James McHugh

Preliminary Geotechnical Assessment: 17 Thompson Street, Scotland Island, NSW

P2108321JR01V01
May 2022

Limitations Statement

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

Contents

1 Proposed Development and Investigation Scope

Table 1 summarises proposed development details and investigation scope.

Table 1: Summary of proposed development details and investigation scope.

Item	Details
Property Address	17 Thompson Street, Scotland Island, NSW ('the site')
Legal Identifier	Lot 242 in DP 12749
Site Area	1377.8 m^2 (WSS, 2021)
LGA	Northern Beaches Council ('Council') – previously Pittwater Council
Proposed Development	The proposal plans (Design Waves, 2022) indicate that the development will include construction of: o A two-storey dwelling in the central portion and adjacent to the southern boundary. o Two 22.5 kL rainwater tanks in the southern portion of the site. o Minor excavation up to 1.0 m below ground level (bgl) to allow construction of the buildings.
Assessment Purpose	A preliminary geotechnical assessment to support a development application (DA) to Council and assist preliminary structural design of the proposed development.
Investigation Scope of Work	Field investigations conducted on 6 July 2021 included: o Review of DBYD survey plans. o General site walkover to gain an appreciation of the site. o Drilling of six boreholes (BH101, BH102, BH103a, BH103b for geotechnical assessment purpose and BH104 and BH105 for wastewater assessment purpose) using manually operated gear up to 1.4 mbgl (refer Attachment B for borehole logs, and associated explanatory notes in Attachment H). o Collection of soil samples from boreholes for future reference. o Four Dynamic Cone Penetrometer (DCP) tests (DCP101 to DCP103a and BH103b) up to 2.0 mbgl (refer DCP 'N' counts in Attachment C). Investigation locations are shown in Figure 1, Attachment A.

2 General Site Details and Subsurface Conditions

General site details and investigation findings are summarised in Table 2.

Table 2: Summary of general site details based on desktop review, site walkover and site investigations.

Item	Comment
Topography	The site forms part of the Hawkesbury soil landscape (eSPADE), characterized by rolling to very steep hills on Hawkesbury Sandstone with slopes greater than 25 %.
Typical Slopes, Aspect, Elevation	The site has a north easterly aspect with overall grades around 40 %. The site elevation ranges between approximately 60 mAHD and 34 mAHD (WSS, 2018).
Expected Geology	Hawkesbury Sandstone comprising medium to coarse grained quartz sandstone with very minor shale and laminite lenses (Sydney 1:100,000 Geological Sheet 9130, 1st edition, 1983).
Existing Development	The site is mostly undeveloped. At the central portion, the site has previously been cut for the construction (not completed). Previously constructed undeveloped strip brick footings and wall (maximum height 0.5 meters) are considered to be of poor condition.
Vegetation	The undeveloped areas of the site are generally densely vegetated with natural bush (grass, shrubs and trees).
Drainage	Via overland flow towards the north east onto Florence Street.
Neighbouring environment	The site is bordered by: o Thompson Street to the southwest. o A double storey dwelling to the southeast. o Florence Street to the north, northeast. o Pathilda Reserve to the northwest.
Sub-surface soil / rock units	Investigation revealed the following generalised subsurface units likely underlie the site below ground surface level: Unit A: Topsoil comprising clayey sand, encountered up to approximately 0.2 mbgl. Unit B: Colluvial soil comprising loose to medium dense sand, encountered up to 0.6 mbgl. Unit C: Residual soil comprising generally stiff to very stiff clay, encountered up to hand auger termination depth of 0.6 mbgl in BH103b. Unit D: Bedrock comprising inferred highly weathered, low to very low strength sandstone. Based on available literature regarding local Hawkesbury Sandstone and visual inspection of local bedrock outcrops, we consider that the sandstone bedrock on-site likely steps down towards the northeast, has a variable soil cover across the site and may be conservatively assumed to be Class IV sandstone, classified in accordance with Bertuzzi and Pells (2002). This should be confirmed / revised by further assessment, as necessary.
Groundwater	Groundwater inflow was not encountered during drilling of the boreholes up to 1.4 mbgl. However, ephemeral perched groundwater may be encountered in the soil profile above top rock originating from infiltration of surface water during prolonged or intense rainfall events. Should further information on permanent site groundwater levels be required, additional investigation would need to be carried out (i.e. installation of groundwater monitoring wells). A drainage gully exists in the northwest continuing through Pathilda Reserve.

3 Geotechnical Assessment

3.1 Preliminary Soil and Rock Properties

Preliminary soil and rock properties inferred from observations during borehole drilling, such as penetration resistance, DCP test results as well as engineering assumptions are summarised in Table 3.

Table 3: Preliminary material properties.

Layer	$Y_{in\text{-}situ}$ [1] (kN/m³)	Cu[2] (kPa)	c'[3] (kPa)	Ø' [4] (deg)	E' [5] (MPa)	K_0[6]	K_a[7]	K_p[8]
Units A: TOPSOIL (Clayey SAND)	16	NA[9]	NA[9]	NA[9]	NA[9]	0.70	0.50	2.00
Unit B: COLLUVIUM (loose to medium dense, SAND)	18	0	NA[9]	30	15	0.50	0.33	3.00
Unit C: RESIDUAL (stiff to very stiff, CLAY)	20	80	4	25	12	0.58	0.41	2.46
Unit D: INFERRED WEATHERED ROCK (highly weathered, inferred very low to low strength)	23	NA[9]	NA[9]	28	85	0.50	0.3	3.0

Notes:

1. Material in-situ unit weight, based on visual assessment (±10 %).
2. Undrained cohesion.
3. Drained cohesion.
4. Effective internal friction angle (±2˚) estimate, assuming drained conditions.
5. Effective elastic modulus (±10 %) estimate.
6. Earth pressure coefficient at rest.
7. Active earth pressure coefficient.
8. Passive earth pressure coefficient.
9. Not applicable.

3.2 Geotechnical Landslip Risk Assessment

The site is mapped as 'Geotechnical Hazard H1' by Council's environment plan. Given the presence of colluvial soil, and some minor leaning trees, soil movements may have occurred previously on site.

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 Australian Geomechanics Society's Landslide Risk Management Guidelines (2007). We have considered five main geotechnical hazards and have assumed inclusion of treatment measures recommended in this report. These and associated risks are described in Attachment D.

The proposed development is considered to constitute an acceptable risk to life and a low risk to property, resulting from assessed geotechnical

hazards, provided that the slope treatment measures presented in Attachment D and recommendations presented in this report are adhered to, where applicable. Typical slope instability risks have been highlighted on the geological cross section (Figure 2, Attachment A). A description of good hillslope engineering practices is provided as Attachment E. Geotechnical Risk Management Policy for Pittwater Forms 1 and 1a are provided as Attachment F.

Condition of loose boulders and detached rock blocks, located upslope and / or within the proposed development area, should be further assessed by a geotechnical engineer during development to determine potential adverse impacts on the proposed development and stabilisation / removal requirements. Care should be taken not to dislodge surrounding materials during removal of boulders or blocks.

3.3 Geotechnical Recommendations

The following recommendations are provided for the proposed development. Further general geotechnical recommendations are provided as Attachment G.

3.3.1 Site Works

Stockpiling of any excavation spoil should be limited during construction to prevent increasing the risk of slope instability, including moving loose boulders and detached blocks. Site works should limit vegetation removal and soil disturbance as much as practicable to limit risk of slope movement.

3.3.2 Retaining Structures

Excavations must be permanently retained to maintain excavation stability. It is recommended that the previously excavated portion should be supported by retaining walls socketed into sandstone bedrock. Parameters provided in Table 3 may be adopted for the design. Rock support in the form of rock bolts or anchors, may be required.

Retaining wall design should consider additional surcharge loading from live loads, new and existing structures, construction equipment, sloping ground behind the wall and hydrostatic pressures behind retaining walls unless subsurface drainage is provided behind retaining walls.

Care must be taken and additional advice sought should excavation cut through or expose sandstone boulders (floaters) in the colluvial soil profile to limit boulder destabilisation or undercutting.

Appropriate support methodologies should be adopted by the excavation contractor and design engineer and approved by a geotechnical engineer.

3.3.3 Footings and foundations

Structural loads associated with the proposed development should be transmitted to rock, below colluvial / residual soil and / or possible surface boulders / detached rock blocks. It is recommended that all permanent structures are supported by piles / piers socketed at least 2 mbgl into rock. Preliminary estimate of safe end bearing capacity for sandstone bedrock is 750 kPa, subject to provision of a level foundation surface as well as inspection and approval by a geotechnical engineer during construction.

The existing old footing on the development area must be demolished and removed prior placement of new footing.

All foundation excavations should be inspected by a geotechnical engineer to confirm expected conditions outlined in this report and encountered conditions satisfy design assumptions.

3.3.4 Site Classification

The site is classified as a class 'M' site in accordance with AS 2870 (2011). A reclassification to Class 'A' may be considered, subject to all shallow footings founding on sandstone bedrock.

3.3.5 Drainage Requirements

Drainage systems should be designed and installed to divert overland flows and potential perched ephemeral groundwater away from excavations and foundations and behind all retaining walls. All site discharges should be passed through a filter material prior to release downslope of the site.

4 Proposed Additional Works

4.1 Works Prior to Construction Certificate

We recommend the following additional geotechnical assessments are carried out to develop the final design and prior to construction:

1. Further assessment of bedrock depths. If higher bearing capacities are required, drilling with tight access rig across the development area is required during the construction certification stage.

2. Review of the final design by a senior geotechnical engineer to confirm adequate consideration of the geotechnical risks and adoption of the recommendations provided in this report.

4.2 Construction Monitoring and Inspections

We recommend inspection and monitoring of works during construction of the project as summarised in Table 4.

Table 4: Recommended inspection / monitoring requirements during site works.

Scope of Works	Frequency/Duration	Who to Complete
Inspect excavation retention (retaining wall) and monitor associated performance to assess need for additional support requirements.	Daily / Every 1 m excavation lift / As required after initial assessment [2]	Builder / MA [1]
Inspect any rock boulders / blocks to assess need for additional support requirements.	Prior to excavation / As required during excavation [2]	Builder / MA [1]
Monitor groundwater seepage from excavation faces, if encountered, to assess stability of exposed materials, suitability of proposed drainage and additional drainage requirements.	When encountered	Builder / MA [1]
Inspect exposed material at foundation / subgrade level to verify suitability as foundation / lateral support.	Prior to reinforcement set-up and concrete placement	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

Notes:

1. MA = Martens and Associates engineer.
2. MA inspection frequency to be determined based on initial inspection findings in line with construction program.

5 References

Australian Geomechanics Society (2007) *Practice Note Guidelines For Landslide Risk Management 2007,* Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007.

Bertuzzi, R. & Pells, P.J.N. (2002), *Geotechnical parameters of Sydney sandstone and shale*, Australian Geomechanics, Vol 37 No 5 pp 41-54.

Design Waves (2022) Site Plan, Drawing No 02, Revision DA.1, dated 03 May 2022.

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

NSW Department of Environment & Heritage (2020), eSPADE, NSW soil and land information, www.environment.nsw.gov.au, accessed May 2020 (eSPADE).

Pittwater Local Environmental Plan (2014), Geotechnical Hazard Map, Sheet GTH_016, File No. 6370_COM_GTH_016_010_20140217.

Standards Australia Limited (1997) AS 1289.6.3.2:1997, *Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer test*, SAI Global Limited.

Standards Australia Limited (2017) AS 1726:2017, *Geotechnical site investigations*, SAI Global Limited.

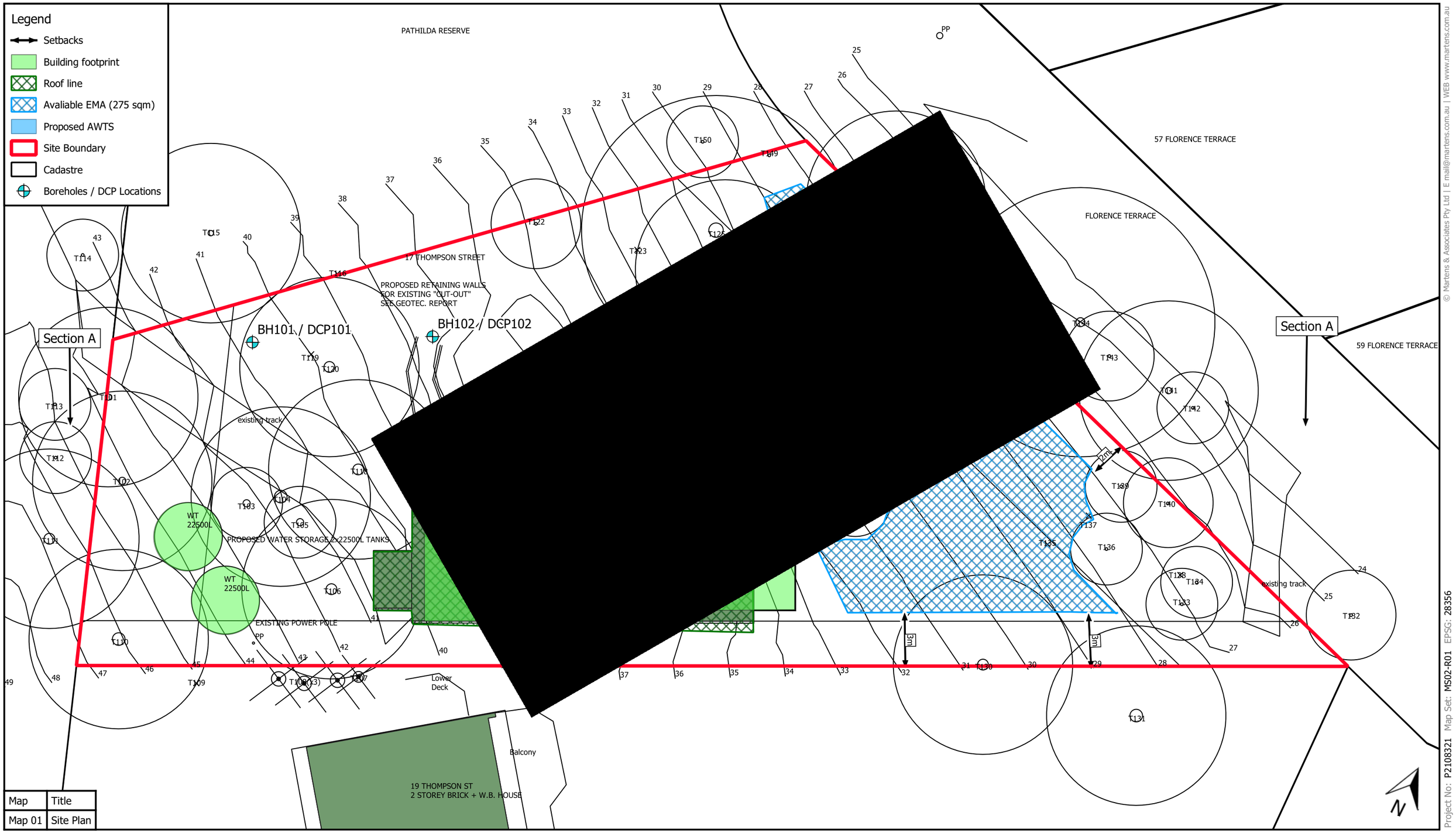
Standards Australia Limited (2009) AS 2159:2009, *Piling – Design and installation*, SAI Global Limited.

Standards Australia Limited (1993) AS 2187.2:1993, *Explosives–Storage, transport and use, Part 2: Use of explosives*, SAI Global Limited.

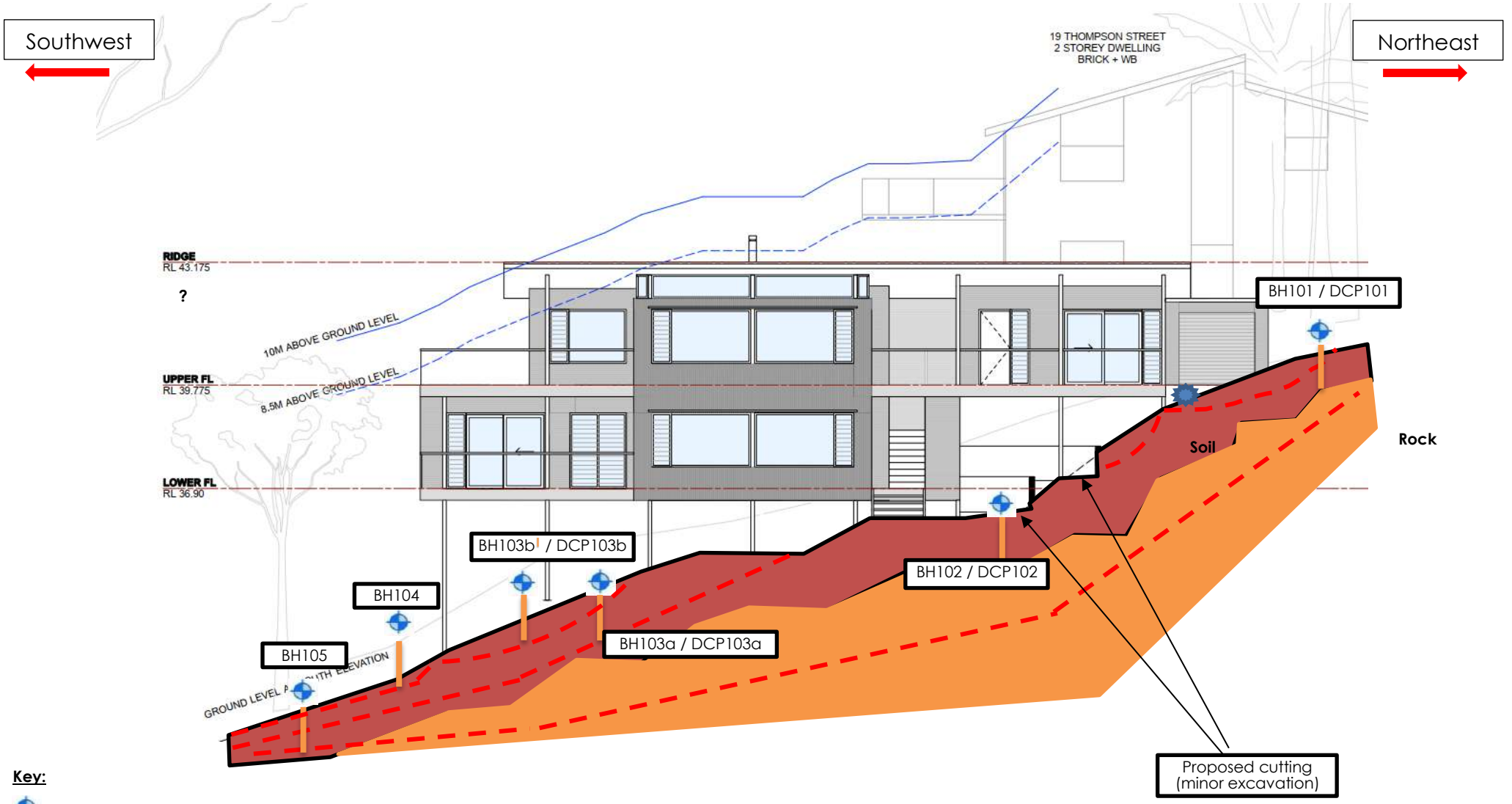
Standards Australia Limited (2011) AS 2870:2011, *Residential slabs and footings*, SAI Global Limited.

Waterview Surveying Services (2021) Survey Plan, Project No 1323, dated 12 April 2020 (WSS, 2021).

6 Attachment A – Figures



Project No: P2108321 Map Set: MS02-R01 EPSG: 28356



Key:

- Approximate test location (Investigation date: 06.07.2021)
- Indicative soil profile (residual and colluvium)
- Indicative rock profile (inferred sandstone)
- Indicative potential landslides
- Indicative potential rock / boulders

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	MZ	**INFERRED GEOLOGICAL MODEL SHOWING POSSIBLE SLOPE INSTABILITY RISKS – SECTION A** **17 Thompson Street, Scotland Island, NSW** (Source: Design by Waves, 2021)	Drawing No: **FIGURE 2**
Approved:	GT		
Date:	09.11.2021		
	NA		

Scale:

Project Number: P2108321JR01V02

7 Attachment B – Test Borehole Logs

CLIENT	James McHugh		COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH101**
PROJECT	Preliminary Geotechincal Investigation		LOGGED	AG	CHECKED	KB	Sheet 1 OF 1
SITE	17 Thompson St, Scotland Island, NSW		GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321
EQUIPMENT		Hand Auger	LONGITUDE	151.29368	RL SURFACE	41 m	DATUM AHD
EXCAVATION DIMENSIONS		⌀75 mm x 0.60 m depth	LATITUDE	-33.6398	ASPECT	North	SLOPE 50 - 60%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered	0.2	41.00 *0.20* 40.80	0.15/S/1 D 0.15 m			SC	TOPSOIL: Clayey SAND; fine to medium grained; dark grey and dark brown; with silt; trace rootlets.		VL	TOPSOIL
	M		0.4					SP	SAND; fine to medium grained; brown, pale brown and grey; with clay; trace silt; trace ironstone and sandstone gravels.	M	L MD	COLLUVIUM
			0.6	*0.60*					Hole Terminated at 0.60 m			0.60: Hand auger refusal on cobbles.
			0.8									
			1.0									
			1.2									
			1.4									
			1.6									
			1.8									

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

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Engineering Log - BOREHOLE

CLIENT	James McHugh		COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH102**
PROJECT	Preliminary Geotechincal Investigation		LOGGED	AG	CHECKED	KB	Sheet 1 OF 1
SITE	17 Thompson St, Scotland Island, NSW		GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321
EQUIPMENT		Hand Auger	LONGITUDE	151.29388	RL SURFACE	34.84 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 0.10 m depth	LATITUDE	-33.63987	ASPECT	North	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered		34.84				CL-CI	TOPSOIL: Clayey SILT; low to medium plasticity; dark grey and dark brown; trace sand.	M (=PL)		TOPSOIL
				0.10					Hole Terminated at 0.10 m			0.10: Hand auger refusal on cobbles and boulders.

0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

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CLIENT	James McHugh	COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH103A**	
PROJECT	Preliminary Geotechincal Investigation	LOGGED	AG	CHECKED	KB	Sheet 1 OF 1	
SITE	17 Thompson St, Scotland Island, NSW	GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321	
EQUIPMENT	Hand Auger	LONGITUDE	151.2939	RL SURFACE	34.1 m	DATUM	AHD
EXCAVATION DIMENSIONS	ø75 mm x 0.50 m depth	LATITUDE	-33.63993	ASPECT	North	SLOPE	5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered	0.2	34.10				SC	TOPSOIL: Clayey SAND; fine to medium grained; dark grey and dark brown; with silt; trace rootlets.		L	TOPSOIL
				0.20								
				33.90	0.3/S/1 D 0.30 m			SP	SAND; fine to medium grained; brown, pale brown and grey; with clay; trace silt; trace ironstone and sandstone gravels.	M	L - MD	COLLUVIUM
			0.4	*0.50*								
									Hole Terminated at 0.50 m			0.50: Hand auger refusal on cobbles and boulders.
			0.6									
			0.8									
			1.0									
			1.2									
			1.4									
			1.6									
			1.8									

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CLIENT	James McHugh		COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH103B**
PROJECT	Preliminary Geotechincal Investigation		LOGGED	AG	CHECKED	KB	Sheet 1 OF 1
SITE	17 Thompson St, Scotland Island, NSW		GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321
EQUIPMENT		Hand Auger	LONGITUDE	151.29334	RL SURFACE	34.1 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 0.60 m depth	LATITUDE	-33.63993	ASPECT	North	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered	0.2	34.10 *0.20* 33.90				SC	TOPSOIL: Clayey SAND; fine to medium grained; dark grey and dark brown; with silt; trace rootlets.	M	L	TOPSOIL
				0.30				SP	SAND; fine to medium grained; brown, pale brown and grey; with clay; trace silt; trace ironstone and sandstone gravels.			COLLUVIUM
	M-H		0.4	33.80	0.4/S/1 D 0.40 m			CI-CH	CLAY; medium to high plasticity; brown, pale yellow and orange; trace ironstone gravels; trace silt.	M (<PL)	F H	RESIDUAL SOIL
			0.6	*0.60*					Hole Terminated at 0.60 m			0.60: Handauger refusal on weathered rock.
			0.8									
			1.0									
			1.2									
			1.4									
			1.6									
			1.8									

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CLIENT	James McHugh		COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH104**
PROJECT	Preliminary Geotechincal Investigation		LOGGED	AG	CHECKED	KB	Sheet 1 OF 1
SITE	17 Thompson St, Scotland Island, NSW		GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321
EQUIPMENT		Hand Auger	LONGITUDE	151.2939	RL SURFACE	29.75 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 1.40 m depth	LATITUDE	-33.6398	ASPECT	North	SLOPE 35 - 40%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered	0	29.75				CL	Clay LOAM; dark brown and dark grey; moderate structure; trace roots; trace sand.			
				0.20								
			0.2	29.55				S	Fine Sandy LOAM; brown, pale brown and grey; trace ironstone and sandstone gravels.			COLLUVIUM
	M		0.4							M		
			0.6									
				0.80								
			0.8	28.95				CI-CH	CLAY; yellow, brown, orange and pale grey; moderate structure.			RESIDUAL SOIL
	H		1.0							M (<PL)		
			1.2									
				1.40								
			1.4						Hole Terminated at 1.40 m			1.40: Hand auger refusal on weathered rock/hard clay.
			1.6									
			1.8									

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CLIENT	James McHugh		COMMENCED	06/07/2021	COMPLETED	06/07/2021	**REF BH105**
PROJECT	Preliminary Geotechincal Investigation		LOGGED	AG	CHECKED	KB	Sheet 1 OF 1
SITE	17 Thompson St, Scotland Island, NSW		GEOLOGY	Hawkesbury Sandstone	VEGETATION	Shrubs	PROJECT NO. P2108321
EQUIPMENT		Hand Auger	LONGITUDE	151.29417	RL SURFACE	28.34 m	DATUM AHD
EXCAVATION DIMENSIONS		⌀75 mm x 1.20 m depth	LATITUDE	-33.6399	ASPECT	East	SLOPE 30 - 40%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
HA	L	Not Encountered	0	28.34				CL	Clay LOAM; dark brown and dark grey; moderate structure; trace roots; trace sand.			
			0.2	*0.20* 28.14					Fine Sandy LOAM; brown, pale brown and grey; moderate structure; trace ironstone and sandstone gravels.	M		COLLUVIUM
	M		0.4									
			0.6	*0.60* 27.74				CI-CH	CLAY; medium to high plasticity; yellow, brown, orange and pale grey; moderate structure.			RESIDUAL SOIL
	H		0.8							M (<PL)		
			1.0									
			1.2	*1.20*					Hole Terminated at 1.20 m			1.20: Hand auger refusal on weathered rock/hard clay.
			1.4									
			1.6									
			1.8									

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

MARTENS & ASSOCIATES PTY LTD
Suite 201, 20 George St. Hornsby, NSW 2077 Australia
Phone: (02) 9476 9999 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - BOREHOLE

8 Attachment C – DCP ‘N’ Counts

Dynamic Cone Penetrometer Test Log Summary

martens
consulting engineers since 1989

Suite 201, 20 George Street, Hornsby, NSW 2077 Ph: (02) 9476 9999 Fax: (02) 9476 8767, mail@martens.com.au, www.martens.com.au

Site	17 Thompson Street, Scotland Isand	**DCP Group Reference**	P2108321JS01V01
Client	James McHugh	**Log Date**	06.07.2021
Logged by	AG		
Checked by	KB		
Comments	All DCP commenced at 50 mm bgl.		

TEST DATA

Depth Interval (m)	DCP101	DCP102	DCP103a	DCP103b				
0.15	HW	28 / 120 mm	HW	HW				
0.30	2	Terminated @ 0.08 m due to double bounce.	1	1				
0.45	4		4	2				
0.60	5		2 / 140 mm	2 / 140 mm				
0.75	8		Terminated @ 0.51 m due to double bounce.	Terminated @ 0.51 m due to double bounce.				
0.90	11							
1.05	9							
1.20	10							
1.35	9							
1.50	10							
1.65	18							
1.80	26							
1.95	28							
2.10	Terminated @ 2.0 m due to high counts.							
2.25								
2.40								
2.55								
2.70								
2.85								
3.00								

9 Attachment D – Geotechnical Risk Calculation Sheet

Slope Instability Risk - Summary Assessment

Method based on Walker et al. in AGS Vol 42 No. 1 March 2007
Method ST-38 V02 Revised 27.05.2020

Suite 201, George Street, Hornsby, NSW 2007, Ph: (02) 9476 9999 Fax: (02) 9476 8767, mail@martens.com.au, www.martens.com.au

PROJECT DETAILS

Client:	James McHugh			**Ref. No.**	P2108321JS03V01
Project:	Preliminary Geotechnical Assessment	**Author:**	AG	**Date Created**	19/07/2021
Address:	17 Thompson Street, Scotland Island, NSW	**Reviewed by:**	RE	**Date Reviewed**	22/07/2021

RISK ASSESSMENT

Risk	Hazard Type:	Likelihood [1]	Consequence [1]
A	Soil creep	Unlikely	Minor
B	Shallow slide	Unlikely	Medium
C	Rock fall	Rare	Minor
D	Deep seated rotational slide	Rare	Medium

Risk to Life [2]		Risk to Property [2]		
Probability	Assessment	Likelihood	Consequence	Assessment
2.35E-07	Lr-A	Possible	Minor	M
1.10E-07	Lr-A	Possible	Minor	L
1.85E-06	Lr-T	Rare	Minor	VL
5.52E-07	Lr-A	Rare	Minor	VL

Notes

1. Based on current conditions.

2. Assumes treatment measures are adopted.

Definitions

1. Risk to Life Assessment - Lr-A: Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.
2. Risk to Life Assessment - Lr-T: Tolerable risk for loss of life for the person(s). Risk level suitable for existing structures > 10 years old. Risk level unsuitable for new developments.
3. Risk to Life Assessment - Lr-U: Unacceptable risk for loss of life for the person(s). Risk level unsuitable for new or existing (>10 years old) developments.

Risk Level Implications

1. VH - Very High Risk - Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce to Low. Cost could be
2. H - High Risk - Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Treatment will be costly.
3. M - Moderate Risk - May be tolerated in certain circumstances but requires investigation, planning and implementation to reduce risk to Low. Treatment options are practical.
4. L - Low Risk - Usually acceptable to regulators. Where treatment has been requir3ed to reduce the risk to this level, ongoing maintenance is required.
5. VL - Very Low Risk - Acceptable. Manage by normal slope maintenance procedures.

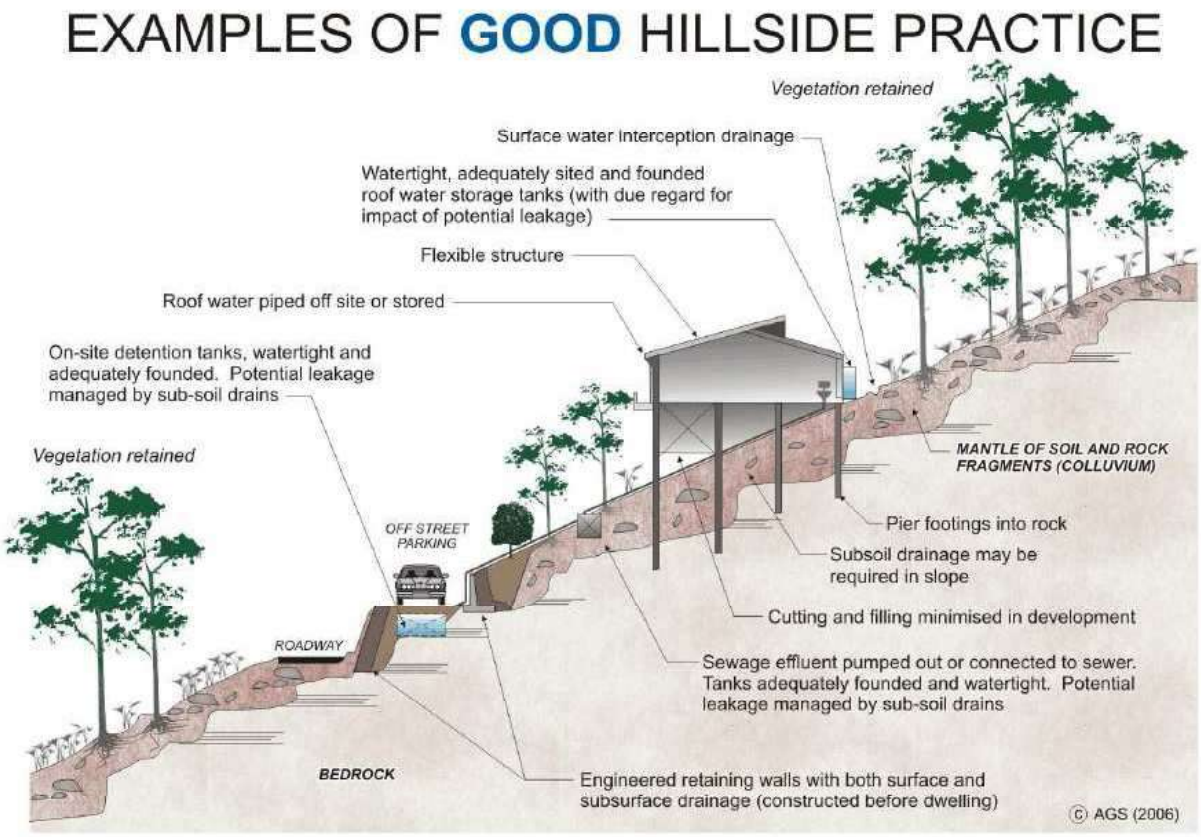
Treatment Measures

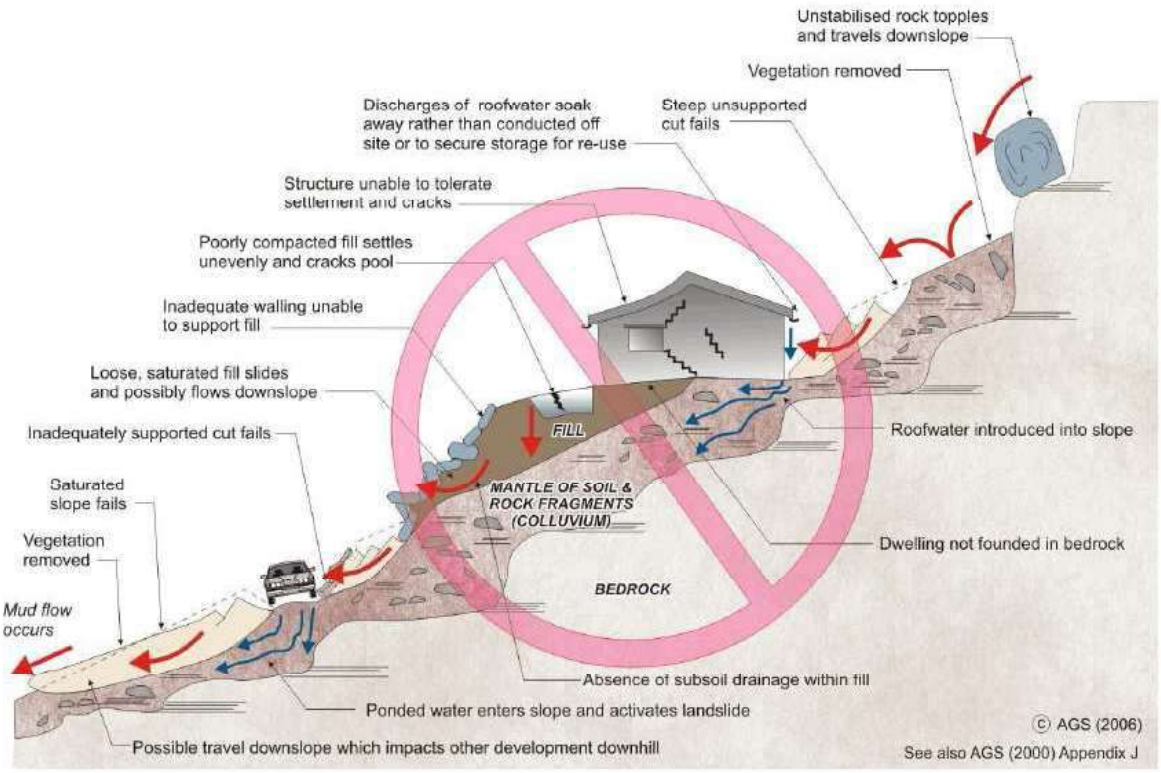
Ensure good hill slope engineering practice is adopted (examples are provided in Attachment E). Maintain vegetation cover. Do not over-steepen existing grades without suitable shoring support. Do not place excessive load onto existing and final sloping surfaces unless designed for. Ensure appropriate foundation and footing design. Ensure placement of new footings on rock. Provide / maintain appropriate surface and sub-surface drainage. Identify and control / remove existing boulders upslope of the proposed development area, as appropriate. Refer report text for further recommendations.

10 Attachment E – Hillside Construction Guidelines (AGS, 2007)

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
© AGS (2006)
Possible travel downslope which impacts other development downhill
See also AGS (2000) Appendix J

11 Attachment F – Geotechnical Risk Management Policy for Pittwater – Forms 1 and 1a

PITTWATER COUNCIL

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for JAMES McHUGH
Name of Applicant
Address of site 17 THOMPSON STREET, SCOTLAND ISLAND NSW

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, KENNETH BURGESS *on behalf of* MARTENS AND ASSOCIATES
(Insert Name) (Trading or Company Name)

on this the 17 MAY 2022 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

☐ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☑ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: PRELIMINARY GEOTECHNICAL ASSESSMENT
Report Date: 17 MAY 2022
Author: AKSHAYA GHIMIRE
Author's Company/Organisation: MARTENS AND ASSOCIATES

Documentation which relate to or are relied upon in report preparation:

DESIGN WAVES (2021) ARCH DRGS NOS 05, 11, 20-24 REV A 31 OCT 2021
HERBERT.C (1983) SYDNEY 1:100,000 GEOLOGICAL SHEET 9130 1ST EDITION GEOLOGICAL SURVEY OF NEW SOUTH WALES

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature .....
Name KENNETH BURGESS
Chartered Professional Status CPEng NER (MEMBER)
Membership No. 3789174
Company MARTENS AND ASSOCIATES

PITTWATER COUNCIL

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for JAMES McHUGH
Name of Applicant
Address of site 17 THOMPSON STREET SCOTLAND ISLAND NSW

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: PRELIMINARY GEOTECHNICAL ASESSMENT
Report Date: 17 MAY 2022
Author: AKSHAYA GHIMIRE
Author's Company/Organisation: MARTENS AND ASSOCIATES

Please mark appropriate box

- ☑ ~~Comprehensive~~ site mapping conducted 6/7/2021 (date)
- ☐ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ☑ Subsurface investigation required
  - ☐ No Justification .....
  - ☑ Yes Date conducted .....6/7/2021.....
- ☑ Geotechnical model developed and reported as an inferred subsurface type-section
- ☑ Geotechnical hazards identified
  - ☑ Above the site
  - ☑ On the site
  - ☑ Below the site
  - ☑ Beside the site
- ☑ Geotechnical hazards described and reported
- ☑ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ☑ Consequence analysis
  - ☑ Frequency analysis
- ☑ Risk calculation
- ☑ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ☑ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- ☑ Design Life Adopted:
  - ☑ 100 years
  - ☐ Other .....
    specify
- ☑ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ☑ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☐ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature .....
Name KENNETH BURGESS
Chartered Professional Status CPEng NER (MEMBER)
Membership No. 3789174
Company MARTENS AND ASSOCIATES

12 Attachment G – General Geotechnical Recommendations

Information

Important Information About Your Report (1 of 2)

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.

Important Information About Your Report (2 of 2)

- 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.

13 Attachment H – Notes About This Report

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 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, moisture, structure, soil or rock type and inclusions.

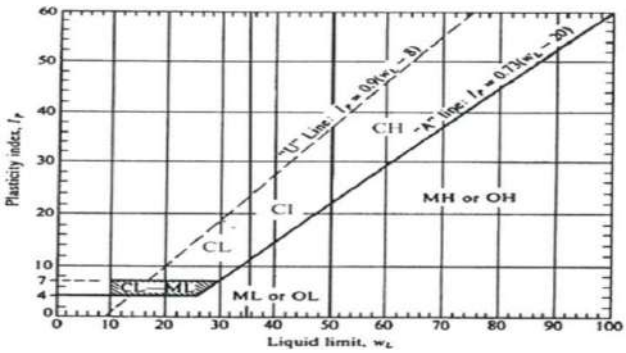
Particle Size

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		Particle Size (mm)
Oversized	BOULDERS		>200
	COBBLES		63 to 200
Coarse Grained Soil	GRAVEL	Coarse	19 to 63
		Medium	6.7 to 19
		Fine	2.36 to 6.7
	SAND	Coarse	0.6 to 2.36
		Medium	0.21 to 0.6
		Fine	0.075 to 0.21
Fine Grained Soil	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.



Soil Moisture Condition

Coarse Grained (Granular) Soil:

Dry (D):	Looks and feels dry. Cemented soils are hard, friable or powdery. Uncemented soils run freely through fingers.
Moist (M):	Feels cool and damp and is darkened in colour. Particles tend to cohere.
Wet (W):	As for moist but with free water forming on hands when handled.

Fine Grained (Cohesive) Soil:

Moist, dry of plastic limit[1] (w < PL):	Looks and feels dry. Hard, friable or powdery.
Moist, near plastic limit (w ≈ PL):	Can be moulded, feels cool and damp, is darkened in colour, at a moisture content approximately equal to the PL.
Moist, wet of plastic limit (w > PL):	Usually weakened and free water forms on hands when handled.
Wet, near liquid limit[2] (w ≈ LL)	
Wet, wet of liquid limit (w > LL)	

[1] Plastic Limit (PL): Moisture content at which soil becomes too dry to be in a plastic condition.

[2] Liquid Limit (LL): Moisture content at which soil passes from plastic to liquid state.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.
(Note: consistency is affected by soil moisture condition at time of measurement)

Term	C_u (kPa)	Field Guide
Very Soft (VS)	≤12	A finger can be pushed well into the soil with little effort. Sample exudes between fingers when squeezed in fist.
Soft (S)	>12 and ≤25	A finger can be pushed into the soil to about 25mm depth. Easily moulded by light finger pressures.
Firm (F)	>25 and ≤50	The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong figure pressure.
Stiff (St)	>50 and ≤100	The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers.
Very Stiff (VSt)	>100 and ≤200	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 (H)	> 200	The surface of the soil can only be marked with the thumbnail. Brittle. Tends to break into fragments.
Friable (Fr)	-	Crumbles or powders when scraped by thumbnail. Can easily be crumbled or broken into small pieces by hand.

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 and ≤35	5 - 10	2 - 5
Medium dense	>35 and ≤65	10 - 30	5 - 15
Dense	>65 and ≤85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

* Values may be subject to corrections for overburden pressures and equipment type and influenced by soil moisture condition at time of measurement.

Minor Components

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

Description of components	Proportion of component in:					
	coarse grained soil				fine grained soil	
	% Fines	Terminology	% Accessory coarse fraction	Terminology	% Sand/ gravel	Terminology
Minor	≤5	Trace clay / silt, as applicable	≤15	Trace sand / gravel, as applicable	≤15	Trace sand / gravel, as applicable
	>5,≤12	With clay / silt, as applicable	>15,≤30	With sand / gravel, as applicable	>5,≤30	With sand / gravel, as applicable
Secondary	>12	Prefix soil name as 'silty' or 'clayey', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable

Soil Data

Explanation of Terms (2 of 3)

Symbols for Soils and Other

SOILS


COBBLES/BOULDERS


GRAVEL (GP or GW)


Silty GRAVEL (GM)


Clayey GRAVEL (GC)


SAND (SP or SW)


Silty SAND (SM)


Clayey SAND (SC)


SILT (ML or MH)


ORGANIC SILT or CLAY (OH or OL)


CLAY (CL, CI or CH)


Silty CLAY


Sandy CLAY


PEAT (Pt)


Gravelly CLAY

OTHER


FILL


TALUS


ASPHALT


CONCRETE


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 65 % 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 2.36 mm.	GRAVEL and GRAVEL-SAND Mixtures (≤ 5% fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes; not enough fines to bind coarse grains; no dry strength	GW	GRAVEL
				Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	GP	GRAVEL
			GRAVEL-SILT and GRAVEL-SAND-SILT mixtures (≥ 12% fines) [1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength; may also contain sand	GM	Silty GRAVEL
				With excess plastic fines (for identification procedures see CL below); medium to high dry strength; may also contain sand	GC	Clayey GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.36 mm	SAND and GRAVEL-SAND mixtures (≤5% fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes; not enough fines to bind coarse grains; no dry strength.	SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	SP	SAND
			SAND-SILT and SAND-CLAY mixtures (≥ 12% fines) [1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength;	SM	Silty SAND
				With excess plastic fines (for identification procedures see CL below); medium to high dry strength	SC	Clayey SAND

FINE GRAINED SOILS More than 35 % of material less than 63 mm is smaller than 0.075 mm	IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
	DRY STRENGTH (Crushing Characteristics)	DILATANCY	TOUGHNESS	DESCRIPTION	USCS	Primary Name
	None to Low	Quick to Slow	Low	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or silt with low plasticity [2]	ML	SILT [3]
	Medium to High	None to Slow	Medium	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL (or CI[4])	CLAY
	Low to Medium	Slow	Low	Organic slits and organic silty clays of low plasticity	OL	Organic SILT or CLAY
	Low to Medium	None to Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	SILT [3]
	High to Very High	None	High	Inorganic clays of high plasticity, fat clays	CH	CLAY
	Medium to High	None to Very Slow	Low to Medium	Organic clays of medium to high plasticity, organic silt of high plasticity	OH	Organic SILT or CLAY
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	PEAT

Notes:

1. Between 5% and 12% - dual classification, e.g. GP-GM.
2. Low Plasticity Clay – Liquid Limit W_L ≤35%; Medium Plasticity Clay – Liquid limit W_L >35%, ≤50%; High Plasticity Clay - Liquid limit W_L > 50%.
3. Low Plasticity Silt – Liquid Limit W_L ≤50%; High Plasticity Silt - Liquid limit W_L > 50%.
4. CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

Soil Data

Explanation of Terms (3 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

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 Material	The intact rock that is bounded by defects.
Rock Defect	Discontinuity, fracture, break or void in the material or minerals across which there is little or no tensile strength.
Rock Structure	The nature and configuration of the different defects within the rock mass and their relationship to each other.
Rock Mass	The entirety of the system formed by all of the rock material and all of the defects that are present.

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	Material is weathered to such an extent that it has soil properties. Mass structure, material texture, and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely weathered[1]	XW	Material is weathered to such an extent that it has soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System. Mass structure and material texture and fabric of original rock are still visible.
Highly weathered[2]	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the original colour of the rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered[2]	MW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the rock is not recognisable. Rock strength shows little or no change from fresh rock.
Slightly weathered	SW	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	FR	Rock substance unaffected by weathering. No sign of decomposition of individual materials or colour changes.

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

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 (Strength)	I_s (50) MPa	Uniaxial Compressive Strength MPa	Field Guide	Symbol
Very low	>0.03 ≤0.1	0.6 – 2	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VL
Low	>0.1 ≤0.3	2 – 6	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	6 – 20	Core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	M
High	>1 ≤3	20 – 60	Core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife. Breaks with single blow from pick.	H
Very high	>3 ≤10	60 – 200	Core 150mm long x 50mm diameter, broken readily with hand held hammer. Cannot be scratched with knife. Breaks after more than one pick strike.	VH
Extremely high	>10	>200	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 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)
- ● Uniaxial 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.

Test, Drill and Excavation Methods

Explanation of Terms (1 of 3)

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

Explanation of Terms (3 of 3)

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

▷ Water inflow

◁ Partial water loss

◀ 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 4,7,11 N=18	Standard Penetration Test to AS1289.6.3.1-2004 4,7,11 = Blows per 150mm. '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 rod weight only
HW	Penetration occurred under hammer and rod weight only
20/100mm	Where practical refusal or hammer double bouncing occurred, blows and penetration for that interval are reported (e.g. 20 blows for 100 mm penetration)

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		