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DEVELOPMENT ASSESSMENT AND
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Catalyst One

Geotechnical Investigation: Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW

P1504591JR01V01
January 2015

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

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All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Introduction

1.1 Overview

This document reports the findings of a geotechnical investigation undertaken for a proposed 25m high telecommunication monopole to be located at Thredbo Ski Resort, Thredbo, NSW (Optus Site S8596). The area of investigation was restricted to the south of the maintenance shed 'The Cat Shed' (Figure 1, Attachment A).

This report has been prepared in general accordance with AS1726 (1993), the requirements of the Client and the agreed scope of work. It provides descriptions of sub-surface conditions encountered during field investigations, with corresponding geotechnical design parameters and recommendations, and in-situ soil resistivity test results.

1.2 Field Investigations

Field investigations, conducted on January14, 2015, included:

- General walkover inspection to assess existing site conditions and local topography, geology, exposed soil conditions, drainage and vegetation.
- Reviewing DBYD survey plans and on-site search for buried services in the investigation area.
- Two test pits (TP101 to TP102), excavated up to 2.4 meters below ground level (m bgl) using a 7t excavator with a toothed bucket to characterise sub-surface materials. Steep grades and loose surface materials along access track prevented the use of a convention drilling rig.
- Two Dynamic Cone Penetrometer (DCP) tests (DCP101 and DCP 102) up to 1.3 m bgl, to estimate soil strength in accordance with AS 1289.6.3.2 (1997).
- Soil resistivity testing using an AEMC 4620 Ground Resistance Tester and adopting the Wenner 4 pin method in accordance with Standards Australia HB 160 (2006).
- Collection of samples for future reference.

Approximate test locations are shown on a site plan in Figure 1, Attachment A.

2 Geotechnical Assessment

2.1 Site Conditions

Table 1 summarises site conditions considered relevant to the investigation. Photos of the investigation area are provided in Attachment A.

Table 1: Site conditions.

Item	Description/ Detail
Topography	Moderately steep to steep grades, moderately undulating terrain.
Expected Geology	The Tallangatta 1:250,000 Geological Series Sheet SJ 55-3 describes the geology at the site as lower Devonian volcanic, generally consisting of granite and granodiorite.
Expected Soil landscape	The NSW Soil and Land Information eSPADE (survey, 0BSCRA – KOSCIUSKO 1003650) describes the soils at the site as humose-acidic mesotrophic yellow kandosol.
Site aspect	South west
Typical slopes/ Elevation	Generally 5-10%, between 1,496 and 1,494m AHD
Existing vegetation	Grass (cleared forest)
Site drainage	Via overland flow south west towards Thredbo River

2.2 Sub-surface Conditions

2.2.1 Observed Sub-surface Conditions

Table 2 presents a summary of encountered sub-surface materials and conditions to investigation termination depth, inferred from test pit and DCP test results. Encountered conditions are described in more detail on excavation logs, Attachment B, photos of test pits, Attachment A and associated explanatory notes, Attachment G.

Table 2: Preliminary material properties based on TP101.

	Depth(m)[2]	
Layer[1]	TP101	TP102
TOPSOIL: Sandy clay (firm to stiff)	0.0 – 0.6	0.0 – 0.5
RESIDUAL: Clay (stiff to very stiff)	0.6 – 1.5	0.5 – 1.1
WEATHERED ROCK: Granite (inferred very low strength) distinctly weathered	1.5 – 2.4[3]	1.1 – 1.8[3]
ROCK: Granite (inferred low to possibly high strength)[4]	>2.4	>1.8

Notes:

[1] Refer to test pit logs (Attachment B) for more detailed material descriptions at test locations.

[2] Indicative depth range below ground level, to end of test pits, which may vary across site depending on site and local geological conditions.

[3] Termination depth due to test pit refusal.

[4] Low strength inferred at test pit termination depth. Strength of granite may increase rapidly to high below this depth. Rock conditions should be further assessed by additional investigation such as rocking coring, to assess foundation and foundation excavation limitations.

Isolated granite exposures were observed at surface level across the area.

2.2.2 Groundwater

Groundwater inflow was not observed in the excavations to a depth of 2.4 m bgl. Further testing would be required to assess long-term groundwater conditions, if necessary.

2.3 Geotechnical Recommendations

2.3.1 Proposed Footing Systems and Founding Levels

We recommend the following options:

- Shallow footings for lightly loaded, high-level structures, such as equipment shelters founding on residual soil, 0.75 m below final ground levels.
- A shallow pad footing e.g. square footing as support for the monopole, founding on low strength (or higher) rock. The limited access conditions will likely preclude the use of a piling rig that is capable of drilling into possible high strength granite for the provision of an adequate socket for pile foundations. Shoring of exposed soils will be required and adequately designed by a qualified geotechnical or structural engineer.
- The use of rock anchors or group of shorter piers may be considered to limit the size of pad footing.

2.3.2 *Preliminary Material Properties and Design Parameters*

Preliminary material properties, inferred from DCP test results and observations during excavations, such as excavation resistance, are summarised in Table 3. Table 4 summarises geotechnical parameters for encountered sub-surface conditions recommended for design of new shallow and deepened single pad footings or anchors for the new monopole.

Table 3: Preliminary material properties.

Layer	γ [1] (kN/m³)	C_u [2,4] (kPa)	Ø' [3,4] (°)	E' [6] (MPa)
TOPSOIL: Sandy clay (firm to stiff)	18	50	-	10
RESIDUAL: Clay (stiff to very stiff)	19	100	-	30
WEATHERED ROCK: Granite (inferred very low strength) distinctly weathered	22	-	35	75
ROCK: Granite (inferred low to possibly high strength)	23	-	40	100

Notes:

[1] Material unit weight, based on visual assessment (± 10%).

[2] Undrained cohesion, assuming normally consolidated clay (± 10%).

[3] Effective internal friction angle (± 2°).

[4] Cohesion and friction angle of soil, that apply to transient loading conditions, e.g. wind loading. In rock, values apply concurrently for short and long-term loading. These are derived by reducing intact rock strength to take account of discontinuities in, and weathering of, the rock mass.

[5] Effective elastic modulus (± 10%), that should be adopted to calculate lateral deflection of pile in soil under serviceability loading.

Table 4: Recommended geotechnical design parameters.

Layer	Shallow Footings AEB [1, 4]	Rock Anchors[2] ASF [3,4]	K_a [5]	K_p [5]
TOPSOIL: Sandy clay (firm to stiff)	NA[8]	NA[8]	0.4	2.4
RESIDUAL: Clay (stiff to very stiff)	85[6]	NA[8]	0.37	2.7
WEATHERED ROCK: Granite (inferred very low strength) distinctly weathered	350[7]	20	-	-
ROCK: Granite (inferred low to possibly high strength)	600[7]	50	-	-

Notes:

[1] Allowable end bearing pressure (kPa) for footings embedded at least 0.5 m into the design material type.

[2] Assuming corrosion protected, grouted rock anchors.

[3] Allowable skin friction (kPa) in uplift, assuming intimate contact between anchor and foundation material. We recommend checking against 'piston' and 'cone' pull-out mechanisms in accordance with AS2159 (2009).

[4] AEB and ASF are given with estimated factors of safety of 3 and 2 respectively. These are generally adopted in geotechnical practice to limit settlement to an acceptable level for conventional building structures and to 25 mm for a large single pad footing.

[5] K_a = Coefficient of active earth pressure; K_p = Coefficient of passive earth pressure.

[6] Assuming lightly loaded structures supported by square footing with $D_f/B < 0.5$ and $D_f > 0.75$m bgl.

[7] Assuming square pad footing with $B < 5$m, $D_f/B < 0.5$ and $D_f > 1.5$m bgl.

[8] Not applicable, or side adhesion not recommended either due to shallow depth or potential internal settlement of materials.

Design parameters in Table 4 assume the base of excavation is free of loose or soft soils and water prior to placement of concrete. Higher design values may be applied subject to results of further investigations, including rock coring, and laboratory testing.

2.3.3 *Seasonal Effects*

We understand the site is situated in an area exposed to extreme seasonal temperature changes and sudden changes in weather conditions. We recommend the following:

- Provision of surface drainage within the development area to limit erosion of surface materials from surface water runoff.
- Provision of surface and subsurface drainage within the development area to limit groundwater infiltration beneath footing which may cause frost heave/thawing settlements.

2.3.4 *Site Classification*

A preliminary site classification of 'M' should be adopted for design of lightly loaded shallow footings, in accordance with AS 2870 (2011), subject to provision of adequate site drainage and recommendations presented in this report.

2.4 Construction Considerations

Trafficability on unsealed tracks and exposed clay soils will likely be poor in wet weather conditions. In addition, site accessibility for machinery will need to be assessed in view of presence and condition of steep access tracks.

The contractor should consider potential difficulties in penetrating possible high (or higher) strength rock in excavations below investigation termination depths in relation to capabilities of specific machinery proposed.

Should groundwater inflows be encountered during deep excavations, these are likely manageable by pumping. Alternatively adopt a tremmie system for concrete/grout placement, from excavation base upwards, limiting delays between placement and excavation completion.

2.5 Inspection and Monitoring and Contingency

2.5.1 *Further Investigations*

We recommend the following supplementary investigations are undertaken and advice is provided for design development (Table 5).

Table 5: Recommended supplementary investigations and advice for design development.

Scope of Works	Timing	Who to Complete
Drilling of additional boreholes to assess depth and condition below investigation termination depths.	Before finalisation of design or construction.	MA[1]

Notes:
[1] MA=Martens & Associates Pty Ltd

2.5.2 *Further Monitoring and Inspection Program*

We recommend the following is inspected and monitored (Table 6) during site construction works.

Table 6: Recommended inspections/ monitoring requirements during site works.

Scope of Works	Frequency/Duration	Who to Complete
Monitor seepage from excavation to assess adequacy of drainage provision	When encountered	Builder/MA[1]
Monitor sedimentation downslope of excavated areas	During and after rainfall events	Builder
Monitor sediment and erosion control structures to assess adequacy and for removal of built up spoil	After rainfall events	Builder
Inspect exposed material at foundation level to verify suitability as foundation/ lateral support/ subgrade	Prior to reinforcement set-up and concrete placement or pavement construction	MA

Notes:
[1] MA=Martens & Associates Pty Ltd

2.5.3 *Contingency Plan*

MA is to be notified and may need to provide additional advice if conditions are different to those reported.

In the event that the proposed development works cause an adverse impact on overall site stability, works shall cease immediately. The nature of the impact shall be documented and the reason(s) for the adverse impact investigated. This might require a site inspection by an experienced geotechnical or structural engineer and a review of geotechnical requirements for site retention and foundations.

3 Risk Assessment of Proposed Development Works

3.1 AGS (2007) Risk Assessment

A geotechnical hazard risk assessment for the proposed works has been completed in accordance with the qualitative risk matrices provided in Section 7 of the AGS (2007) guidelines. We have considered five main geotechnical hazards. These and associated risks are described in Table 7 and Table 8, respectively, assuming recommend treatment option have been adopted. Risk calculation sheets are provided as Attachment D.

Table 7: Geotechnical hazards and treatment.

Hazard	Probability	Treatment Recommendations
Shallow Rotational Slides (upslope and downslope of development area)	Possible/Unlikely	Ensure good hill slope engineering practice is adopted. Maintain vegetation cover. Do not over-steepen natural grades without suitable shoring support. Do not place excessive load onto natural surfaces unless designed for. Limit ponding of surface water and provide adequate surface and sub-surface drainage throughout the site.
Translational Slide	Unlikely	Ensure good hill slope engineering practice is adopted. Maintain vegetation cover where possible. Do not over-steepen natural grades without suitable shoring support. Do not place excessive load onto natural surfaces unless designed for. Maintain appropriate surface and subsurface drainage.
Soil Creep	Likely	Ensure good hills slope engineering practice is adopted. Maintain vegetation. Ensure appropriate foundations and footings design. Maintain appropriate surface and subsurface drainage.
Boulders	Unlikely	Ensure good hills slope engineering practice is adopted. Maintain vegetation. Do not place excessive load onto natural surfaces unless designed for.

Notes:

[1] Assuming treatment recommendations have been included in the development.

Table 8: Slope instability risk assessment based on AGS (2007).

Hazard	Risk to Life		Risk to Property		Conclusion
	Probability	Risk	Consequence	Risk	
Shallow rotational slide	Unlikely	1.13×10^{-7}	Minor	Low	Acceptable
Deep rotational slide	Unlikely/ possible	2.50×10^{-7}	Minor	Low	Acceptable
Translational slide	Unlikely	1.13×10^{-7}	Minor	Low	Acceptable
Soil creep	Likely	5.00×10^{-7}	Minor	Low	Acceptable
Boulders	Unlikely	4.50×10^{-7}	Moderate	Low	Acceptable

The proposed development is considered to constitute an acceptable risk to life and property resulting from assessed geotechnical hazards in accordance with AGS 2007, provided that good hill slope engineering practices (as provided as Attachment F), the slope treatment measures presented in Table 7 and recommendations presented in this report are adopted. We point out that it is the responsibility of the client and stakeholders to ultimately decide whether the risk is acceptable.

3.2 Conclusion

In conclusion, this report has documented the sub-surface conditions encountered at the site and has provided geotechnical design recommendations and parameters for the proposed monopole based on existing site conditions and constraints. Provided that all the recommendations and advice have been adopted in this report, the site is suitable for the proposed development.

4 Soil Resistivity

The results of in-situ soil resistivity testing are summarised in Table 9.

Table 9: Soil resistivity test data.

		North - South Transect[1]		East – West Transect[1]	
Test Number	Rod Spacing (m)	Rod Depth (m)	Measured Ohms (Ω)	Rod Depth (m)	Measured Ohms (Ω)
1	1	0.2	1,642	0.2	1,800
2	2	0.2	730.0	0.2	678.9
3	4	0.2	521.9	0.2	462.0
4	8	0.2	164.0	0.2	291.0

<u>Notes:</u>

[1] Refer to the site plan in Attachment A for indicative transect alignments.

[2] The following formula can be used to determine resistivity (based on AEMC Instruments user manual (2012), Section 5.5): $\mathbf{p = 2\pi ra}$, where

- p = resistivity (Ωm)
- r = measurement in Ω from columns 4 and 6
- a = rod spacing from column 2

5 Limitations

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

Occasionally, sub-surface conditions between and below the completed boreholes and other tests may be found to be different (or may be interpreted to be different) from those expected. Groundwater conditions may also vary, especially after climatic changes. If such differences appear to exist during construction, we recommend that you immediately contact Martens & Associates.

6 References

Australian Geomechanics Society, Landslide Zoning Working Group(March 2007), Guidelines for landslide susceptibility, hazard and risk zoning for land use planning, Australian Geomechanics Vol. 42, No 1.

Australian Standard 1289.6.3.2 (1997) *Determination of the penetration resistance of a soil - 9kg dynamic cone penetrometer test.*

Australian Standard 1726 (1993) *Geotechnical site investigations.*

AEMC Instruments user manual (2012) *Digital Ground Resistance Tester Model 4620 and 4630.*

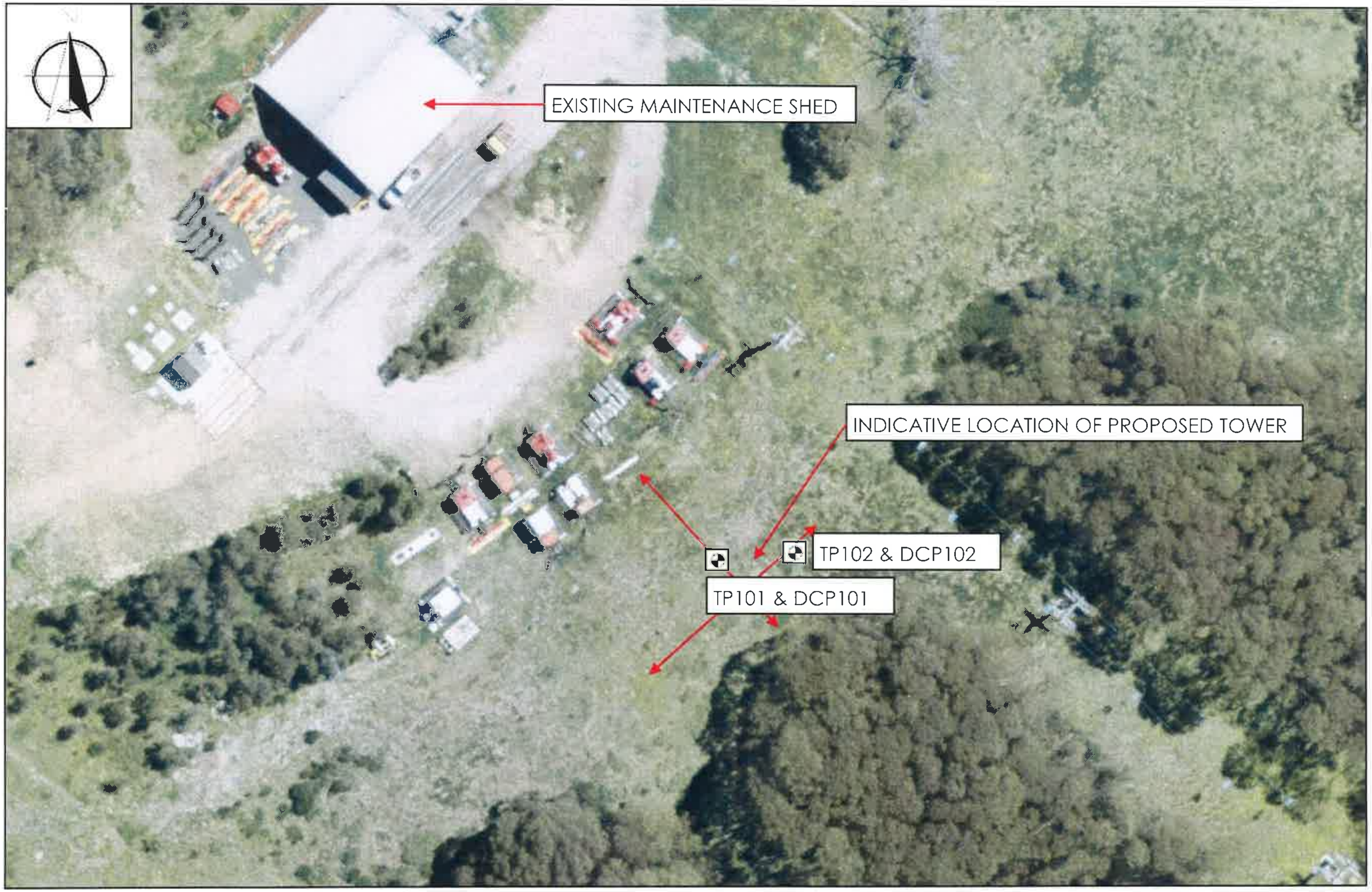
The Tallangatta 1:250,000 Geological Series Sheet SJ 55-3

Look, B.G. (2007) Handbook of Geotechnical Investigation and Design Tables, CRC Press.

NSW Environment & Heritage (eSPADE) *NSW soil and land information*.

Waltham, T, (1994) *Foundations of Engineering Geology*, Third Edition, Spon Press.

7 Attachment A – Figures



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KEY

◈ APPROXIMATE TEST PIT (TP)/ DYNAMIC CONE PENETROMETER (DCP) TESTING LOCATION AND IDENTIFIER

↔ APPROXIMATE SOIL RESISTIVITY TRANSECTS LOCATION

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	AB	**GEOTECHNICAL TESTING LOCATIONS** **(SOURCE: Sixmaps)**	Drawing No: Figure 1
Approved:	JF		
Date:	16.01.15		
Scale:	NA		Job No: P1504591

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CALCULATION SHEET

REFERENCE NO.

Project	**Page No.**	**Date**
MA Officer	**MA Officer Signature**	

Martens & Associates Cross Section 19.01.15

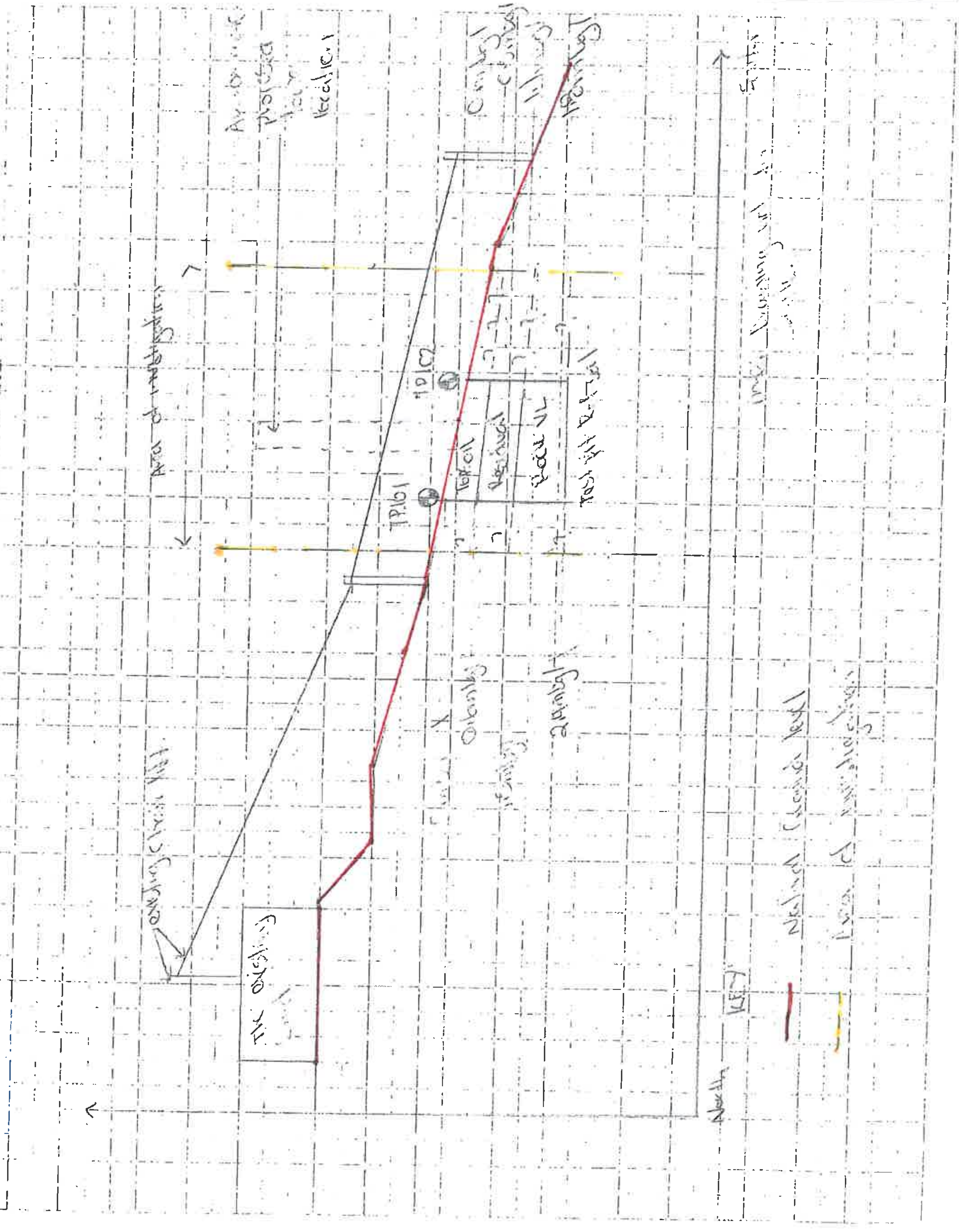

FIGURE 2

Plate 1: Looking upslope to the north.

Plate 2: Looking upslope to the north west.

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Drawn:	AB	**OPTUS SITE S8596, THREDBO SKI RESORT, THREDBO, NSW** **PLATES**	Drawing No: **FIGURE 3**
Approved:	JF		
Date:	22.01.15		
Scale:	NA		Job No: P1504591

Plate 3: Looking upslope to the north east.

Plate 4: Looking downslope to the south.

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Drawn:	AB	**OPTUS SITE S8596, THREDBO SKI RESORT, THREDBO, NSW** **PLATES**	Drawing No: **FIGURE 4**
Approved:	JF		
Date:	22.01.15		
Scale:	NA		Job No: P1504591

Plate 5: Test pit TP101. Test pit refusal at 2.4m on granite.

Plate 6: Test pit TP102. Test pit refusal at 1.8m on granite.

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Drawn:	AB	**OPTUS SITE S8596, THREDBO SKI RESORT, THREDBO, NSW** **PLATES**	Drawing No: **Figure 5**
Approved:	JF		
Date:	22.01.15		
Scale:	NA		Job No: P1504591

8 ATTACHMENT B – Test Pit Logs

CLIENT	Catalyst One	**COMMENCED** 14/1/15	**COMPLETED** 14/1/15	**REF**	**TP101**	
PROJECT	Geotechnical Investigation	**LOGGED** AB	**CHECKED** JF/RE	Sheet 1 of 1		
SITE	Optus Site S8596, Thredbo Ski Resort, Thredbo NSW	**GEOLOGY** Lower Devonian	**VEGETATION** Grass	**PROJECT NO.** P1504591		
EQUIPMENT	7t Excavator	**EASTING** -	**RL SURFACE** 1495.821m AHD			
EXCAVATION DIMENSIONS	400mm wide toothed bucket X 2.4m depth	**NORTHING** -	**ASPECT** South	**SLOPE** 5-10°		

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	DRILLING RESISTANCE L M H R	GRAPHIC LOG	CLASSIFICATION	MATERIAL DESCRIPTION SOIL NAME, plasticity or particle characteristics, colour, secondary and minor components, moisture condition, consistency/relative density, ROCK NAME, grain size, texture/fabric, colour, strength, weathering.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
													- TOPSOIL
E	Nil	N	M	0.6			CL	Sandy CLAY - Low plasticity, dark brown, with rootlets, trace gravels.	F-St		A	0.5	4591/101/0.5
													- RESIDUAL
E	Nil	N	M	1.0 1.5			CL-CI	CLAY - Low to medium plasticity, light brown, with sand and gravels (5-10mm, sub angular).	St-VSt		A	1.0	4591/101/1.0
													- WEATHERED ROCK
E	Nil	N	D	2.0 2.4				GRANITE - Inferred very low strength, brown/ white/ red/ light brown, distinctly weathered.			A A	1.8 2.0	4591/101/1.8 4591/101/2.0
				3.0 4.0 4.5				Test pit refusal at 2.4m with toothed bucket.					

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
HA Hand auger
S Spade
CC Concrete Corer
V V-Bit
TC Tungsten Carbide Bit
E Excavator

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
▽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

DRILLING RESISTANCE
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

Quality Sheet No. 4

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Engineering Log - Excavation

CLIENT	**Catalyst One**	**COMMENCED**	14/1/15	**COMPLETED**	14/1/15	**REF**	**TP102**
PROJECT	**Geotechnical Investigation**	**LOGGED**	AB	**CHECKED**	JF/RE	**Sheet** 1 **of** 1	
SITE	**Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW**	**GEOLOGY**	Lower Devonian	**VEGETATION**	Grass	**PROJECT NO.**	P1504591
EQUIPMENT	7t Excavator	**EASTING**	-	**RL SURFACE**	1493.823m AHD		
EXCAVATION DIMENSIONS	400mm wide toothed bucket X 1.8m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10°

EXCAVATION DATA						MATERIAL DATA					SAMPLING & TESTING		
METHOD	**SUPPORT**	**WATER**	**MOISTURE**	**DEPTH (M)**	**DRILLING RESISTANCE** L M H R	**GRAPHIC LOG**	**CLASSIFICATION**	**MATERIAL DESCRIPTION** SOIL NAME, plasticity or particle characteristics, colour, secondary and minor components, moisture condition, consistency/relative density, ROCK NAME, grain size, texture/fabric, colour, strength, weathering.	**CONSISTENCY**	**DENSITY INDEX**	**TYPE**	**DEPTH (M)**	**RESULTS AND ADDITIONAL OBSERVATIONS**
E	Nil	N	M	0.5			CL	Sandy CLAY - Low plasticity, dark brown, with rootlets, trace gravels.	F-St				- TOPSOIL
E	Nil	N	M	1.0 1.1			CL-CI	CLAY - Low to medium plasticity, light brown, with sand and gravels (5-10mm,sub angular).	St-VSt				- RESIDUAL 1.0
E	Nil	N	D	1.8				GRANITE - Inferred very low strength brown/ white/ red/ light brown, distinctly weathered.					- WEATHERED ROCK
				2.0 3.0 4.0 4.5				Test pit refusal at 1.8m with toothed bucket.					2.0 3.0 4.0 4.5

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
HA Hand auger
S Spade
CC Concrete Corer
V V-Bit
TC Tungsten Carbide Bit
E Excavator

SUPPORT
SH Shoring
SC Shotcrete
RB Rock Bolts
Nil No support

WATER
N None observed
X Not measured
⊽ Water level
◁ Water outflow
▷ Water inflow

MOISTURE
D Dry
M Moist
W Wet
Wp Plastic limit
Wl Liquid limit

DRILLING RESISTANCE
L Low
M Moderate
H High
R Refusal

CONSISTENCY
VS Very Soft
S Soft
F Firm
St Stiff
VSt Very Stiff
H Hard
F Friable

DENSITY
VL Very Loose
L Loose
MD Medium Dense
D Dense
VD Very Dense

SAMPLING & TESTING
A Auger sample
B Bulk sample
U Undisturbed sample
D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

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Engineering Log - Excavation

9 ATTACHMENT C – DCP 'N' Counts

Dynamic Cone Penetrometer Test Log Summary

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Site	Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW	**DCP Group Reference**	**P1504591**
Client	Catalyst One	**Log Date**	14.01.15
Logged by	AB		
Checked by	JF/ RE		
Comments			

TEST DATA

Depth Interval (m)	**DCP101**	**DCP102**						**Design**
0.15	2	2						**2**
0.30	2	2						**2**
0.45	3	2						**2**
0.60	7	7						**7**
0.75	7	12						**7**
0.90	11	22						**11**
1.05	17	27						**17**
	10/50mm	10/50mm						
	Bounce	Bounce						
	@	@						
	1.1m	1.3m						

10 ATTACHMENT D – AGS (2007) Risk Assessment

Landslide Hazard Evaluation - Risk to Life Assessment

Method based on Walker *et al.* in AGS Vol 42 No. 1 March 2007

Method ST-24 Revised 20.02.08

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PROJECT DETAILS

Project	Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW			Ref. No.	P1504591
Author	AB	Reviewed	JF/ RE	Created	16.01.15

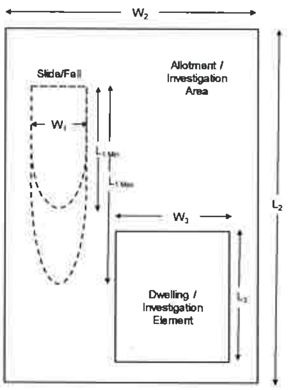
STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type: Shallow rotational slide

$P_{(H)}$ Annual probability of landslide: 0.0001

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	1,000,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction: 0.45



FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	5
W_2	Width of allotment / investigation area	m	29.95
W_3	Width of dwelling / investigation element	m	10
L_{1Min}	Minimum run-out length	m	1
L_{1Max}	Maximum run-out length	m	5
L_2	Length of allotment / investigation area	m	40.4
L_3	Length of dwelling / investigation element	m	35
L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	0.90
L_{PMax}	Probability of runout being 5 - 5 m long	(0 - 1)	0.10
W_F	Likelihood of across slope strike on risk element	(0 - 1)	0.50
$L_{F\ Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.69
$L_{F\ Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F\ Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	0.90

$P_{(T:S)}$ Temporal spatial probability given the spatial impact: 0.01

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	5%
T_2	Percentage of dwelling / element that person(s) occupy	%	10%

$V_{(D:T)}$ Vulnerability of the individual (ie. probability of loss of life given the impact): 0.50

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual): 1.13E-07

Risk Assessment: Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.

Landslide Hazard Evaluation - Risk to Life Assessment

Method based on Walker *et al.* in AGS Vol 42 No. 1 March 2007

Method ST-24 Revised 20.02.08

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PROJECT DETAILS

Project	Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW			Ref. No.	P1504591
Author	AB	Reviewed	JF/ RE	Created	16.01.15

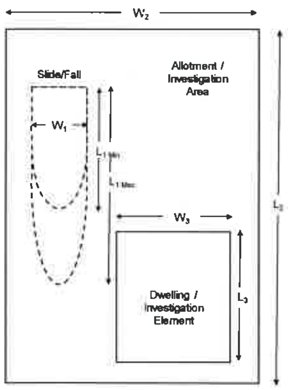
STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type — Deep rotational slide

$P_{(H)}$ Annual probability of landslide — 0.005

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	1,000,000 years	The event is inconceivable or fanciful over the design life	BARELY CREDIBLE	F

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction — 1.00



FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	5
W_2	Width of allotment / investigation area	m	29.95
W_3	Width of dwelling / investigation element	m	10
L_{1Min}	Minimum run-out length	m	1
L_{1Max}	Maximum run-out length	m	5
L_2	Length of allotment / investigation area	m	40.4
L_3	Length of dwelling / investigation element	m	35
L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	0.10
L_{PMax}	Probability of runout being 5 - 5 m long	(0 - 1)	0.90
W_F	Likelihood of across slope strike on risk element	(0 - 1)	0.50
$L_{F Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.89
$L_{F Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	0.99

$P_{(T:S)}$ Temporal spatial probability given the spatial impact — 0.01

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	5%
T_2	Percentage of dwelling / element that person(s) occupy	%	10%

$V_{(D:T)}$ Vulnerability of the individual (ie. probability of loss of life given the impact) — 0.01

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual) — 2.50E-07

Risk Assessment — Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.

Landslide Hazard Evaluation - Risk to Life Assessment

Method based on Walker *et al.* in AGS Vol 42 No. 1 March 2007

Method ST-24 Revised 20.02.08

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PROJECT DETAILS

Project	Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW		Ref. No.	P1504591
Author	AT	Reviewed JF/ RE	Created	16.01.15

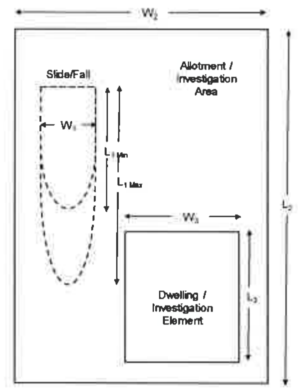
STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type: Translational Slide

$P_{(H)}$ Annual probability of landslide: 0.0001

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life	RARE	E
10^{-6}	1,000,000 years	The event is inconceivable or fanciful over the design life	BARELY CREDIBLE	F

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction: 0.45



FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	5
W_2	Width of allotment / investigation area	m	29.95
W_3	Width of dwelling / investigation element	m	10
L_{1Min}	Minimum run-out length	m	1
L_{1Max}	Maximum run-out length	m	5
L_2	Length of allotment / investigation area	m	40.4
L_3	Length of dwelling / investigation element	m	35
L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	0.90
L_{PMax}	Probability of runout being 5 - 5 m long	(0 - 1)	0.10
W_F	Likelihood of across slope strike on risk element	(0 - 1)	0.50
$L_{F Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.89
$L_{F Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	0.90

$P_{(T:S)}$ Temporal spatial probability given the spatial impact: 0.01

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	5%
T_2	Percentage of dwelling / element that person(s) occupy	%	10%

$V_{(D:T)}$ Vulnerability of the individual (ie. probability of loss of life given the impact): 0.50

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual): 1.13E-07

Risk Assessment: Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.

Landslide Hazard Evaluation - Risk to Life Assessment

Method based on Walker *et al.* in AGS Vol 42 No 1 March 2007

Method ST-24 Revised 20.02.08

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PROJECT DETAILS

Project	Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW			Ref. No.	P1504591
Author	AB	Reviewed	JF/ RE	Created	16.01.15

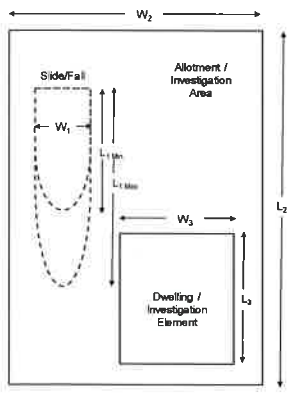
STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type — **Soil Creep**

$P_{(H)}$ Annual probability of landslide — **0.01**

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	1,000,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction — **0.10**



FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	5
W_2	Width of allotment / investigation area	m	29.95
W_3	Width of dwelling / investigation element	m	10
L_{1Min}	Minimum run-out length	m	1
L_{1Max}	Maximum run-out length	m	5
L_2	Length of allotment / investigation area	m	40.4
L_3	Length of dwelling / investigation element	m	35
L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	0.90
L_{PMax}	Probability of runout being 1 - 5 m long	(0 - 1)	0.10
W_F	Likelihood of across slope strike on risk element	(0 - 1)	0.50
$L_{F\ Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.89
$L_{F\ Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F\ Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	0.90

$P_{(T:S)}$ Temporal spatial probability given the spatial impact — **0.01**

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	5%
T_2	Percentage of dwelling / element that person(s) occupy	%	10%

$V_{(D:T)}$ Vulnerability of the individual (ie probability of loss of life given the impact) — **0.100**

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual) — **5.00E-07**

Risk Assessment — **Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.**

Landslide Hazard Evaluation - Risk to Life Assessment

Method based on Walker *et al.* in AGS Vol 42 No. 1 March 2007

Method ST-24 Revised 20.02.08

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PROJECT DETAILS

Project: Optus Site S8596, Thredbo Ski Resort, Thredbo, NSW

Ref. No.: P1504591

Author: AB

Reviewed: JF/ RE

Created: 16.01.15

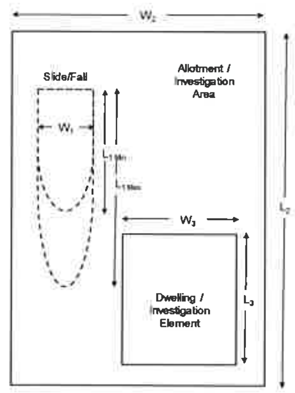
STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type: Boulders

$P_{(H)}$ Annual probability of landslide: **0.0001**

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under fadverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	1,000,000 years	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

$P_{(S:H)}$ Probablity of spatial impact impacting building location taking into account travel distance and travel direction: **0.90**



FACTOR	DESCRIPTION	UNITS	VALUE
W_1	Likely slide/fall width	m	6
W_2	Width of allotment / investigation area	m	45
W_3	Width of dwelling / investigation element	m	35
L_{1Min}	Minimum run-out length	m	5
L_{1Max}	Maximum run-out length	m	10
L_2	Length of allotment / investigation area	m	50
L_3	Length of dwelling / investigation element	m	35
L_{PMin}	Probability of runout being 0 - 5 m long	(0 - 1)	0.50
L_{PMax}	Probability of runout being 0 - 10 m long	(0 - 1)	0.50
W_F	Likelihood of across slope strike on risk element	(0 - 1)	1.00
$L_{F\,Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.80
$L_{F\,Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
$L_{F\,Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	0.90

$P_{(T:S)}$ Temporal spatial probability given the spatial impact: **0.01**

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	m	5%
T_2	Percentage of dwelling / element that person(s) occupy	m	10%

$V_{(D:T)}$ Vulnerability of the individual (ie. probability of loss of life given the impact): **1.00**

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Death is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$ Risk (annual probability of loss of life of an individual): **4.50E-07**

Risk Assessment: **Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.**

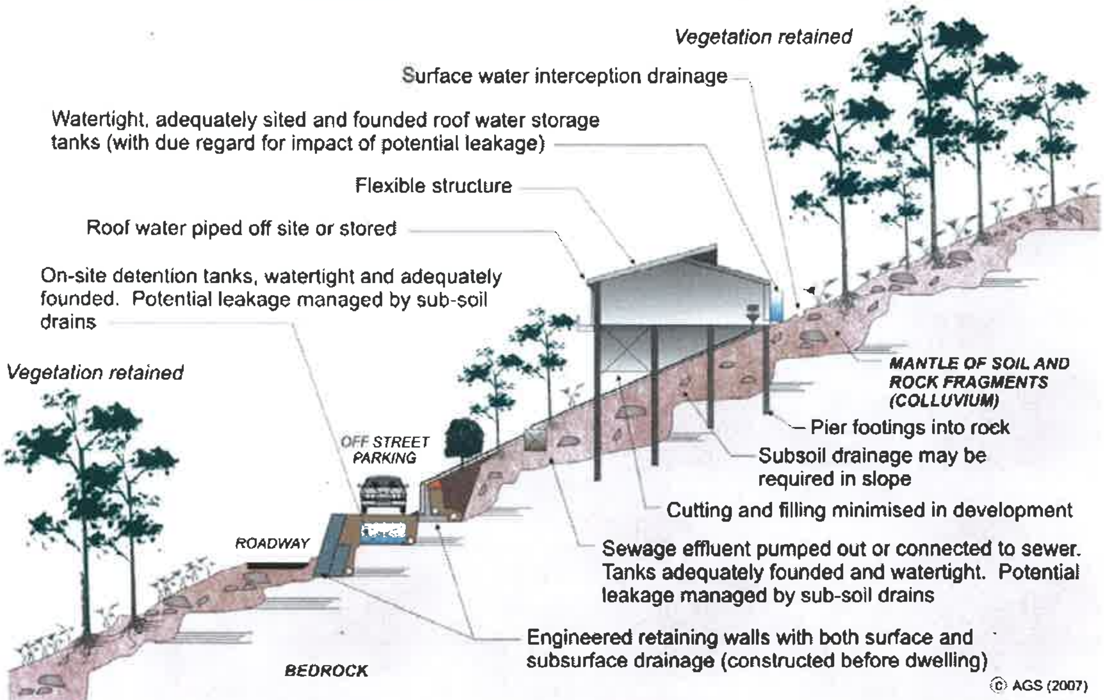
11 ATTACHMENT E – Example of Good Hill Slope Engineering Practices

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



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See also AGS (2000) Appendix J

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.

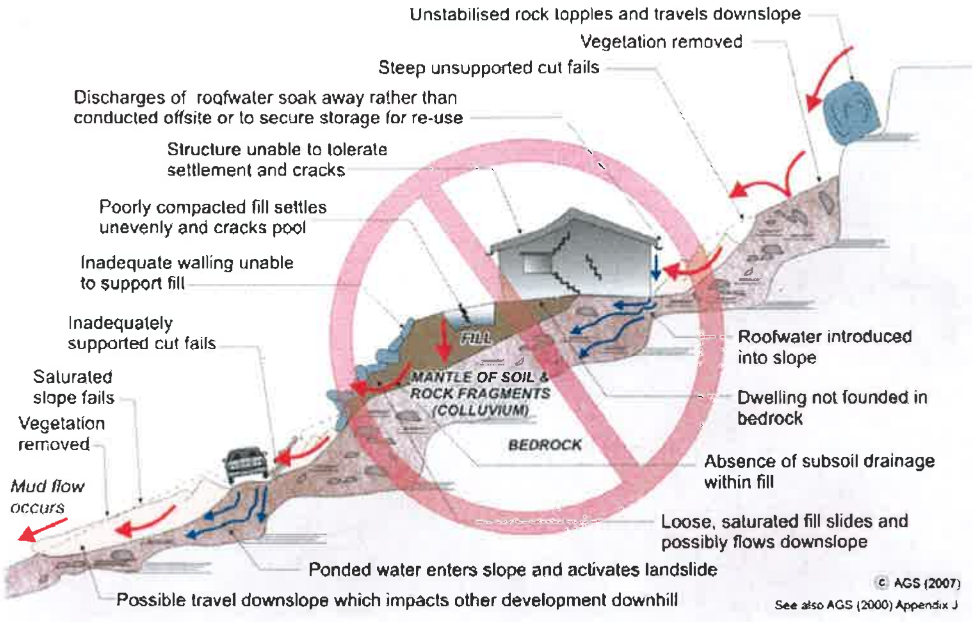
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

12 ATTACHMENT F – Form 1

Geotechnical Policy – Kosciuszko Alpine Resorts Form 1 – Declaration and certification made by geotechnical engineer or engineering geologist in a geotechnical report.

Date received: ____/____/____ DA no: ______________

To be submitted with a development application

You can use Form 1 to verify that the author of a geotechnical report is a geotechnical engineer or engineering geologist as defined by DIPNR Geotechnical Policy. Alternatively, where a geotechnical report has been prepared by a professional person not recognised by DIPNR Geotechnical Policy, then form 1 may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by the DIPNR Geotechnical Policy.

Please contact the Alpine Resorts Assessments Team in Jindabyne for further information. Phone 02 6456 1733.

To complete this form, please place a cross in the boxes ☐ and fill out the white sections.

1. Declaration made by geotechnical engineer or engineering geologist as part of a geotechnical report

I,

Mr ☒ Ms ☐ Mrs ☐ Dr ☐ Other

RALPH

Family name: ERNI

OF

Company/organisation: MARTENS & ASSOCIATES PTY LTD

on this the 16th day of January 2015,

certify that I am a geotechnical engineer or engineering geologist as defined by the "Policy" and I; (tick appropriate box)

☐ prepared the geotechnical report referenced below in accordance with the AGS ~~2000~~ 2007 and DIPNR Geotechnical Policy – Kosciuszko Alpine Resorts.

☑ am wiling to technically verify that the Geotechnical Report referenced below has been prepared in accordance the AGS ~~2000~~ 2007 and the Geotechnical Policy – Kosciuszko Alpine Resorts.

2. Geotechnical Report Details

Report Title: Geotechnical Investigation: OPHS Site SA5496, Thredbo Ski Resort, Thredbo NSW

Author: Adam Budiji

Dated: January 2015

DA Site Address: Thredbo Ski Resort, Alpine Way, Thredbo, NSW

DA Applicant: Catalyst One

I am aware that the Geotechnical Report I have either prepared or am technically verifying, (referenced above) is to be submitted in support of a development application for the proposed development site (referenced above), and it's findings will be relied upon by the Consent Authority in determining the development application.

3. Checklist of essential requirements to be contained in a geotechnical risk assessment report to be submitted with a development application

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Report. This checklist is to accompany the report.

Please tick appropriate box

- ☑ Risk assessment of all identifiable geotechnical hazards in accordance with AGS ~~2000,~~ 2007 as per 6.1 (a) of the policy.
- ☑ Site plans with key hazards identified and other information as per 6.1 (b)
- ☑ Details of site investigation and inspections as per 6.1 (c)
- ☑ Photographs and/or drawings of the site as per 6.1 (d)
- ☑ Presentation of geotechnical model as per 6.1 (e)
- ☑ A specific conclusion as to whether the site is suitable for the development proposed on the above site, if applicable, subject to the following conditions;
  - ☑ Conditions to be provided to establish design parameters,
  - ☑ Conditions to be incorporated into the detailed design to be submitted for the construction certificate,
  - ☑ Conditions applying to the construction phase,
  - ☑ Conditions relating to ongoing management of the site/structure.

4. Signatures

Signature

Chartered professional status: CPENG NPER3 2061149

Name: RALPH ERNI

Date: 21/1/15

5. Contact details

Alpine Resorts Assessments team
Snowy River Avenue
PO Box 36 JINDABYNE 2627
t: 02 6456 1733
f: 02 6456 1736
e: alpineresorts_assessments@dipnr.nsw.gov.au

13 ATTACHMENT G – Notes Relating To This Report

Information

Important Information About Your Report

Subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all of course, are necessarily relevant to all reports, but are included as general reference.

Engineering Reports - Limitations

Geotechnical reports are based on information gained from limited sub-surface site testing and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel and are based on the information obtained, on current engineering standards of interpretation and analysis, and on the basis of your unique project specific requirements as understood by Martens. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the Client.

Where the report has been prepared for a specific design proposal (eg. a three storey building), the information and interpretation may not be relative if the design proposal is changed (eg. to a twenty storey building). Your report should not be relied upon if there are changes to the project without first asking Martens to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Martens will not accept responsibility for problems that may occur due to design changes if they are not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced and therefore your site investigation report recommendations should only be regarded as preliminary.

Only Martens, who prepared the report, are fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Martens cannot be held responsible for such misinterpretation.

Engineering Reports – Use For Tendering Purposes

Where information obtained from this investigation is provided for tendering purposes, Martens recommend that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. Attention is drawn to the document 'Guidelines for the Provision of Geotechnical Information in Tender Documents', published by the Institution of Engineers, Australia.

The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Engineering Reports – Data

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings *etc* are customarily included in a Martens report and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Engineering Reports – Other Projects

To avoid misuse of the information contained in your report it is recommended that you confer with Martens before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Subsurface Conditions - General

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

- Unexpected variations in ground conditions - the potential for will depend partly on test point (eg. excavation or borehole) spacing and sampling frequency which are often limited by project imposed budgetary constraints.

- Changes in guidelines, standards and policy or interpretation of guidelines, standards and policy by statutory authorities.

- The actions of contractors responding to commercial pressures.

- Actual conditions differing somewhat from those inferred to exist, because no professional, no matter how qualified, can reveal precisely what is hidden by earth, rock and time.

  The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions

If these conditions occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Subsurface Conditions - Changes

Natural processes and the activity of man create subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Reports are based on conditions which existed at the time of the subsurface exploration.

Decisions should not be based on a report whose adequacy may have been affected by time. If an extended period of time has elapsed since the report was prepared, consult Martens to be advised how time may have impacted on the project.

Subsurface Conditions - Site Anomalies

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

Report Use By Other Design Professionals

To avoid potentially costly misinterpretations when other design professionals develop their plans based on a report, retain Martens to work with other project professionals who are affected by the report. This may involve Martens explaining the report design implications and then reviewing plans and specifications produced to see how they have incorporated the report findings.

Subsurface Conditions - Geoenvironmental Issues

Your report generally does not relate to any findings, conclusions, or recommendations about the potential for hazardous or contaminated materials existing at the site unless specifically required to do so as part of the Company's proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geoenvironmental or site contamination assessments. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Martens for information relating to such matters.

Responsibility

Geotechnical reporting relies on interpretation of factual information based on professional judgment and opinion and has an inherent level of uncertainty attached to it and is typically far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded.

To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Martens to other parties but are included to identify where Martens' responsibilities begin and end. Their use is intended to help all parties involved to recognize their individual responsibilities. Read all documents from Martens closely and do not hesitate to ask any questions you may have.

Site Inspections

Martens will always be pleased to provide engineering inspection services for aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site. Martens is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Soil Data

Explanation of Terms (1 of 3)

Definitions

In engineering terms, soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material does not exhibit any visible rock properties and can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726 and the S.A.A Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

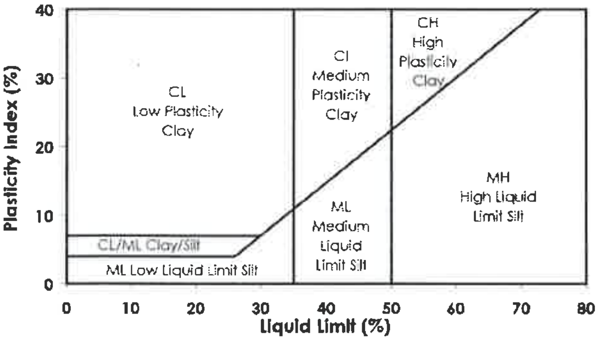
Particle Size

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. sandy clay). Unless otherwise stated, particle size is described in accordance with the following table.

Division	Subdivision	Size
BOULDERS		>200 mm
COBBLES		60 to 200 mm
GRAVEL	Coarse	20 to 60 mm
	Medium	6 to 20 mm
	Fine	2 to 6 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties

Plasticity properties can be assessed either in the field by tactile properties, or by laboratory procedures.



Moisture Condition

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

Term	C_u (kPa)	Apprx SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort. Sample extrudes between fingers when squeezed in fist.
Soft	12 - 25	2 to 4	A finger can be pushed into the soil to about 25mm depth. Easily moulded in fingers.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong pressure in the figures.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure. Difficult to cut with a knife. Thumbnail can readily indent.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail. Brittle. Tends to break into fragments.
Friable	-	-	Crumbles or powders when scraped by thumbnail

Density of Granular Soils

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration test (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	%	SPT 'N' Value (blows/300mm)	CPT Cone Value (q_c Mpa)
Very loose	< 15	< 5	< 2
Loose	15 – 35	5 - 10	2 -5
Medium dense	35 – 65	10 - 30	5 - 15
Dense	65- 85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

Minor Components

Minor components in soils may be present and readily detectable, but have little bearing on general geotechnical classification. Terms include:

Term	Assessment	Proportion of Minor component In:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: < 5 % Fine grained soils: < 15 %
With some	Presence easily detectable by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 % Fine grained soils: 15 – 30 %

Soil Data

Explanation of Terms (2 of 3)

Soil Agricultural Classification Scheme

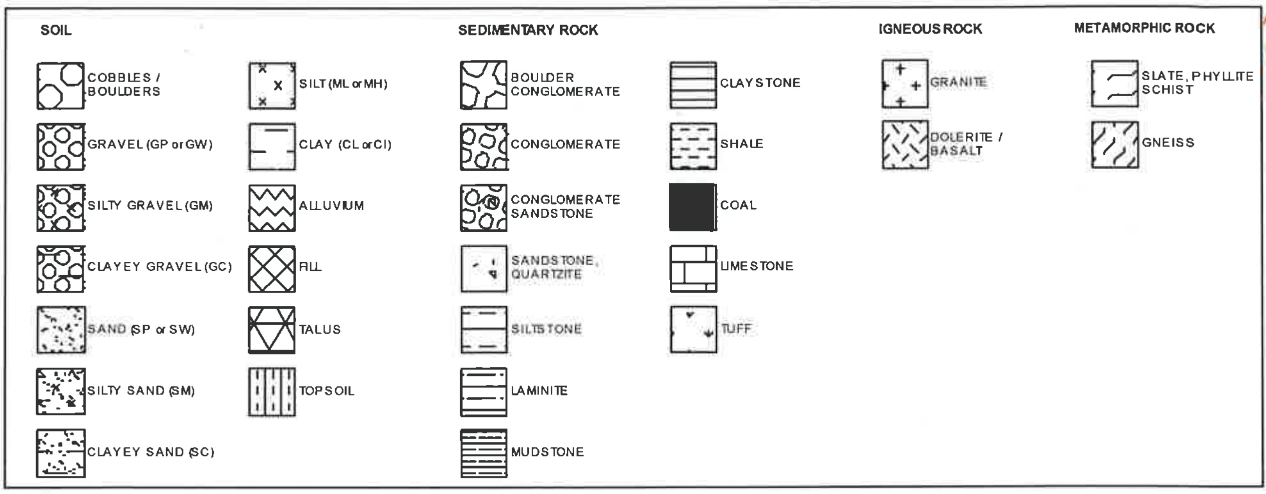
In some situations, such as where soils are to be used for effluent disposal purposes, soils are often more appropriately classified in terms of traditional agricultural classification schemes. Where a Martens report provides agricultural classifications, these are undertaken in accordance with descriptions by Northcote, K.H. (1979) *The factual key for the recognition of Australian Soils*, Rellim Technical Publications, NSW, p 26 - 28.

Symbol	Field Texture Grade	Behaviour of moist bolus	Ribbon length	Clay content (%)
S	Sand	Coherence nil to very slight; cannot be moulded; single grains adhere to fingers	0 mm	< 5
LS	Loamy sand	Slight coherence; discolours fingers with dark organic stain	6.35 mm	5
CLS	Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	6.35mm - 1.3cm	5 - 10
SL	Sandy loam	Bolus just coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible	1.3 - 2.5	10 - 15
FSL	Fine sandy loam	Bolus coherent; fine sand can be felt and heard	1.3 - 2.5	10 - 20
SCL	Light sandy clay loam	Bolus strongly coherent but sandy to touch, sand grains dominantly medium size and easily visible	2.0	15 - 20
L	Loam	Bolus coherent and rather spongy; smooth feel when manipulated but no obvious sandiness or silkiness; may be somewhat greasy to the touch if much organic matter present	2.5	25
Lfsy	Loam, fine sandy	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated	2.5	25
SiL	Silt loam	Coherent bolus, very smooth to silky when manipulated	2.5	25 + > 25 silt
SCL	Sandy clay loam	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix	2.5 - 3.8	20 - 30
CL	Clay loam	Coherent plastic bolus; smooth to manipulate	3.8 - 5.0	30 - 35
SiCL	Silty clay loam	Coherent smooth bolus; plastic and silky to touch	3.8 - 5.0	30- 35 + > 25 silt
FSCL	Fine sandy clay loam	Coherent bolus; fine sand can be felt and heard	3.8 - 5.0	30 - 35
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

Soil Data

Explanation of Terms (3 of 3)

Symbols for Soil and Rock



Unified Soil Classification Scheme (USCS)

<table>
<tr><th colspan="6">FIELD IDENTIFICATION PROCEDURES
(Excluding particles larger than 63 mm and basing fractions on estimated mass)</th><th>USCS</th><th>Primary Name</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS
More than 50 % of material less than 63 mm is larger than 0.075 mm</td><td rowspan="16">(A 0.075 mm particle is about the smallest particle visible to the naked eye)</td><td rowspan="4">GRAVELS
More than half of coarse fraction is larger than 2.0 mm.</td><td rowspan="2">CLEAN GRAVELS (Little or no fines)</td><td colspan="2">Wide range in grain size and substantial amounts of all intermediate particle sizes.</td><td>GW</td><td>Gravel</td></tr>
<tr><td colspan="2">Predominantly one size or a range of sizes with more intermediate sizes missing</td><td>GP</td><td>Gravel</td></tr>
<tr><td rowspan="2">GRAVELS WITH FINES (Appreciable amount of fines)</td><td colspan="2">Non-plastic fines (for identification procedures see ML below)</td><td>GM</td><td>Silty Gravel</td></tr>
<tr><td colspan="2">Plastic fines (for identification procedures see CL below)</td><td>GC</td><td>Clayey Gravel</td></tr>
<tr><td rowspan="4">SANDS
More than half of coarse fraction is smaller than 2.0 mm</td><td rowspan="2">CLEAN SANDS (Little or no fines)</td><td colspan="2">Wide range in grain sizes and substantial amounts of intermediate sizes missing.</td><td>SW</td><td>Sand</td></tr>
<tr><td colspan="2">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>SP</td><td>Sand</td></tr>
<tr><td rowspan="2">SANDS WITH FINES (Appreciable amount of fines)</td><td colspan="2">Non-plastic fines (for identification procedures see ML below)</td><td>SM</td><td>Silty Sand</td></tr>
<tr><td colspan="2">Plastic fines (for identification procedures see CL below)</td><td>SC</td><td>Clayey Sand</td></tr>
<tr><td rowspan="8">FINE GRAINED SOILS
More than 50 % of material less than 63 mm is smaller than 0.075 mm</td><th colspan="6">IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM</th></tr>
<tr><th>DRY STRENGTH (Crushing Characteristics)</th><th>DILATANCY</th><th>TOUGHNESS</th><th>DESCRIPTION</th><th>USCS</th><th>Primary Name</th></tr>
<tr><td>None to Low</td><td>Quick to Slow</td><td>None</td><td>Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity</td><td>ML</td><td>Silt</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Medium</td><td>Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays</td><td>CL</td><td>Clay</td></tr>
<tr><td>Low to Medium</td><td>Slow to Very Slow</td><td>Low</td><td>Organic slits and organic silty clays of low plasticity</td><td>OL</td><td>Organic Silt</td></tr>
<tr><td>Low to Medium</td><td>Slow to Very Slow</td><td>Low to Medium</td><td>Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td><td>MH</td><td>Silt</td></tr>
<tr><td>High</td><td>None</td><td>High</td><td>Inorganic clays of high plasticity, fat clays</td><td>CH</td><td>Clay</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Low to Medium</td><td>Organic clays of medium to high plasticity</td><td>OH</td><td>Organic Silt</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td colspan="4">Readily identified by colour, odour, spongy feel and frequently by fibrous texture</td><td>Pt</td><td>Peat</td></tr>
<tr><td colspan="8">Low Plasticity – Liquid Limit W_L < 35 % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit W_L > 60 %</td></tr>
</table>

Rock Data

Explanation of Terms (1 of 2)

Definitions

Descriptive terms used for Rock by Martens are given below and include rock substance, rock defects and rock mass.

Rock Substance	In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot, unless extremely weathered, be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Rock substance is effectively homogeneous and may be isotropic or anisotropic.
Rock Defect	Discontinuity or break in the continuity of a substance or substances.
Rock Mass	Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

Degree of Weathering

Rock weathering is defined as the degree in rock structure and grain property decline and can be readily determined in the field.

Term	Symbol	Definition
Residual Soil	Rs	Soil derived from the weathering of rock. The mass structure and substance fabric are no longer evident. There is a large change in volume but the soil has not been significantly transported.
Extremely weathered	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - ie. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decrease compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original 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 rock is recognisable.
Fresh	Fr	Rock substance unaffected by weathering

Rock Strength

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance is the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	Is (50) MPa	Field Guide	Symbol
Extremely low	≤0.03	Easily remoulded by hand to a material with soil properties.	EL
Very low	>0.03 ≤0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VL
Low	>0.1 ≤0.3	A piece of core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	L
Medium	>0.3 ≤1.0	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	M
High	>1 ≤3	A piece of core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife.	H
Very high	>3 ≤10	A piece of core 150mm long x 50mm diameter may be broken readily with hand held hammer. Cannot be scratched with pen knife.	VH
Extremely high	>10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	EH

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

This 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 excludes fractures such as drilling breaks.

Term	Description
Fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than 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 of 100mm-300mm.
Unbroken	The core does not contain any fractures.

Rock Core Recovery

TCR = Total Core Recovery

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\%$$

SCR = Solid Core Recovery

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\%$$

RQD = Rock Quality Designation

$$= \frac{\sum \text{Axial lengths of core} > 100\text{mm long}}{\text{Length of core run}} \times 100\%$$

Rock Strength Tests

▼	Point load strength Index (Is50) - axial test (MPa)
▶	Point load strength Index (Is50) - diametrall test (MPa)
●	Unconfined compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)		**Coating or Filling**		**Roughness**	
BP	Bedding plane parting	Cn	Clean	Po	Polished
X	Foliation	Sn	Stain	Ro	Rough
L	Cleavage	Ct	Coating	Sl	Slickensided
JT	Joint	Fe	Iron Oxide	Sm	Smooth
F	Fracture			Vr	Very rough
SZ	Sheared zone (Fault)	**Planarity**		**Inclination**	
CS	Crushed seam	Cu	Curved	The inclination of defects are measured from perpendicular to the core axis.	
DS	Decomposed seam	Ir	Irregular		
IS	Infilled seam	Pl	Planar		
V	Vein	St	Stepped		
		Un	Undulating		

Test Methods

Explanation of Terms (1 of 2)

Sampling

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

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

Undisturbed samples may be taken by pushing a thin-walled sample tube into the soils and withdrawing a soil sample in a relatively undisturbed state. 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. Other sampling methods may be used. Details of the type and method of sampling are given in the report.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the Company and some comments on their use and application.

Hand Excavation – in some situations, excavation using hand tools such as mattock and spade may be required due to limited site access or shallow soil profiles.

Hand Auger - the hole is advanced by pushing and rotating either a sand or clay auger generally 75-100mm in diameter into the ground. The depth of penetration is usually limited to the length of the auger pole, however extender pieces can be added to lengthen this.

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the *in-situ* soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) - the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling - the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength *etc.* is only marginally affected.

Continuous Spiral Flight Augers - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or *in-situ* testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling - similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling - a continuous core sample is obtained using a diamond tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in AS 1289 Methods of Testing Soils for Engineering Purposes - Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

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

as 4, 6, 7
N = 13
(ii) In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm

as 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borelogs in brackets.

CONE PENETROMETER TESTING AND INTERPRETATION

Cone penetrometer testing (sometimes referred to as Dutch Cone - abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in AS 1289 - Test F4.1.

In the test, a 35mm diameter rod with a cone tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on separate 130mm long sleeve, immediately behind the cone. Tranducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output on continuous chart

Test Methods

Explanation of Terms (2 of 2)

recorders. The plotted results given in this report have been traced from the original records.

The information provided on the charts comprises:
Cone resistance - the actual end bearing force divided by the cross sectional area of the cone - expressed in MPA.
Sleeve friction - the frictional force of the sleeve divided by the surface area - expressed in kPa.
Friction ratio - the ratio of sleeve friction to cone resistance - expressed in percent.

There are two scales available for measurement of cone resistance. The lower (A) scale (0 - 5 Mpa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main (B) scale (0 - 50 Mpa) is less sensitive and is shown as a full line.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1%-2% are commonly encountered in sands and very soft clays rising to 4%-10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:

q_c (Mpa) = (0.4 to 0.6) N (blows/300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:

$q_c = (12 \text{ to } 18)\ c_u$

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

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes *etc.* This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

DYNAMIC CONE (HAND) PENETROMETERS
Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods. Two relatively similar tests are used.

Perth sand penetrometer - a 16 mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS 1289 - Test F 3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
Cone penetrometer (sometimes known as the Scala Penetrometer) - a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289 - Test F 3.2). The test was developed initially for pavement sub-grade investigations, with correlations of the test results with California bearing ratio published by various Road Authorities.

LABORATORY TESTING
Laboratory testing is carried out in accordance with AS 1289 Methods of Testing Soil for Engineering Purposes. Details of the test procedure used are given on the individual report forms.

TEST PIT / BORE LOGS
The test pit / bore log(s) presented herein are an engineering and/or geological interpretation of the sub-surface conditions and their reliability will depend to some extent on frequency of sampling and the method of excavation / drilling. Ideally, continuous undisturbed sampling or excavation / core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variation between the boreholes.

GROUND WATER
Where ground water levels are measured in boreholes, there are several potential problems:

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 are indicated in the report.
The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.