Tolucy Pty Ltd

martens
consulting engineers

Preliminary Geotechnical Assessment: 85 Booralie Road, Terrey Hills, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1705808JR03V02
March 2017

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Document and Distribution Status								
Author(s)		Reviewer(s)		Project Manager		Signature		
Michael Huan		Ralph Erni		Gray Taylor				
Revision No.	Description	Status	Release Date	Document Location				
				File Copy	Tolucy Pty Ltd			
1	Preliminary Geotechnical Assessment	Final	01.03.2017	1E,1P,1H	1P			
1	Preliminary Geotechnical Assessment	Draft	09.02.2017	1E,1P,1H	1P			

Distribution types: F = Fax, H = Hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

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

Contents

1 Introduction

1.1 Overview

This report documents the findings of a preliminary geotechnical assessment completed to support an application for a site compatibility certificate (SCC) for the proposed development at 85 Booralie Road, Terrey Hills, NSW (the 'site').

No geotechnical testing has been conducted at the site. Results for investigations undertaken at the neighbouring property (85 Booralie Road, Terrey Hills, NSW) were relied upon in carrying out this assessment. We have assumed that supplementary geotechnical assessments, as recommended in Section 3.3, will be undertaken at the site following DA approval and for detailed design and construction advice.

The site location is shown in Figure 1 (Attachment A).

1.2 Objectives

The assessment objectives include:

- Review Martens & Associates' (MA) previous geotechnical assessments relevant to the site development.
- Assess possible risks of geotechnical and hydrogeological conditions impacting the proposed development and surrounding properties and infrastructure as a result of the proposed development.
- Provision of preliminary recommendations for design and construction of new structures and further assessments.

1.3 Proposed Development

Preliminary architectural sketches and details provided by the client indicate that the development will include:

- Proposed seniors development with 37 dwellings.
- Construction of new access roads and pathways throughout the site development.
- Cut and fill to create level pads for dwellings.
- Provision of buried services and landscaping.

1.4 Site Description

General site details are summarised in Table 1.

Table 1: General site description summary.

Element	Description/Detail
Lot / DP	Lot 2, DP530145
Local Government Area (LGA)	Northern Beaches Council (formerly Warringah Council)
Site Area	Approximately1.9 ha (based on SIXmaps lot boundaries, accessed February 2017)
Existing site development	Rural development
Neighbouring environment	The site is bordered by Booralie Road to the north and rural properties to the east, south and west. The adjacent property to the east is currently undergoing works for a senior's housing development.
Expected Geology	Hawkesbury Sandstone comprising medium to coarse-grained quartz sandstone, very minor shale and laminate lenses (Sydney *1:100 000 Geological Map Sheet 9130, 1st edition,* Geological Survey of New South Wales, Sydney)
Expected Soil Landscape	The NSW Office of Environment and Heritage eSpade website indicates the site is located in the Somersby soil landscape. Dominant soils of this landscape consist of moderately deep to deep red earths and yellow earths overlying laterite gravels and clays on crests and upper slopes, grey earths, leached sands and siliceous sands on lower slopes and drainage lines, and gleyed podzolic soils in low lying poorly drained areas.
Site Topography	Site is located on a plateau within moderately undulating land
Site Aspect	South
Site Elevation	Ranges between approximately 190 mAHD (south) and 200 mAHD (north)
Typical Slope	Approximately 5 %
Existing Vegetation	Majority of site covered by grass, with trees near the site's southern boundary
Site Drainage	Via overland flow south towards Neverfail Gully located approximately 200 m south-west

2 Geotechnical Assessment

2.1 Available Data

This assessment has been prepared based on findings of previous assessments conducted by MA:

- Geotechnical assessments carried out on 19 October 2012 at the neighbouring site to the west (83 Booralie Road, Terrey Hills, NSW), report reference numbers P1203558JR04V01 ('MA01, 2013') and P1404413JR02V01 ('MA02, 2015').
- A site walkover at 83 Booralie Road, Terrey Hills, NSW on 22 March 2016.
- Supplementary geotechnical and hydrogeological advice prepared on 8 April 2016 for the abovementioned site, letter reference number P1404413JC09V01 ('MA03, 2016').

Relevant geotechnical and hydrogeological data from the previous assessments was attained by carrying out the following:

- Eight boreholes (BH101 to BH108) drilled using a truck-mounted hydraulic drill rig and hand auger up to 5.5 metres below ground level (mBGL).
- Eight Dynamic Cone Penetrometer (DCP) tests up to 4.1 mBGL, one test conducted at each borehole.
- Groundwater level monitoring data via data logger between 18.10.2012 and 09.01.2013 using groundwater monitoring wells installed in boreholes BH103 and BH105.
- Laboratory testing for Atterberg Limit, Shrinkage Index and CBR analysis.

Approximate borehole and groundwater monitoring well locations are shown in Figure 1, Attachment A. Previous assessment results have been reproduced in this report, where relevant for the purposes of geotechnical analysis and provision of recommendations.

2.2 Expected Sub-Surface Conditions

Sub-surface conditions at the site are expected to be similar to the neighbouring site as both sites have similar elevation and geomorphology. Therefore sub-surface conditions at the site are expected to comprise the following likely major soil and rock layers, or units:

Unit A: Silty sand topsoil with organic material, or variable uncontrolled fill material. Unit assumed to be loose or of firm to stiff consistency.

Unit B: Natural residual sand / silty sand / sandy clay / clay soils, with possible ironstone bands. Unit assumed to be medium dense or of stiff to very stiff consistency.

Unit C: Extremely to very low strength sandstone.

Unit D: Low to medium strength sandstone.

Based on the reviewed data, Table 2 summarises expected depths of sub-surface conditions at the site subject to revision following results of further assessments as outlined in Section 3.3.

Table 2: Indicative depths of expected sub-surface profile of likely major soil and rock layers.

Unit	Indicative depth range (mBGL)
A	0.0 – 0.2 [1]
B	0.2 – 2.0
C	2.0 – 5.0
D	> 5.0

Notes:

1. Depth range may be greater if uncontrolled fill material is encountered.

2.3 Expected Groundwater Conditions

Groundwater level monitoring data indicates that the water level is within the sandstone layer at BH103 and within the clay layer and near rock in BH105. Furthermore, groundwater levels were observed to fluctuate by up to 0.96 m in a three month period.

Groundwater conditions in the north of the site are expected to be similar to conditions encountered in the north of the neighbouring property, at locations with similar ground levels to the ground levels of neighbouring boreholes. In the south of the site, groundwater levels are likely to be deeper in comparison to groundwater levels in the south of the neighbouring site due to the greater offset from a small unnamed creek, which is a tributary of Neverfail Gully, and comparatively higher ground elevations at the site.

These inferences are subject to revision following results of further assessments as outlined in Section 3.3.

3 Recommendations and Further Works

3.1 Key Constraints

The proposed development is expected to be impacted by the following key constraints:

1. Variable soil profile: Localised areas containing deep fill or loose / firm soils may occur at the site, overlying deep natural soils. Excavation of boreholes and testing will need to be conducted to assess foundation conditions at proposed footing locations to assist preliminary design.

2. Groundwater level fluctuation: Long term groundwater levels at the site are expected to fluctuate by up to 0.9 m, similar to groundwater level fluctuations encountered in the neighbouring site. Groundwater monitoring wells will need to be installed to assess site groundwater levels and the possible impact of the proposed development on groundwater flows.

3.2 Recommendations

General geotechnical recommendations for the proposed development are provided in Attachment D. Additional site specific recommendations are as follows:

- Shallow footings, such as pad or strip footings, may be adopted provided they are founding on at least medium dense or stiff to very stiff residual soils.

- Alternatively, deepened footings, such as bored cast in-situ concrete piles, may be adopted to extend foundations to material with higher end bearing capacity, such as sandstone.

- A preliminary site classification of 'M', and a classification of 'P' where >0.4 m of fill is encountered, should be adopted for design of lightly loaded shallow footings, in accordance with AS 2870 (2011). This classification is subject to the recommendations presented in this report, CSIRO guidelines and the design of footings in accordance with the relevant Australian Standards.

- Preliminary soil and rock strength parameters and design parameters in Table 3 and Table 4 may be used for preliminary design of footings and foundations; however all parameters, site classifications and preliminary designs are to be revised following further assessments as specified in Section 3.3.

Table 3: Preliminary material properties of likely major soil and rock layers.

Unit	$\gamma_{in\text{-}situ}$ [1] (kN/m³)	UCS [2] (MPa)	Ø' [3] (deg)	Cu [4] (kPa)	E' [5] (MPa)	K_s [6] (MPa/m)
A	15	NA [7]	27 (for sands)	15 (for clays)	5	5
B	17	NA [7]	29 (for sands)	50 (for at least stiff clays)	15	15
C	22	2	30	NA [7]	300	180
D	23	5	32	NA [7]	500	385

Notes:

1. Material in-situ unit weight, based on visual assessment (±10 %).
2. Unconfined compressive strength of intact material (inferred average for unit).
3. Effective internal friction angle (±2 °) assuming drained conditions; may be dependent on rock defect conditions.
4. Undrained cohesion, assuming normally consolidated clay (±10 %).
5. Effective elastic modulus (±10 %), that should be adopted to calculate lateral deflection of pile in soil / rock under serviceability loading.
6. Modulus of subgrade reaction (vertical). For horizontal modulus, 1/3 vertical Ks may be adopted.
7. Not applicable.

Table 4: Preliminary geotechnical design parameters of likely major soil and rock layers.

Unit	Shallow Footings	Piles [1]			K_a [6]	K_p [6]
	ABC [2, 5]	ABC [2, 5]	ALBC [3,5]	ASF [4, 5]		
A	NA [8]	NA [8]	NA [8]	NA [8]	0.50	2.00
B	100 [7]	NA [8]	15	5	0.35	2.85
C	250 [7]	500	180	50	NA [8]	NA [8]
D	NA [8]	1000	350	75	NA [8]	NA [8]

Notes:

1. Assuming bored cast in-situ concrete pile.
2. Allowable end bearing capacity (kPa) for footings embedded at least 0.3 m for lightly loaded footings, and piles embedded at least 0.5 m or 1 pile diameter, whichever is greater, into design material type subject to confirmation on site by a geotechnical engineer of inferred foundation conditions.
3. Allowable lateral bearing capacity (kPa).
4. Allowable skin friction (kPa) below 1 m depth for bored pile in compression, assuming intimate contact between pile and foundation material. For up lift resistance, we recommend reducing ASF by 50% and checking against 'piston' and 'cone' pull-out mechanisms in accordance with AS2159 (2 009).
5. ABC and ASF are given with estimated factors of safety of 3 and 2 respectively, generally adopted in geotechnical practice to limit settlement to an acceptable level for conventional building structures (< 1% of minimum footing width).
6. K_a = Coefficient of active earth pressure; K_p = Coefficient of passive earth pressure.
7. Assuming lightly loaded high level structures supported by square footing with $D_f/B < 0.5$ and $D_f > 0.7$ mBGL.
8. Not applicable or side adhesion not recommended either due to shallow depth or potential internal settlement of materials.

3.3 Further Investigations

As part of the preliminary design and documentation process, the following should be undertaken:

1. Boreholes and rock coring below proposed excavation levels at footing locations, to characterise underlying geology, assess bedrock depth and strength and assess foundation conditions.

2. Further laboratory testing of soils, including shrink/swell, Atterberg Limit testing and CBR testing to confirm or modify material properties or site classifications.

3. Laboratory testing of rock samples, including point load testing of rock cores, to determine rock strength parameters.

4. Should excavations extend below expected groundwater table levels, then install monitoring wells with subsequent groundwater level monitoring over a minimum period of three months and carry out, if necessary, slug testing to assess the hydraulic conductivity of the soil/rock profile.

5. Preparation of a filling and compaction specification plan for the site earthworks.

6. Preparation of a revised geotechnical / hydrogeological report based on site testing, including required construction monitoring and inspections.

7. Review of final design details by a senior geotechnical engineer.

4 Conclusion

The proposed development is not considered to pose a geotechnical risk subject to following the recommendations provided in this report.

5 References

CSIRO (2012) *Building Technology File (BTF) 18-2011 – Foundation Maintenance and Footing Performance: A Homeowner's Guide*.

Herbert C. (1983) *Sydney 1:100 000 Geological Map Sheet 9130, 1st edition*, Geological Survey of New South Wales, Sydney.

Landcom (2004) *Managing Urban Stormwater: Soils and Construction.*

Pells P.J.N. et al (1989) *Engineering Geology of the Sydney Region*.

Standards Australia AS1289.6.3.2 (1984) *Soil strength and consolidation tests – Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test.*

Standards Australia AS1726 (1993) *Geotechnical site investigations*.

Standards Australia AS2870 (2011) *Residential slabs and footings*.

Standards Australia AS3798 (2007) *Guidelines on earthworks for commercial and residential developments.*

WorkCover NSW (2015) *Work Health and Safety (Excavation Work) Code of Practice 2015.*

6 Attachment A – Site Layout (Showing Boreholes in 83 Booralie Road, Terrey Hills, NSW)

KEY:

Indicative borehole and / or groundwater monitoring bore location

martens

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	MH	SITE LAYOUT (SHOWING BOREHOLES IN 83 BOORALIE ROAD, TERREY HILLS, NSW) 85 Booralie Road, Terrey Hills, NSW (Source: SIXmaps)	Drawing: FIGURE 1
Approved:	RE		
Date:	01.03.2017		
Scale:	NA		File No: P1705808JR03V02

7 Attachment B – Borehole Logs for 83 Booralie Road, Terrey Hills, NSW (MA, 2013)

CLIENT	Bayview Links Pty Ltd	COMMENCED	18.10.2012	COMPLETED	18.10.2012	REF BH101
PROJECT	Geotechnical and Contamination Assessment	LOGGED	BM/GL	CHECKED	GT	Sheet 1 of 1
SITE	83 Booralie Road, Terrey Hills, NSW	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO. P1203558
EQUIPMENT	Hydraulic Auger	EASTING	NA	RL SURFACE	197mAHD	
EXCAVATION DIMENSIONS	100mmØ X 4.0m depth	NORTHING	NA	ASPECT	South	SLOPE <5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
V	Nil	N	D	0.1			SM	TOP SOIL - SILTY SAND - Light brown, organics present.		L	E	0.1	3558/1/ 0.1
V	Nil	N	D	0.6			SP	GRAVELLY SAND - Red/brown, ferruginised iron stone inclusions, gravels (5-20mm, 20%). Grading to		L-MD	E	0.5	3558/1/ 0.5
V	Nil	N	D	1.0 1.2			EW	SANDY CLAY/ CLAY - Light brown	F-St		E	1.0	3558/1/ 1.0
V	Nil	N	M	2.0			EW	EXTREMELY WEAK SANDSTONE - Light brown, moist.			E	1.5	3558/1/ 1.5
		2.15											
V	Nil	Y	W	3.0 4.0			W	WEAK SANDSTONE - Light brown, saturated.			E	2.5	3558/1/ 2.5
				5.0 6.0 7.0 8.0 9.0				Borehole terminated at 4.0m on weak sandstone.					

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

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

PENETRATION
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)
E Environmental sample
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample
PID Photo Ionization Detector

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 - Borehole

CLIENT	Bayview Links Pty Ltd	COMMENCED	18.10.2012	COMPLETED	18.10.2012	REF	BH102
PROJECT	Geotechnical and Contamination Assessment	LOGGED	BM	CHECKED	GT	Sheet 1 of 1	
SITE	83 Booralie Road, Terry Hills, NSW	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO.	P1203558
EQUIPMENT	Hydraulic Auger	EASTING	NA	RL SURFACE	196mAHD		
EXCAVATION DIMENSIONS	100mmØ X 3.0m depth	NORTHING	NA	ASPECT	South	SLOPE	<5%

EXCAVATION DATA | **MATERIAL DATA** | **SAMPLING & TESTING**

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
V	Nil	N	D	0.1			SM	TOP SOIL - SILTY SAND - Light brown, organics present.		L	E D	0.1 0.2-0.4	3558/2/0.1 CBR2
V	Nil	N	D	0.8			SP	GRAVELLY SAND - Red/brown, ferruginised iron stone inclusions, gravels (5-40mm, 40%).		MD	E	0.5	3558/2/0.5
V	Nil	N	D	1.0 1.9			SP	SAND - Light brown, medium to large grained. Grading to		MD-D	E E	1.0 1.5	3558/2/1.0 3558/2/1.5
V	Nil	2.25 N	D	2.0 3.0			W	WEAK SANDSTONE - Light brown/white, fine grained sand.			E	2.5	3558/2/2.5
				4.0 5.0 6.0 7.0 8.0 9.0				V Bit refusal at 3.0m on medium strong sandstone.					

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

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

PENETRATION
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)
E Environmental sample
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample
PID Photo Ionization Detector

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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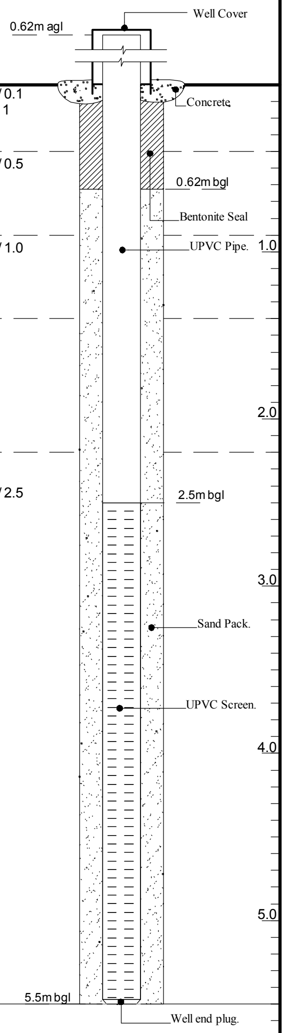
Engineering Log - Borehole

CLIENT	Bayview Links Pty Ltd	COMMENCED	18.10.2012	COMPLETED	18.10.2012	REF BH103
PROJECT	Geotechnical and Contamination Assessment	LOGGED	BM/GL	CHECKED	GT	Sheet 1 of 1
SITE	83 Booralie Road, Terry Hills, NSW	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO. P1203558
EQUIPMENT	Hydraulic Auger	EASTING	NA	RL SURFACE	195mAHD	
EXCAVATION DIMENSIONS	100mmØ X 5.5m depth	NORTHING	NA	ASPECT	South	SLOPE <5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WATER WELL DETAILS
V	Nil	N	D	0.4			XX SC	FILL - SILTY CLAYEY SAND - Gravels (5-10mm, 10%), extremely weathered sandstone gravels.		L-MD	E	0.1	3558/3/ 0.1 + DUP 1
V	Nil	N	D	0.9			SM	SILTY SAND - With minor gravels (5-10mm, 5-10%).		MD	E	0.5	3558/3/ 0.5
V	Nil	N	D	1.0 – 1.4			SP	SAND - Fine to medium grained, ferruginised iron stone inclusion, minor fines, minor gravels (5-10mm, 5-10%).		MD	E	1.0	3558/3/ 1.0
V	Nil	N	M	2.0 – 2.2			W	SANDY CLAY: Light brown, medium to coarse grained sand. Grades to					
V	Nil	N	M	3.0 – 4.0 – 5.0 – 5.5			W	WEAK SANDSTONE - Light brown grey, becoming saturated with depth.			E	2.5	3558/3/ 2.5
				6.0 – 7.0 – 8.0 – 9.0				Borehole terminated at 5.5m in weak sandstone.					



EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING		CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure	SH Shoring	N None observed	D Dry	L Low	VS Very Soft	VL Very Loose	A Auger sample	pp Pocket penetrometer	Y USCS
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test	N Agricultural
BH Backhoe bucket	RB Rock Bolts	Water level	W Wet	H High	F Firm	MD Medium Dense	U Undisturbed sample	VS Vane shear	
HA Hand auger	Nil No support	Water outflow	Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	DCP Dynamic cone penetrometer	
E Excavator		Water inflow	Wl Liquid limit		VSt Very Stiff	VD Very Dense	M Moisture content	FD Field density	
CC Concrete Corer					H Hard		Ux Tube sample (x mm)	WS Water sample	
V V-Bit					F Friable		E Environmental sample	PID Photo Ionization Detector	
TC Tungsten Carbide Bit									
S Spade									

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

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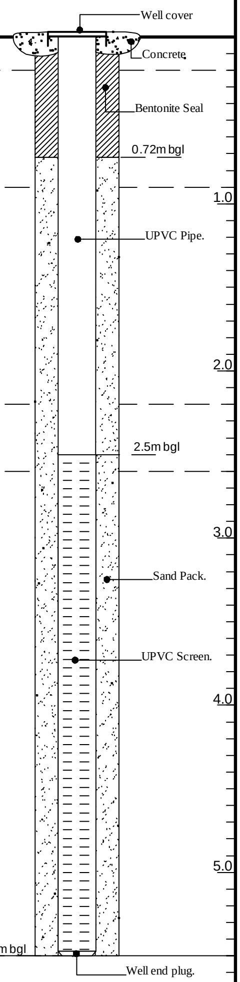
Engineering Log - Borehole

CLIENT	**Bayview Links Pty Ltd**	**COMMENCED**	18.10.2012	**COMPLETED**	18.10.2012	**REF**	**BH104**
PROJECT	**Geotechnical and Contamination Assessment**	**LOGGED**	BM/GL	**CHECKED**	GT	**Sheet** 1 **of** 1	
SITE	**83 Booralie Road, Terry Hills, NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Grass	**PROJECT NO.**	P1203558
EQUIPMENT	Hydraulic Auger	**EASTING**	NA	**RL SURFACE**	194mAHD		
EXCAVATION DIMENSIONS	100mmØ X 5.5m depth	**NORTHING**	NA	**ASPECT**	South	**SLOPE**	<5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WATER WELL DETAILS
V	Nil	N	D	0.2	XX SC	FILL - SILTY CLAYEY SAND - Gravels (5-10mm, 10%), extremely weathered sandstone gravels.		L-MD	E	0.1	3558/4/ 0.1
V	Nil	N	D	0.9	SM	SILTY SAND - With minor gravels (5-10mm, 5-10%).		MD	E	0.5	3558/4/ 0.5
V	Nil	N	D	2.2	SP	SANDY CLAYE- Light grey, with orange mottles			E E	1.0 1.5	3558/4/ 1.0 3558/4/ 1.5
V	Nil	Y (2.3)	W	2.6	W	EXTREMELY WEAK SANDSTONE - Grey/orange. Grading to			E	2.5	3558/4/ 2.5
V	Nil	Y	W	5.5	W	WEAK SANDSTONE - Grey, saturated.					
						Borehole terminated at 5.5m on sandstone.					



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

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

PENETRATION
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)
E Environmental sample
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample
PID Photo Ionization Detector

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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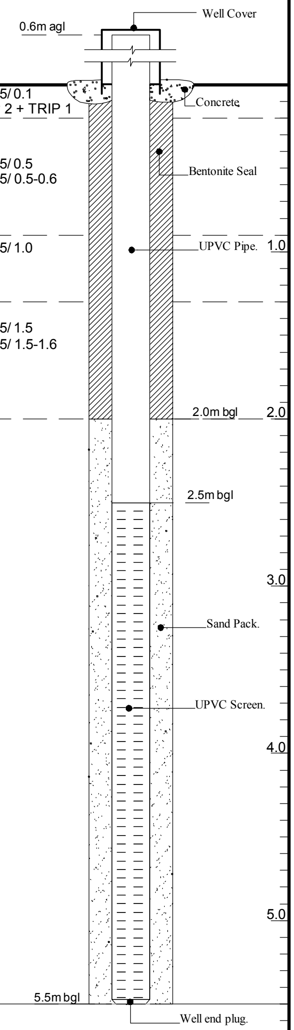
Engineering Log - Borehole

CLIENT	**Bayview Links Pty Ltd**	COMMENCED	18.10.2012	COMPLETED	18.10.2012	**REF**	**BH105**
PROJECT	**Geotechnical and Contamination Assessment**	LOGGED	BM/GL	CHECKED	GT	Sheet 1 of 1	
SITE	**83 Booralie Road, Terry Hills, NSW**	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO.	P1203558
EQUIPMENT	Hydraulic Auger	EASTING	NA	RL SURFACE	193mAHD		
EXCAVATION DIMENSIONS	100mmØ X 5.5m depth	NORTHING	NA	ASPECT	South	SLOPE	<5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	CLASSIFICATION	DESCRIPTION OF STRATA (Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.)	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	WATER WELL DETAILS
V	Nil	N	D	0.2	XX CL	FILL - SILTY CLAY , brown - Gravels (5-20mm, 10%).			E	0.1	3558/5/ 0.1 + DUP 2 + TRIP 1
V	Nil	N	D	0.9	CL	FILL CLAY - extremely weathered sandstone, gravels.			E B	0.5 0.5-0.6	3558/5/ 0.5 3558/5/ 0.5-0.6
V	Nil	N	D	1.0–1.3	SM	SILTY SAND - Dark brown/black, minor gravels.			E	1.0	3558/5/ 1.0
V	Nil	N	D	2.0	CL	CLAY - Light brown, with minor sand and gravel. Grading to			E B	1.5 1.5-1.6	3558/5/ 1.5 3558/5/ 1.5-1.6
V	Nil	Y (2.5)	M	5.5	EW	EXTREMELY WEAK SANDSTONE - Light grey/orange, sandy clay like properties, Note: Seepage observed at approximatley 3.4m during drilling.					
						Borehole terminated at 5.5m on sandstone.					



EQUIPMENT / METHOD	SUPPORT	WATER	MOISTURE	PENETRATION	CONSISTENCY	DENSITY	SAMPLING & TESTING		CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
N Natural exposure	SH Shoring	N None observed	D Dry	L Low	VS Very Soft	VL Very Loose	A Auger sample	pp Pocket penetrometer	Y USCS
X Existing excavation	SC Shotcrete	X Not measured	M Moist	M Moderate	S Soft	L Loose	B Bulk sample	S Standard penetration test	N Agricultural
BH Backhoe bucket	RB Rock Bolts	Water level	W Wet	H High	F Firm	MD Medium Dense	U Undisturbed sample	VS Vane shear	
HA Hand auger	Nil No support	Water outflow	Wp Plastic limit	R Refusal	St Stiff	D Dense	D Disturbed sample	DCP Dynamic cone penetrometer	
E Excavator		Water inflow	Wl Liquid limit		VSt Very Stiff	VD Very Dense	M Moisture content	FD Field density	
CC Concrete Corer					H Hard		Ux Tube sample (x mm)	WS Water sample	
V V-Bit					F Friable		E Environmental sample	PID Photo Ionization Detector	
TC Tungsten Carbide Bit									
S Spade									

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

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Engineering Log - Borehole

Quality Sheet No. 4

CLIENT	**Bayview Links Pty Ltd**	**COMMENCED**	18.10.2012	**COMPLETED**	18.10.2012	**REF**	**BH106**
PROJECT	**Geotechnical and Contamination Assessment**	**LOGGED**	BM/GL	**CHECKED**	GT	Sheet 1 of 1	
SITE	**83 Booralie Road, Terry Hills, NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Grass	**PROJECT NO.**	P1203558
EQUIPMENT	Hydraulic Auger	**EASTING**	NA	**RL SURFACE**	191mAHD		
EXCAVATION DIMENSIONS	100mmØ X 4.0m depth	**NORTHING**	NA	**ASPECT**	South	**SLOPE**	<5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
V	Nil	N	D	0.2			XX CL	FILL - SILTY CLAY - Gravels (5-20mm, 10%).			E	0.2	3558/6/0.2 + DUP 4
V	Nil	N	D	0.9			SP	FILL - SILTY GRAVELY SAND - Light brown, plastics inclusions (wiring).			D E	0.2-0.4 0.5	CBR6 3558/6/0.5
V	Nil	N	D	1.0 1.4			EW	SANDY CLAY - Light brown with grey and orange mottles			E E B	1.0 1.5 1.5	3558/6/1.0 3558/6/1.5 3558/6/1.5
V	Nil	N	D	2.0 2.2			EW						
V	Nil	N	D	3.0 4.0			S	WEAK SANDSTONE - Grey.			B B	3.0-3.1 3.8-4.0	3558/6/3.0-3.1 3558/6/3.8-4.0
				5.0 6.0 7.0 8.0 9.0				Borehole terminated at 4.0m on medium strong sandstone.					

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

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

PENETRATION
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)
E Environmental sample
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample
PID Photo Ionization Detector

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 - Borehole

CLIENT	Bayview Links Pty Ltd	COMMENCED	18.10.2012	COMPLETED	18.10.2012	REF BH107
PROJECT	Geotechnical and Contamination Assessment	LOGGED	BM/GL	CHECKED	GT	Sheet 1 of 1
SITE	83 Booralie Road, Terry Hills, NSW	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO. P1203558
EQUIPMENT	Hand Auger	EASTING	NA	RL SURFACE	191mAHD	
EXCAVATION DIMENSIONS	70mmØ X 1.2m depth	NORTHING	NA	ASPECT	South	SLOPE <5%

EXCAVATION DATA | **MATERIAL DATA** | **SAMPLING & TESTING**

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
HA	Nil	N	D	0.2			SM	TOP SOIL - SILTY SAND - Light brown.		L	E	0.1	3558/7/0.1 + DUP 3
HA	Nil	N	D	1.0 1.2			SP	SAND - Light brown, fine grained, with minor clay.		L	E E	0.5 1.0	3558/7/0.5 3558/7/1.0
HA	Nil	N	D				SC	SANDY CLAY - Light grey, with orange mottles.	F-St		E B	1.5 1.5-1.6	3558/7/1.5 3558/7/1.5-1.6
				2.0 3.0 4.0				EXTREMELY WEAK to WEAK SANDSTONE - Light grey.					
				5.0 6.0 7.0 8.0 9.0				Borehole terminated at 4.0m on extremely weak sandstone.					

EQUIPMENT / METHOD N Natural exposure X Existing excavation BH Backhoe bucket HA Hand auger E Excavator CC Concrete Corer V V-Bit TC Tungsten Carbide Bit S Spade	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	PENETRATION 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) E Environmental sample	pp Pocket penetrometer S Standard penetration test VS Vane shear DCP Dynamic cone penetrometer FD Field density WS Water sample PID Photo Ionization Detector	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 - Borehole

CLIENT	Bayview Links Pty Ltd	COMMENCED	18.10.2012	COMPLETED	18.10.2012	REF	BH108
PROJECT	Geotechnical and Contamination Assessment	LOGGED	BM/GL	CHECKED	GT	Sheet 1 of 1	
SITE	83 Booralie Road, Terry Hills, NSW	GEOLOGY	Sandstone	VEGETATION	Grass	PROJECT NO.	P1203558
EQUIPMENT	Hand Auger	EASTING	NA	RL SURFACE	191mAHD		
EXCAVATION DIMENSIONS	70mmØ X 1.4m depth	NORTHING	NA	ASPECT	South	SLOPE	<5%

EXCAVATION DATA | **MATERIAL DATA** | **SAMPLING & TESTING**

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
HA	Nil	N	D	0.3			SM	SILTY SAND - Light brown, fine grained.			E	0.1	3558/8/ 0.1
HA	Nil	N	D	1.0 1.4			SP	SAND - Light brown/brown, minor fines, fine to medium grained.			E E	0.5 1.0	3558/8/ 0.5 3558/8/ 1.0
				2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0				Borehole terminated at 1.4m on extremely weak sandstone(possibly a floater).					

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

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

PENETRATION
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)
E Environmental sample
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample
PID Photo Ionization Detector

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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

martens

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Engineering Log - Borehole

8 Attachment C – DCP 'N' Counts for 83 Booralie Road, Terrey Hills, NSW (MA, 2013)

Dynamic Cone Penetrometer Test Log Summary

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Site	Geotechnical Investigation	DCP Group Reference		3558
Client	Bayview Links Pty Ltd	Log Date		19.10.2012
Logged by	BM / GL			
Checked by	GT			
Comments				

TEST DATA

Depth Interval (m)	DCP 1	DCP 2	DCP 3	DCP 4	DCP 5	DCP 6	DCP 7	DCP 8	Design
0.15	7	9	3	5	8	3	3	1	1
0.30	10	11	4	3	14	4	2	3	2
0.45	17	13	6	4	11	5	6	4	4
0.60	20	9	6	4	3	3	8	9	3
0.75	13	10	6	3	3	3	3	8	3
0.90	20	8	8	4	4	3	4	11	3
1.05	9	5	7	2	7	2	5	14	2
1.20	9	7	3	3	3	2	2	12	2
1.35	18	24	4	3	4	1	6	13	1
1.50			4	5	3	2	7	10	2
1.65			6	5	2	2	7	12	2
1.80			6	10	2	3	13	15	2
1.95			7	9	5	3	16	10	3
2.10			17	9	6		18	12	6
2.25			18	30	6		26	10	6
2.40					7		27	11	7
2.55					7		36	10	7
2.70							40	9	9
2.85								10	10
3.00								11	11
3.15								13	13
3.30								16	16
3.45								19	19
3.60								22	22
3.75								27	27
3.90								30	30
	Refusal @ 1.35	Refusal @ 1.40	Refusal @ 2.25	Refusal @ 2.40	Refusal @ 2.6	Refusal @ 2.10	Refusal @ 2.7	Refusal @4.1	

9 Attachment D – General Geotechnical Recommendations

Geotechnical Recommendations

These general geotechnical recommendations have been prepared by Martens to help you deliver a safe work site, to comply with your obligations, and to deliver your project. Not all are necessarily relevant to this report but are included as general reference. Any specific recommendations made in the report will override these recommendations.

Batter Slopes

Excavations in soil and extremely low to very low strength rock exceeding 0.75 m depth should be battered back at grades of no greater than 1 Vertical (V) : 2 Horizontal (H) for temporary slopes (unsupported for less than 1 month) and 1 V : 3 H for longer term unsupported slopes.

Vertical excavation may be carried out in medium or higher strength rock, where encountered, subject to inspection and confirmation by a geotechnical engineer. Long term and short term unsupported batters should be protected against erosion and rock weathering due to, for example, stormwater run-off.

Batter angles may need to be revised depending on the presence of bedding partings or adversely oriented joints in the exposed rock, and are subject to on-site inspection and confirmation by a geotechnical engineer. Unsupported excavations deeper than 1.0 m should be assessed by a geotechnical engineer for slope instability risk.

Any excavated rock faces should be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete, is required.

Earthworks

Earthworks should be carried out following removal of any unsuitable materials and in accordance with AS3798 (2007). A qualified geotechnical engineer should inspect the condition of prepared surfaces to assess suitability as foundation for future fill placement or load application.

Earthworks inspections and compliance testing should be carried out in accordance with Sections 5 and 8 of AS3798 (2007), with testing to be carried out by a National Association of Testing Authorities (NATA) accredited testing laboratory.

Excavations

All excavation work should be completed with reference to the *Work Health and Safety (Excavation Work) Code of Practice (2015)*, by Safe Work Australia. Excavations into rock may be undertaken as follows:

1. Extremely low to low strength rock - conventional hydraulic earthmoving equipment.

2. Medium strength or stronger rock - hydraulic earthmoving equipment with rock hammer or ripping tyne attachment.

Exposed rock faces and loose boulders should be monitored to assess risk of block / boulder movement, particularly as a result of excavation vibrations.

Fill

Subject to any specific recommendations provided in this report, any fill imported to site is to comprise approved material with maximum particle size of two thirds the final layer thickness. Fill should be placed in horizontal layers of not more than 300 mm loose thickness, however, the layer thickness should be appropriate for the adopted compaction plant.

Foundations

All exposed foundations should be inspected by a geotechnical engineer prior to footing construction to confirm encountered conditions satisfy design assumptions and that the base of all excavations is free from loose or softened material and water. Water that has ponded in the base of excavations and any resultant softened material is to be removed prior to footing construction.

Footings should be constructed with minimal delay following excavation. If a delay in construction is anticipated, we recommend placing a concrete blinding layer of at least 50 mm thickness in shallow footings or mass concrete in piers / piles to protect exposed foundations.

A geotechnical engineer should confirm any design bearing capacity values, by further assessment during construction, as necessary.

Shoring - Anchors

Where there is a requirement for either soil or rock anchors, or soil nailing, and these structures penetrate past a property boundary, appropriate permission from the adjoining land owner must be obtained prior to the installation of these structures.

Shoring - Permanent

Permanent shoring techniques may be used as an alternative to temporary shoring. The design of such structures should be in accordance with the findings of this report and any further testing recommended by this report. Permanent shoring may include [but not be limited to] reinforced block work walls, contiguous and semi contiguous pile walls, secant pile walls and soldier pile walls with or without reinforced shotcrete infill panels. The choice of shoring system will depend on the type of structure, project budget and site specific geotechnical conditions.

Permanent shoring systems are to be engineer designed and backfilled with suitable granular material and free-draining drainage material. Backfill should be placed in maximum 100 mm thick layers compacted using a hand operated compactor. Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls.

Shoring design should consider any surcharge loading from sloping / raised ground behind shoring structures, live loads, new structures, construction equipment, backfill compaction and static water pressures. All shoring systems shall be provided with adequate foundation designs.

Suitable drainage measures, such as geotextile enclosed 100 mm agricultural pipes embedded in free-draining gravel, should be included to redirect water that may collect behind the shoring structure to a suitable discharge point.

Shoring - Temporary

In the absence of providing acceptable excavation batters, excavations should be supported by suitably designed and installed temporary shoring / retaining structures to limit lateral deflection of excavation faces and associated ground surface settlements.

Soil Erosion Control

Removal of any soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in any formal stormwater drainage system, on neighbouring land and in receiving waters. Where possible, this may be achieved by one or more of the following means:

1. Maintain vegetation where possible
2. Disturb minimal areas during excavation
3. Revegetate disturbed areas if possible

All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods in accordance with Landcom (2004) shall be required.

Trafficability and Access

Consideration should be given to the impact of the proposed works and site subsurface conditions on trafficability within the site e.g. wet clay soils will lead to poor trafficability by tyred plant or vehicles.

Where site access is likely to be affected by any site works, construction staging should be organised such that any impacts on adequate access are minimised as best as possible.

Vibration Management

Where excavation is to be extended into medium or higher strength rock, care will be required when using a rock hammer to limit potential structural distress from excavation-induced vibrations where nearby structures may be affected by the works.

To limit vibrations, we recommend limiting rock hammer size and set frequency, and setting the hammer parallel to bedding planes and along defect planes, where possible, or as advised by a geotechnical engineer. We recommend limiting vibration peak particle velocities (PPV) caused by construction equipment or resulting from excavation at the site to 5 mm/s (AS 2187.2, 2006, Appendix J).

Waste – Spoil and Water

Soil to be disposed off-site should be classified in accordance with the relevant State Authority guidelines and requirements.

Any collected waste stormwater or groundwater should also be tested prior to discharge to ensure contaminant levels (where applicable) are appropriate for the nominated discharge location.

MA can complete the necessary classification and testing if required. Time allowance should be made for such testing in the construction program.

Water Management - Groundwater

If the proposed works are likely to intersect ephemeral or permanent groundwater levels, the management of any potential acid soil drainage should be considered. If groundwater tables are likely to be lowered, this should be further discussed with the relevant State Government Agency.

Water Management – Surface Water

All surface runoff should be diverted away from excavation areas during construction works and prevented from accumulating in areas surrounding any retaining structures, footings or the base of excavations.

Any collected surface water should be discharged into a suitable Council approved drainage system and not adversely impact downslope surface and subsurface conditions.

All site discharges should be passed through a filter material prior to release. Sump and pump methods will generally be suitable for collection and removal of accumulated surface water within any excavations.

Contingency Plan

In the event that proposed development works cause an adverse impact on geotechnical hazards, overall site stability or adjacent properties, the following actions are to be undertaken:

1. Works shall cease immediately.
2. The nature of the impact shall be documented and the reason(s) for the adverse impact investigated.
3. A qualified geotechnical engineer should be consulted to provide further advice in relation to the issue.

10 Attachment E – Notes Relating To This Report

These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all are necessarily relevant to all reports but are included as general reference.

Engineering Reports - Limitations

The recommendations presented in this report are based on limited investigations and include specific issues to be addressed during various phases of the project. If the recommendations presented in this report are not implemented in full, the general recommendations may become inapplicable and Martens & Associates accept no responsibility whatsoever for the performance of the works undertaken.

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

Relative ground surface levels at borehole locations may not be accurate and should be verified by on-site survey.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel. They are based on 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 (e.g. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (e.g. 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, which 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 not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that site conditions, as may be revealed through selective point sampling, are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced. 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 investigations 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.

Martens 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 a site assessment and 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), desktop studies 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 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 in relation 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 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 logged 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, Martens will be pleased to assist with investigation or providing 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 / assessment.

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, Martens 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 Martens report, retain Martens to work with other project professionals 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 – Geo-environmental 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 Martens' proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geo-environmental 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

Geo-environmental 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 recognise 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 relates. 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.

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 typically based on Australian Standard 1726 and the Unified Soil Classification System (USCS) – refer Soil Data Explanation of Terms (2 of 3). In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

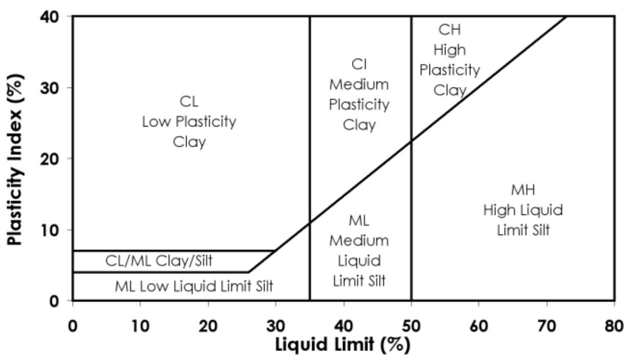
Particle Size

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

Division	Subdivision	Size (mm)
BOULDERS		>200
COBBLES		63 to 200
GRAVEL	Coarse	20 to 63
	Medium	6 to 20
	Fine	2.36 to 6
SAND	Coarse	0.6 to 2.36
	Medium	0.2 to 0.6
	Fine	0.075 to 0.2
SILT		0.002 to 0.075
CLAY		< 0.002

Plasticity Properties

Plasticity properties of cohesive soils can be assessed 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)	Approx. 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 – 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 standard penetration test (SPT) or Dutch cone penetrometer test (CPT) results 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

* Values may be subject to corrections for overburden pressures and equipment type.

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. 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

Symbols for Soils and Other

SOILS		OTHER
COBBLES/BOULDERS	SILT (ML OR MH)	FILL
GRAVEL (GP OR GW)	ORGANIC SILT (OH)	TALUS
SILTY GRAVEL (GM)	CLAY (CL, CI OR CH)	ASPHALT
CLAYEY GRAVEL (GC)	SILTY CLAY	CONCRETE
SAND (SP OR SW)	SANDY CLAY	
SILTY SAND (SM)	PEAT	
CLAYEY SAND (SC)	TOPSOIL	

Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					USCS	Primary Name
COARSE GRAINED SOILS More than 50 % of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm.	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Gravel
				Predominantly one size or a range of sizes with more intermediate sizes missing	GP	Gravel
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	Silty Gravel
				Plastic fines (for identification procedures see CL below)	GC	Clayey Gravel
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of intermediate sizes missing.	SW	Sand
				Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Sand
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM	Silty Sand
				Plastic fines (for identification procedures see CL below)	SC	Clayey Sand

		IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
		DRY STRENGTH (Crushing Characteristics)	DILATANCY	TOUGHNESS	DESCRIPTION	USCS	Primary Name
FINE GRAINED SOILS More than 50 % of material less than 63 mm is smaller than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	None to Low	Quick to Slow	None	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Silt
		Medium to High	None	Medium	Inorganic clays of low to medium plasticity [1], gravely clays, sandy clays, silty clays, lean clays	CL [2]	Clay
		Low to Medium	Slow to Very Slow	Low	Organic slits and organic silty clays of low plasticity	OL	Organic Silt
		Low to Medium	Slow to Very Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	Silt
		High	None	High	Inorganic clays of high plasticity, fat clays	CH	Clay
		Medium to High	None	Low to Medium	Organic clays of medium to high plasticity	OH	Organic Silt
HIGHLY ORGANIC SOILS		Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	Peat

Notes:

1. Low Plasticity – Liquid Limit $W_L < 35$ % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit $W_L > 60$ %.
2. CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

Soil Data

martens consulting engineers

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

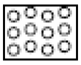
Rock Data

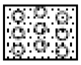
Explanation of Terms (1 of 2)

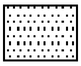
Symbols for Rock

SEDIMENTARY ROCK

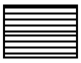
 BRECCIA

 CONGLOMERATE

 CONGLOMERATIC SANDSTONE

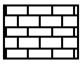
 SANDSTONE/QUARTZITE

 SILTSTONE

 MUDSTONE/CLAYSTONE

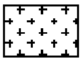
 SHALE

 COAL

 LIMESTONE

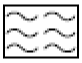
 LITHIC TUFF

IGNEOUS ROCK

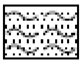
 GRANITE

 DOLERITE/BASALT

METAMORPHIC ROCK

 SLATE, PHYLLITE, SCHIST

 GNEISS

 METASANDSTONE

 METASILTSTONE

 METAMUDSTONE

Definitions

Descriptive terms used for Rock by Martens are based on AS1726 and encompass rock substance, defects and mass.

Rock Substance — In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot 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 of decline in rock structure and grain property and can be determined in the field.

Term	Symbol	Definition
Residual soil[1]	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[1]	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 rock is still evident.
Highly weathered[2]	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[2]	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

Notes:
1 The term "Distinctly Weathered" (DW) may be used to cover the range of substance weathering between EW and SW.
2 Rs and EW material is described using soil descriptive terms.

Rock Strength

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

Term	Is (50) MPa	Field Guide	Symbol
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

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 exclude fractures such as drilling breaks (DB) or handling breaks (HB).

Term	Description
Fragmented	The core is comprised primarily of fragments of length less than 20 mm, and mostly of width less than core diameter.
Highly fractured	Core lengths are generally less than 20 mm to 40 mm with occasional fragments.
Fractured	Core lengths are mainly 30 mm to 100 mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300 mm to 1000 mm, with occasional longer sections and sections of 100 mm to 300 mm.
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) - diametral test (MPa)
●	Unconfined compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)

BP	Bedding plane parting
FL	Foliation
CL	Cleavage
JT	Joint
FC	Fracture
SZ/SS	Sheared zone/ seam (Fault)
CZ/CS	Crushed zone/ seam
DZ/DS	Decomposed zone/ seam
FZ	Fractured Zone
IS	Infilled seam
VN	Vein
CO	Contact
HB	Handling break
DB	Drilling break

Planarity

Pl	Planar
Cu	Curved
Un	Undulating
St	Stepped
Ir	Irregular
Dis	Discontinuous

Roughness

Pol	Polished
Sl	Slickensided
Sm	Smooth
Ro	Rough
VR	Very rough

Thickness

Zone	> 100 mm
Seam	> 2 mm < 100 mm
Plane	< 2 mm

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Vnr	Veneer
Fe	Iron Oxide
X	Carbonaceous
Qz	Quartzite
MU	Unidentified mineral

Inclination

Inclination of defect is measured from perpendicular to and down the core axis.

Direction of defect is measured clockwise (looking down core) from magnetic north.

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 or excavation 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 sampling tube, e.g. U_{50} (50 mm internal diameter thin walled tube), into 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 / Excavation Methods

The following is a brief summary of drilling and excavation 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 75-100 mm in diameter, into the ground. The penetration depth 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 and, if it is safe to descend into the pit, collection of bulk disturbed samples. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (e.g. Pengo) - the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) 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 (Push Tube) - the hole is advanced by pushing a 50 - 100 mm 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 of usually 50 mm internal diameter. Provided full core recovery is achieved (not always possible in very weak or fractured rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

In-situ Testing and Interpretation

Cone Penetrometer Testing (CPT)

Cone penetrometer testing (sometimes referred to as Dutch Cone) described in this report has been carried out using an electrical friction cone penetrometer.

The test is described in AS 1289.6.5.1-1999 (R2013). In the test, a 35 mm 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 a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the push rod centre to an amplifier and recorder unit mounted on the control truck. As penetration occurs (at a rate of approximately 20 mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records. The information provided on the charts comprises:

(i) Cone resistance (q_c) - the actual end bearing force divided by the cross sectional area of the cone, expressed in MPa.

(ii) Sleeve friction (q_f) - the frictional force of the sleeve divided by the surface area, expressed in kPa.

(iii) 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:

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6)\ N \text{ (blows/300 mm)}$$

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.

Standard Penetration Testing (SPT)

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 1289.6.3.1-2004. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm penetration depth increments and the 'N' value is taken as the number of blows for the last two 150 mm depth increments (300 mm total penetration). In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued. The test results are reported in the following form:

(i) Where full 450 mm penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7 blows:

as 4, 6, 7
N = 13

(ii) 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 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

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 (PSP) - a 16 mm diameter flat ended rod is driven with a 9 kg hammer, dropping 600 mm. The test, described in AS 1289.6.3.3-1997 (R2013), was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

Cone penetrometer (DCP) - sometimes known as the Scala Penetrometer, a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm. The test, described in AS 1289.6.3.2-1997 (R2013), was developed initially for pavement sub-grade investigations, with correlations of the test results with California Bearing Ratio published by various Road Authorities.

Pocket Penetrometers

The pocket (hand) penetrometer (PP) is typically a light weight spring hand operated device with a stainless steel loading piston, used to estimate unconfined compressive strength, q_u, (UCS in kPa) of a fine grained soil in field conditions. In use, the free end of the piston is pressed into the soil at a uniform penetration rate until a line, engraved near the piston tip, reaches the soil surface level. The reading is taken from a gradation scale, which is attached to the piston via a built-in spring mechanism and calibrated to kilograms per square centimetre (kPa) UCS. The UCS measurements are used to evaluate consistency of the soil in the field moisture condition. The results may be used to assess the undrained shear strength, C_u, of fine grained soil using the approximate relationship:

$q_u = 2 \times C_u$.

It should be noted that accuracy of the results may be influenced by condition variations at selected test surfaces. Also, the readings obtained from the PP test are based on a small area of penetration and could give misleading results. They should not replace laboratory test results. The use of the results from this test is typically limited to an assessment of consistency of the soil in the field and not used directly for design of foundations.

Test Pit / Borehole Logs

Test pit / borehole log(s) presented herein are an engineering and / or geological interpretation of the subsurface conditions. Their reliability will depend to some extent on frequency of sampling and methods 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 test pit / borehole logs 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 test pits / boreholes, the frequency of sampling and the possibility of other than 'straight line' variation between the test pits / boreholes.

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.

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.

Test, Drill and Excavation Methods

martens consulting engineers

DRILLING / EXCAVATION METHOD

HA	Hand Auger	RD	Rotary Blade or Drag Bit	NQ	Diamond Core - 47 mm
AD/V	Auger Drilling with V-bit	RT	Rotary Tricone bit	NMLC	Diamond Core – 51.9 mm
AD/T	Auger Drilling with TC-Bit	RAB	Rotary Air Blast	HQ	Diamond Core – 63.5 mm
AS	Auger Screwing	RC	Reverse Circulation	HMLC	Diamond Core – 63.5 mm
HSA	Hollow Stem Auger	CT	Cable Tool Rig	DT	Diatube Coring
S	Excavated by Hand Spade	PT	Push Tube	NDD	Non-destructive digging
BH	Tractor Mounted Backhoe	PC	Percussion	PQ	Diamond Core - 83 mm
JET	Jetting	E	Tracked Hydraulic Excavator	X	Existing Excavation

SUPPORT

Nil	No support	S	Shotcrete	RB	Rock Bolt
C	Casing	Sh	Shoring	SN	Soil Nail
WB	Wash bore with Blade or Bailer	WR	Wash bore with Roller	T	Timbering

WATER

▽ Water level at date shown

◁ Partial water loss

▷ Water inflow

◀ Complete water loss

GROUNDWATER NOT OBSERVED (NO) — The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED (NX) — The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

PENETRATION / EXCAVATION RESISTANCE

L	Low resistance: Rapid penetration possible with little effort from the equipment used.
M	Medium resistance: Excavation possible at an acceptable rate with moderate effort from the equipment used.
H	High resistance: Further penetration possible at slow rate & requires significant effort equipment.
R	Refusal/ Practical Refusal. No further progress possible without risk of damage/ unacceptable wear to digging implement / machine.

These assessments are subjective and dependent on many factors, including equipment power, weight, condition of excavation or drilling tools, and operator experience.

SAMPLING

D	Small disturbed sample	W	Water Sample	C	Core sample
B	Bulk disturbed sample	G	Gas Sample	CONC	Concrete Core

U63 Thin walled tube sample - number indicates nominal undisturbed sample diameter in millimetres

TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11	4,7,11 = Blows per 150mm.
N=18	'N' = Recorded blows per 300mm penetration following 150mm seating
DCP	Dynamic Cone Penetration test to AS1289.6.3.2-1997. 'n' = Recorded blows per 150mm penetration

Notes:

RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB 30/80mm	Hammer double bouncing on anvil after 80 mm penetration
N=18	Where practical refusal occurs, report blows and penetration for that interval

CPT	Static cone penetration test
CPTu	CPT with pore pressure (u) measurement
PP	Pocket penetrometer test expressed as instrument reading (kPa)
FP	Field permeability test over section noted
VS	Field vane shear test expressed as uncorrected shear strength (sv = peak value, sr = residual value)
PM	Pressuremeter test over section noted
PID	Photoionisation Detector reading in ppm
WPT	Water pressure tests

SOIL DESCRIPTION

Density		Consistency		Moisture	
VL	Very loose	VS	Very soft	D	Dry
L	Loose	S	Soft	M	Moist
MD	Medium dense	F	Firm	W	Wet
D	Dense	St	Stiff	Wp	Plastic limit
VD	Very dense	VSt	Very stiff	Wl	Liquid limit
		H	Hard		

ROCK DESCRIPTION

Strength		Weathering	
VL	Very low	EW	Extremely weathered
L	Low	HW	Highly weathered
M	Medium	MW	Moderately weathered
H	High	SW	Slightly weathered
VH	Very high	FR	Fresh
EH	Extremely high		