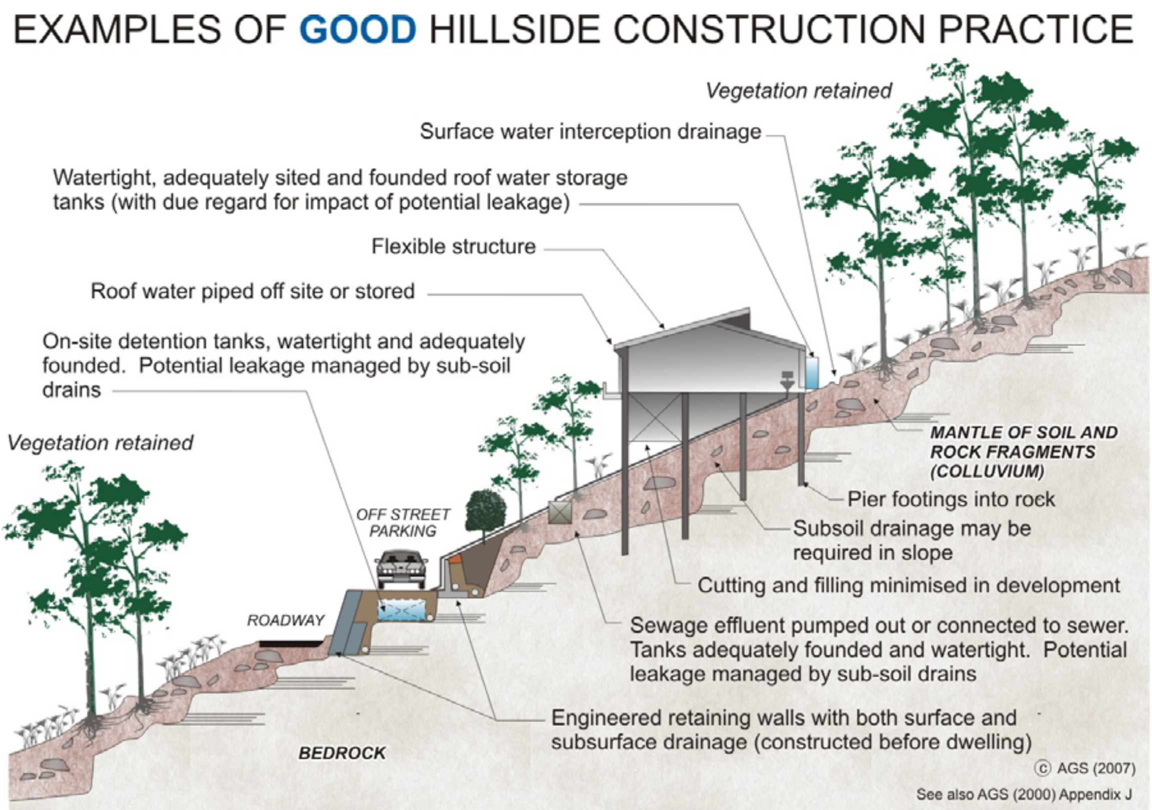
This table is an extract from GEOTECHNICAL RISKS ASSOCIATED WITH HILLSIDE DEVELOPMENT as presented in Australian Geomechanics News, Number 10, December, 1985. It provides a simplified classification allowing a uniform language for geotechnical consultants.

RISK OF INSTABILITY	EXPLANATION	IMPLICATIONS FOR DEVELOPMENT
VERY HIGH	Evidenive of active or past landslips or rockface failure, instability may occur.	Unsuitable for development unless major geotechnical extensive work can satisfactorily improve the instability. Extensive geotechnical investigation necessary. Risk after development may be higher than usually accepted.
HIGH	Evidence of active soil creep or minor slips or rockface instability; significant instability may occur during and after extreme climatic conditions.	Development restricitions and/or geotechnical works required. Geotechnical investigation usually necessary. Risk after development may be higher than usually accepted.
MEDIUM	Evidence of possible soil creep or a steep soil covered slope; significant instability can be expected if the development dies not have due regard for the site conditions.	Development restrictions may be required. Engineering practices suitable to hillside construction necessary. Geotechnical investigation may be needed. Risk after development generally no higher than usually accepted.
LOW	No evidence of instability ovserved, instability not expected unless major site changes occur.	Good engineering practices suitable for hillside construction required. Risk after development normally acceptable.
VERY LOW	Typically shallow soil cover with flat to gently sloping topography.	Good engineering practices should be followed.

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.



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.

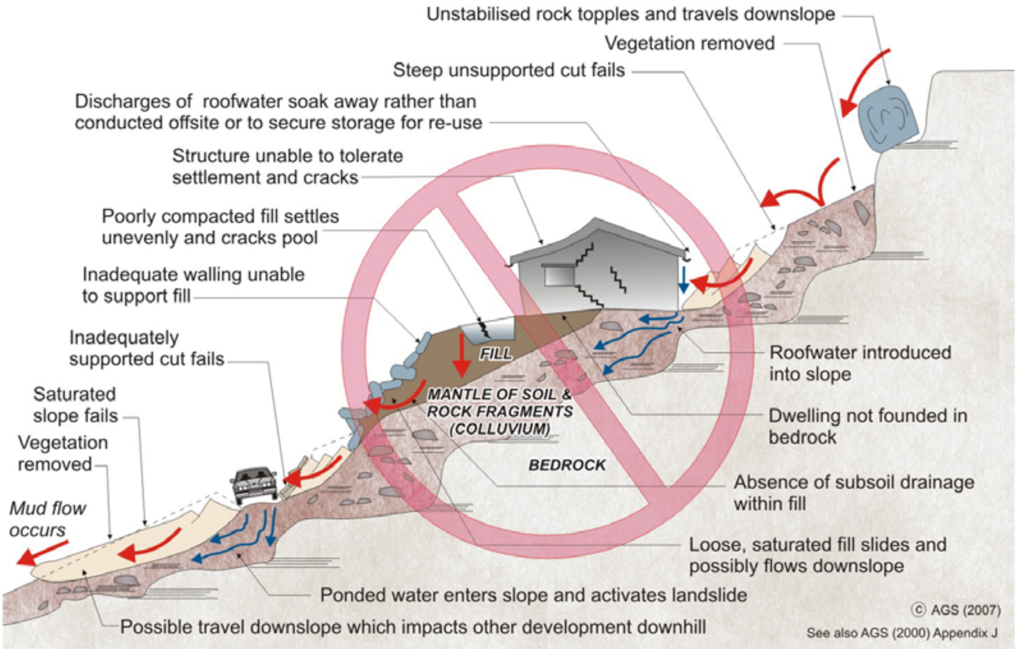
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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:

- 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 LR7 - Landslide Risk
- 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.