Mr Garry Smith

Geotechnical Assessment: 20 Carlton Street, Freshwater, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1404156JR01V01
March 2014

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

Contents

1 Introduction

1.1 Scope of Work

This report documents the findings of a preliminary geotechnical assessment completed to support a development application (DA) for proposed alterations and additions to the existing dwelling at 20 Carlton Street, Freshwater, NSW. The objective of the assessment is to determine site geotechnical conditions and any associated geotechnical risks which may affect the site and the proposed development.

1.2 Proposed Development

We understand that the proposed development will include construction of a new driveway and garage on the lower level and study/bedroom on the upper level, adjacent to the existing dwelling. Excavations will be taken to approximately 4.5 metres below existing ground level (m bgl).

1.3 Warringah Council DCP

In accordance with Warringah Council (2011) *Development Control Plan, E10 Landslip Risk,* a preliminary assessment of site conditions is required to determine if a geotechnical report is required. Due to the site being mapped by Council as 'B – Flanking Slopes' as well as the extent of excavation, a full report has been undertaken.

1.4 Relevant Guidelines and Standards

The assessment has been prepared in general accordance with the following guidelines and standards:

- Australian Geomechanics Society, *Practice Note Guidelines for Landslide Risk Management* (2007), Volume 42 No 1
- Australian Standard 1726 (1993) *Geotechnical Site Investigations*
- Australian Standard 1289.6.3.2 (1997) *Determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test*
- Australian Standard 2870 (2011) *Residential slabs and footings*
- Warringah Council (2011) *Development Control Plan*

2 Site Description

2.1 Summary

Site information is summarised in Table 1.

Table 1: Site description summary.

Element	Description/Detail
Site Address	20 Carlton Street, Freshwater, NSW, (Investigation area is outlined on Figure 1 in Attachment A).
Site Area	490.30 m^2
Lot/DP	Lot E, DP345308
Existing site development	Two storey rendered residence
Aspect	South west
Typical slopes	<5%
Vegetation	Grass and managed gardens.
Neighbouring environment	Bordered by Carlton Street to the east and Wyndora Avenue to the south. Residential allotments border along the remaining site boundaries.
Local Government Area (LGA)	Warringah Council
Easements	None based on review of survey and site investigation.
Drainage	No natural drainage lines on-site. Drainage via overland flow in concrete swale along the northern boundary and site pit/pipe stormwater network.

2.2 Site Stability and Condition of Existing Structures

Field investigations revealed the following:

- At the time of inspection there was no obvious evidence of recent major gross slope instability on-site or near to the site in the vicinity of the proposed garage.
- At the time of inspection the existing dwelling and the retaining wall to the south appeared to be in a serviceable condition with no significant cracking or settlement observed in the vicinity of the proposed garage.

3 Preliminary Geotechnical Assessment

3.1 Field Investigations

Field investigations undertaken on November 20, 2013 included:

- Completion of a Dial Before You Dig (DBYD) and service locating in the vicinity of the proposed garage excavation.
- Walkover inspection to assess existing site conditions, local topography, geology, soil conditions and vegetation.
- Excavation of four boreholes and three test pit using a hand auger/spade to classify underlying soils and geology.
- Completion of ten dynamic cone penetrometer (DCP) tests to estimate soil strength properties.
- Collection of soil samples for future reference.

A geotechnical site testing plan is provided in Attachment A, excavation logs in Attachment B and DCP 'N' counts in Attachment C.

3.2 Sub-surface Conditions

3.2.1 Geological Mapping

The Sydney 1:100,000 Geological Sheet 9130 (NSW Dept. Mineral Resources) describes geology at the site as Hawkesbury sandstone being fine to medium grained quartz sandstone with very minor shale and laminite lenses.

3.2.2 Observed Materials

Summary of sub-surface materials observed during site investigations are provided in Table 2.

Table 2: Sub-surface materials summary.

Testing Location Identifier	Materials[1]			
	FILL: Silty Sand	FILL: Clayey Sand	Sandy Clay	Low to Medium Strength Sandstone[4]
BH101	0.0 - 0.1	0.1 – 0.5	0.5 – 0.7	> 0.7
BH102	0.0 – 0.1	0.1 – 0.4	-[2]	> 0.4
BH103	0.0 – 0.1	0.1 – 0.35	-	> 0.35
BH104	0.0 – 0.1	0.1 – 0.35	-	> 0.35
TP105	0.0 – 0.1	> 0.1[3]	-	-
TP106	0.0 – 0.1	0.1 – 0.2	-	> 0.2
TP107	0.0 – 0.1	0.1 – 0.4	-	> 0.4

[1.] Units are in metres below existing grades (m)
[2.] Material not observed.
[3] Excavation terminated on fill.
[4] Rock strength estimated based on scratch test of exposed sandstone cut to the south of the site.
[5] Depths vary across the site. Refer to borehole logs for full soil description details.

Borehole investigations revealed that typical sub-surface condition consisted of silty sand/clayey sand (fill) and sandy clay overlying weathered sandstone. A preliminary geological cross section is provided in Attachment A.

Top of weathered sandstone bedrock is expected to be near DCP refusal depths (i.e. 0.2 – 1.1 m bgl). However this method is uncertain unless confirmed with mechanical augering as DCP may have refused on large floaters. A summary of DCP 'N' counts are provided in Attachment C.

3.2.3 Existing Dwelling Foundations

Three test pits were conducted adjacent to the existing dwelling on the south east corner, to determine founding material. We provide the following comments:

- Test pitting revealed footings are mostly founded on weathered sandstone at approximately 0.4m bgl. TP207 revealed formed brickwork below the footing, taken to rock.
- We note, due to site constraints, no test pitting was conducted at the north end of the property, however based on DCP 'N' counts and observation in other test pits it is likely footings are founded on weathered rock at approximately 0.5m bgl.

Supporting plates are provided in Attachment A

3.3 Preliminary Soil and Rock Strength

Preliminary soil strength properties were estimated based on interpolation of hand auger excavations, DCP tests and our experience in the area (Table 3). Methods are approximate and estimates are preliminary. Should further details or higher bearing pressures be required for foundation design purposes then further testing (rock coring and lab testing) is recommended.

Table 3: Preliminary soil and rock strength properties estimates.

Material Description [1]	Y_d[2] (kN/m³)	C_u[3](kPa)	ϕ'[4] (°)	ASF [5] (kPa)	ABC [6] (kPa)
FILL: SILTY SAND: Loose to Medium Dense	15	-	27	-	40
FILL: CLAYEY SAND: Medium Dense - Dense	17	-	32	-	60
SANDY CLAY: Very Stiff	17	100	-	-	80
L - M Strength Sandstone: Highly - Moderately Weathered	23	-	35	150	500

Notes:
[1] L = Low Strength, M = Medium Strength.
[2] *Dry* unit weight.
[3] Undrained shear strength assuming normally consolidated clay.
[4] Effective friction angle assuming drained conditions.
[5] Allowable skin friction assuming bored piers. For Foundation purposes, all designs must take into account appropriate socket depths.
[6] Allowable bearing capacity estimates assuming square footing with $D_f/B < 0.5$.

3.4 Site Classification

As footings and foundations for the proposed garage will be taken through fill into sandstone, the site maintains a site classification of 'A –

most sand and rock sites with little or no ground movement from moisture changes'.

3.5 Groundwater

We expect that seepage will be present at the soil/rock interface following periods of rainfall. Due to the site location and local cuttings observed in the area, it is unlikely that the proposed excavation will encounter the permanent groundwater table.

3.6 Risk Assessment of Proposed Development Works

A geotechnical hazard risk assessment for the proposed works has been completed in accordance with the qualitative risk matrices provided in Section 7 of the AGS (2007) guidelines and Warringah Council's (2013) – E10 Landslip Risk policy.

Risk Assessment was based on several site factors:

- The generally flat grades on the existing property;
- The lack of boulders upslope;
- The shallow soil profile; and
- The lack of significant cracking in the existing dwelling.

These factors indicate a very low risk of slope instability. The proposed development is considered to constitute an acceptable risk to life and a low risk to property provided that the recommendations made in this report are adhered to.

3.7 Recommendations

Geotechnical recommendations for the development site are provided to ensure existing site and neighbouring infrastructure is protected during works (Table 4).

Table 4: Geotechnical recommendations.

<table>
<tr><th>Geotechnical Issue</th><th>Recommendations</th></tr>
<tr><td>Excavations and Vibrations</td><td>We understand that the proposed development works will involve excavation of up to 4.5 m bgl in the eastern portion of the site for a proposed garage. Based on sub-surface conditions observed we recommend the following excavation techniques:
Fill and residual soils should be readily excavated using conventional earthmoving equipment.
Excavations are likely to encounter large sandstone floaters or low to medium strong sandstone bedrock or greater and will require hydraulic hammering or rock saw and wedge techniques.
Where any hydraulic hammering is proposed, we recommend vibration monitoring during excavation by a qualified and experienced geotechnical engineer.
Care will be required when excavation close to boundaries and existing dwelling as structural distress may occur from vibration produced by construction equipment. Recommended maximum levels of ground vibration as per 2187.2, 2006) are 5 mm/s PPV (peak particle velocity) at the site boundary or at closer site structures (such as the dwelling).
All excavation work should be completed with reference to the Code of Practice 'Excavation Work', Cat. No. 312 dated 31 March 2000 by WorkCover. Excavation method statements will need to be prepared by the excavation contractor prior to the issue of a construction certificate.</td></tr>
<tr><td>Retention and shoring structures</td><td>We recommend the following batter slopes for soil/rock on the site.<table><tr><th rowspan="2">Material</th><th colspan="2">Slope Batters (Vertical:Horizontal)</th></tr><tr><th>Temporary (< 1 week)</th><th>Permanent</th></tr><tr><td>Fill/residual soils</td><td>1:1</td><td>1:2</td></tr><tr><td>L – M strength Sandstone</td><td>6:1</td><td>4:1</td></tr><tr><td>M Strength Sandstone or greater</td><td>8:1</td><td>6:1</td></tr></table>Where it is not possible to achieve the above batter slopes and depending on the final extent of the excavation, shoring may be required.
Any new proposed retaining walls are to be designed by a qualified geotechnical or structural engineer and take appropriate surcharge (and possibly hydrostatic loads). We provide the following comments:
Backfill materials immediately behind any retaining wall should comprise of high strength, durable, single sized washed aggregate.
Retaining walls should be keyed into underlying sandstone bedrock where possible. Typical lateral earth pressures for retaining wall design are k_a = 0.35, k_p = 2.7, k_0 = 0.55 with design friction angle of 27 degrees.
Fill behind retaining walls should be placed in a maximum of 200mm horizontal layers and compacted using hand held compactor.</td></tr>
</table>

Geotechnical Issue	Recommendations
	o Drainage systems are to be installed behind all backfilled retaining walls to dissipate pore pressures and drain water collected move to the stormwater system.
Footings and Foundations	Footing and foundation design should take into consideration of preliminary soil/rock strengths provided in Table 3 of this report and be designed by an experienced and qualified structural or geotechnical engineer. Considering proposed excavation depth and observed sandstone depth, pad/strip foundations on medium strength sandstone would likely be an acceptable foundation solution subject to loading requirements. It is possible that higher strength sandstone is located on the site however further investigation (i.e. rock coring) would be needed to determine this. All footings should be excavated and poured with minimal delay and footings should be free from all loose or softened materials prior to pouring. If water ponds in the base of the footings, they should be pumped dry and then re excavated to remove all loose and softened material. If a delay in pouring is anticipated, a binding layer of at least 50mm concrete is to be placed to protect the base of the footing excavation. All footing excavation should inspected by a geotechnical engineer to confirm the required founding strata has been met.
Groundwater	It is considered that excavations for footings are unlikely to intercept the permanent groundwater table. Sump and pump methods are considered to be appropriate for any temporary dewatering during construction if water is found. All site discharges should be passed through a filter material prior to release off-site. Any seepage should be monitored during excavation by a geotechnical engineer.
Overland Flows	There exists a potential for stormwater flows to enter excavated areas during construction. All surface runoff should be diverted away from excavation areas during construction works. All site discharges should be passed through a filter material prior to release. Diverted flows should be directed (where possible) off-site so as to prevent water accumulating in areas surrounding retaining structures or footings.
Soil Erosion Control	Removal of soil overburden should be performed in a manner that reduces the risk of sedimentation occurring on neighbouring lands. 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) are required.
Off-site Removal of Overburden	Off-site disposal of soil may require classification in accordance with the NSW EPA guidelines. We can complete the necessary classification and testing if required. Time allowance should be made for such testing in the construction program unless testing is completed prior to construction.

4 Further Investigations, Inspections and Contingency

4.1 Further Investigations and Works

We provide the following comments:

- A vibration monitoring plan should be prepared prior the issue of construction certificate if rock hammering is proposed as an excavation technique.

4.2 Recommended Monitoring and Inspection Program

To ensure site stability, prevent adverse geotechnical impacts and reduce the risk reduction of sediment transportation off site due to erosion, we recommend the following be monitored regularly (daily or otherwise) during site works:

Table 5: Monitoring and Inspection schedule.

Monitoring and Inspection Works	To be Inspected By
Vibration monitoring inspection at on-set of rock excavation.	A suitably qualified and experienced geotechnical engineer.
Inspection of footings and foundations prior to placement of concrete.	A suitably qualified and experienced geotechnical engineer.
Monitoring of any rock excavations at 1m depth increments (where required).	A suitably qualified and experienced geotechnical engineer.
Monitoring sedimentation downslope of excavated areas during and after rainfall events.	Site foreman
Monitoring of sediment erosion control structures (for functioning condition and removal of built up spoil).	Site foreman

4.3 Contingency Plan

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

5 Limitations

In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and Martens & Associates accept no responsibility whatsoever for the performance of the project where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, sub-surface conditions between and below the completed boreholes/test pits and other tests may be found to be different (or may be interpreted to be different) from those expected (particularly with DCP refusal). 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.

6 References

Australian Geomechanics Society, Landslide Zoning Working Group (March 2007), *Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning*, Australian Geomechanics Vol 42 No 1.

Australian Standard 1726 (1993) *Geotechnical Site Investigations.*

Australia Standard 1289.6.3.2 (1997), *Determination of the Penetration Resistance of a Soil using the 9kg Dynamic Cone Penetrometer.*

Australian Standard 2870 (2011) *Residential slabs and footings – Construction.*

Look, B. (2007) Handbook of Geotechnical Investigation and Design Tables, Taylor and Francis

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

NSW Department of Mineral Resources (1983), Sydney Australia 1:100,000 Geological Series Sheet 9130.

Waltham, T. (2009), *Foundations of Engineering Geology, Third Edition, Spoon Press.*

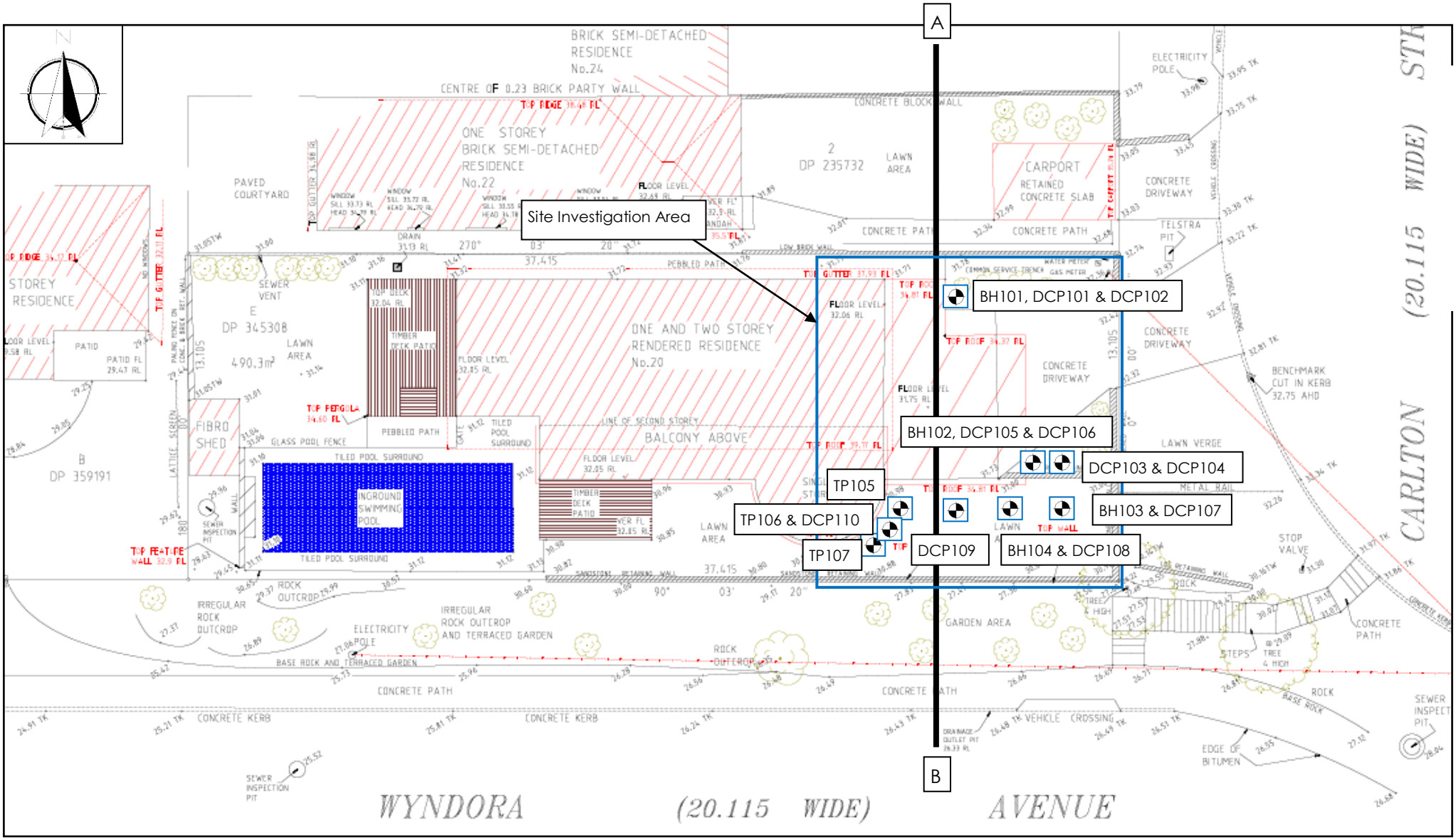
Warringah Council (2011) *Development Control Plan, E10 Landslip Risk*

7 Attachment A – Figures

- Geotechnical site testing plan

- Geological section

- Supporting plates



BOREHOLE (BH)/TEST PIT (TP)/ DYNAMIC CONE PENETROMETER (DCP) TESTING LOCATION AND IDENTIFIER

GEOLOGICAL CROSS SECTION

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	AB	**GEOTECHNICAL SITE TESTING PLAN**	Drawing No: **Figure 1**
Approved:	JF/KW		
Date:	6.3.14		
Scale:	NA		Job No: P404156

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Plate 1: Test pit 107

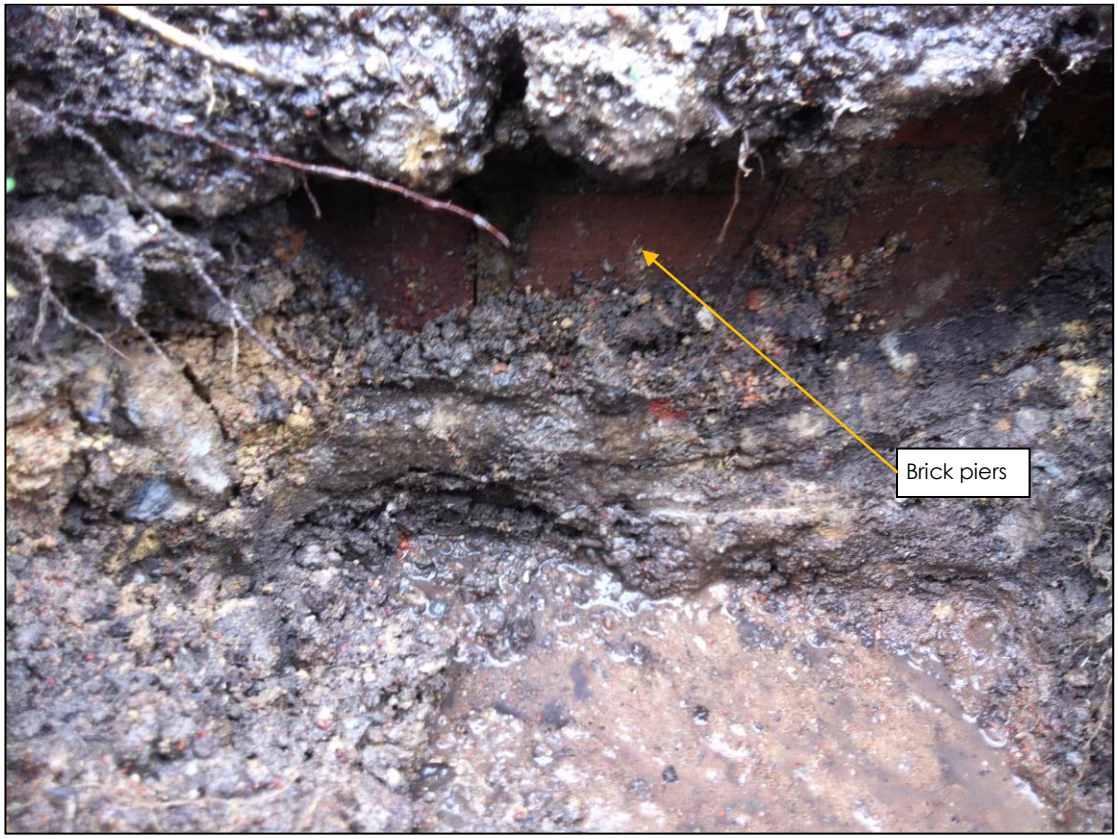

Plate 2: Brick piers observed in TP107

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	AB	**PLATES**	Drawing No: **FIGURE 2**
Approved:	JF		
Date:	7.3.14		
Scale:	NA		Job No: P1404156

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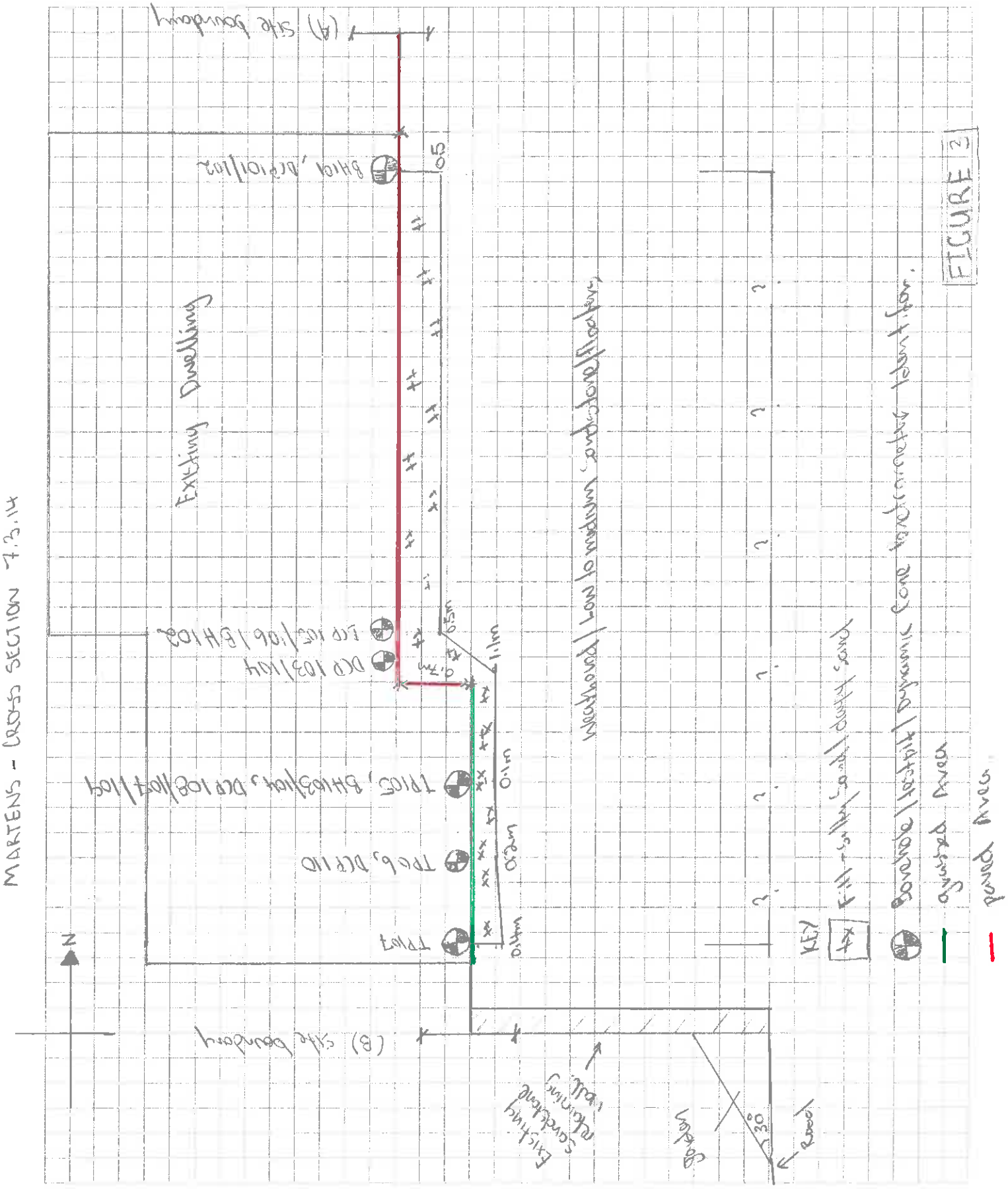
CALCULATION SHEET

REFERENCE NO.

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



8 Attachment B - Excavation Logs

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**BH101**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Hand Auger	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	Ø70mm X 0.7m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		L-MD			- FILL
HA	Nil	N	M	0.5			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL 0.5
HA	Nil	N	M	0.7			SC	SANDY CLAY - Low plasticity, grey.	VSt-H				- RESIDUAL
				1.0				Refusal at 0.7m on low to medium strength sandstone.					1.0
				1.5									1.5
				2.0									2.0
				2.25									2.25

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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

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Engineering Log - Borehole

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**BH102**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1** of **1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Hand Auger	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	Ø70mm X 0.4m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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	M	0.1			XX	WOOD CHIPS - Dark brown/black.		L			- FILL
HA	Nil	N	M	0.4			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL
				0.5				Refusal at 0.4m on low to medium strength sandstone.					0.5
				1.0									1.0
				1.5									1.5
				2.0									2.0
				2.25									2.25

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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

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Engineering Log - Borehole

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**BH103**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Hand Auger	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	Ø70mm X 0.35m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		MD			- FILL
HA	Nil	N	M	0.35			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL
				0.5				Refusal at 0.35m on low strength sandstone.					
				1.0									
				1.5									
				2.0									
				2.25									

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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

Quality Sheet No. 4

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mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Borehole

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**BH104**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Hand Auger	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	Ø70mm X 0.35m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		MD			- FILL
HA	Nil	N	M	0.35			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL
				0.5				Refusal at 0.35m on low strength sandstone.					0.5
				1.0									1.0
				1.5									1.5
				2.0									2.0
				2.25									2.25

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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

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mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Borehole

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**TP105**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Spade	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	0.3 x 0.3 x 0.1m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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
S	Nil	N	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		L			- FILL
								Refusal at 0.1m on fill.					
				0.5									0.5
				1.0									1.0
				1.5									1.5
				2.0									2.0
				2.25									2.25

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

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
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D Disturbed sample
M Moisture content
Ux Tube sample (x mm)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

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Engineering Log - Excavation

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**TP106**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Spade	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	0.3 x 0.3 x 0.2m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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
S	Nil	N	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		L-MD			- FILL
S	Nil	N	M	0.2			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL
								Refusal at 0.2m on low to medium strength sandstone.					
				0.5									
				1.0									
				1.5									
				2.0									
				2.25									

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
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Engineering Log - Excavation

CLIENT	**Mr Garry Smith**	**COMMENCED**	28.02.14	**COMPLETED**	28.02.14	**REF**	**TP107**
PROJECT	**Preliminary Geotechnical Assessment**	**LOGGED**	AB	**CHECKED**	KW/JSF	**Sheet**	**1 of 1**
SITE	**20 Carlton St, Freshwater NSW**	**GEOLOGY**	Sandstone	**VEGETATION**	Managed gardens	**PROJECT NO.**	P1404156
EQUIPMENT	Spade	**EASTING**	-	**RL SURFACE**	-		
EXCAVATION DIMENSIONS	0.3 x 0.3 x 0.4m depth	**NORTHING**	-	**ASPECT**	South	**SLOPE**	5-10%

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
S	Nil	N	M	0.1			SM XX	TOP SOIL: SILTY SAND - Fine to medium grained, dark brown.		L-MD			- FILL
S	Nil	N	M	0.4			SC XX	CLAYEY SAND: WITH GRAVELS - Medium to coarse grained, grey/brown, poorly graded, angular, some brick and glass.		D			- FILL
				0.5				Refusal at 0.4m on low to medium strength sandstone.					0.5
				1.0									1.0
				1.5									1.5
				2.0									2.0
				2.25									2.25

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

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)
pp Pocket penetrometer
S Standard penetration test
VS Vane shear
DCP Dynamic cone penetrometer
FD Field density
WS Water sample

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
Y USCS
N Agricultural

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Engineering Log - Excavation

9 Attachment C – DCP Log Sheet

Dynamic Cone Penetrometer Test Log Summary

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consulting engineers since 1989
6 / 37 Leighton Place, Hornsby, NSW 2159, Ph: (02) 9476 9999 Fax: (02) 9476 8767, mail@martens.com.au, www.martens.com.au

Site	20 Carlton Street, Freshwater, NSW		
Client	Mr Garry Smith		
Logged by	AB	**Date Logged**	28.20.14
Checked by	JF/KW	**Date Checked**	28.20.14
Comments	DCP's 107-110 conducted on the grassed area to the south east with a 0.7m difference in elevation compared to DCP's 101 - 106.		

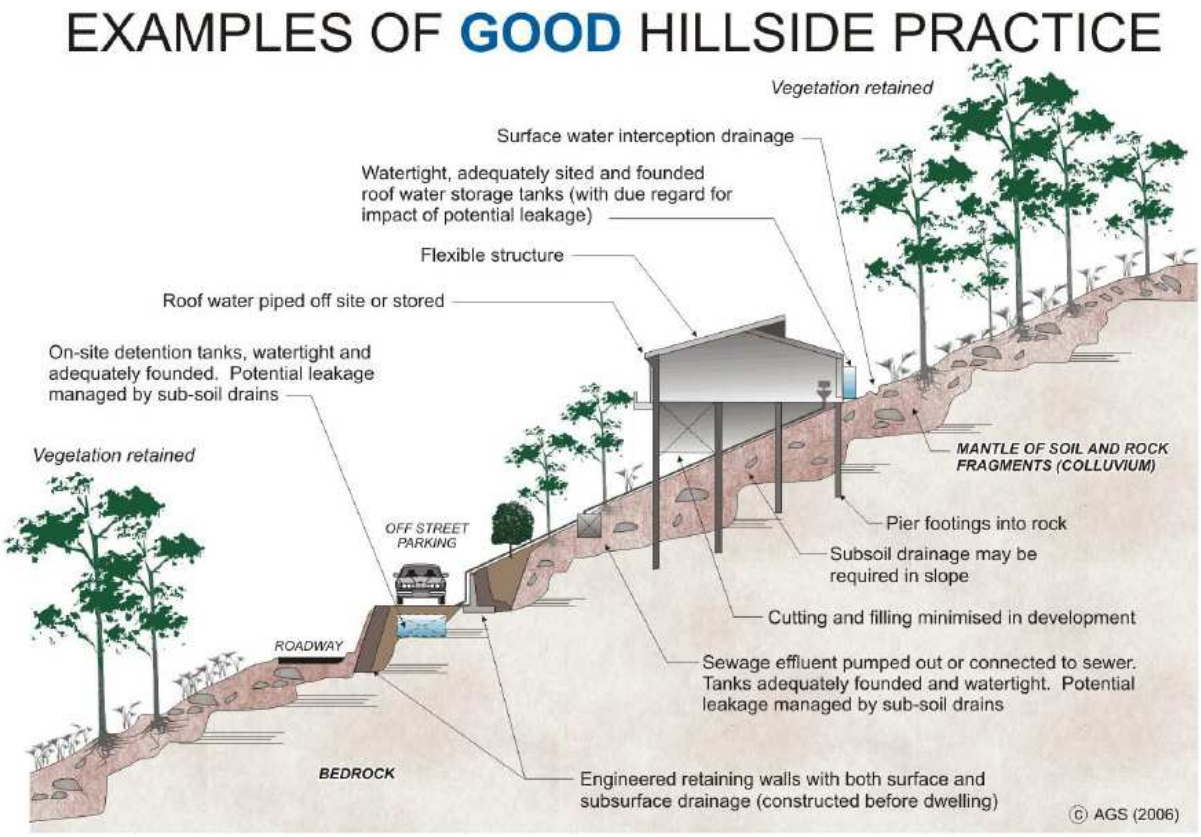
TEST DATA

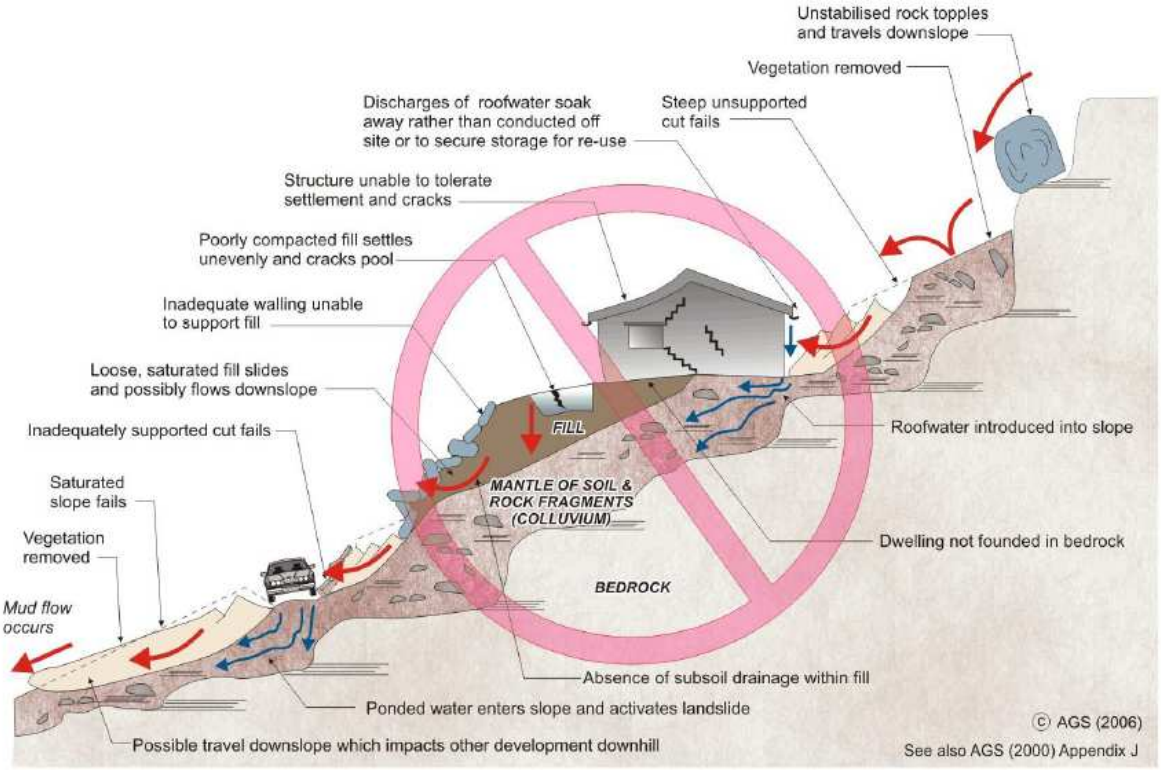
Depth Interval (m)	DCP 101	DCP 102	DCP 103	DCP 104	DCP 105	DCP 106	DCP 107	DCP 108	DCP 109	DCP 110
0.15	4	2	4	2	2	2	4	2	40	40
0.30	11	11	8	10	10	11	6	8		
0.45	6	8	40	11	12	40	40	40	Bounce	Bounce
0.60	7	2		2	40				@	@
0.75	40	40	Bounce	8		Bounce	Bounce	Bounce	0.1m	0.2m
0.90			@	9	Bounce	@	@	@		
1.05	Bounce	Bounce	0.4m	10	@	0.35m	0.35m	0.35m		
1.20	@	@		40	0.55m					
	0.7m	0.7m								
				Bounce						
				@						
				1.1m						

10 Attachment D- 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
Possible travel downslope which impacts other development downhill
© AGS (2006)
See also AGS (2000) Appendix J

11 Attachment F- Notes about this report

Information

Important Information About Your Report

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

Engineering Reports - Limitations

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

Engineering Reports – Project Specific Criteria

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

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

Engineering Reports – Recommendations

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

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

Engineering Reports – Use For Tendering Purposes

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

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

Engineering Reports – Data

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

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

Engineering Reports – Other Projects

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

Subsurface Conditions - General

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

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

- Changes in guidelines, standards and policy or interpretation of guidelines, standards and

policy by statutory authorities.

- The actions of contractors responding to commercial pressures.

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

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

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

Subsurface Conditions - Changes

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

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

Subsurface Conditions - Site Anomalies

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

Report Use By Other Design Professionals

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

Subsurface Conditions - Geoenvironmental Issues

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

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

Responsibility

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

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

Site Inspections

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

Soil Data

Explanation of Terms (1 of 3)

Definitions

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

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

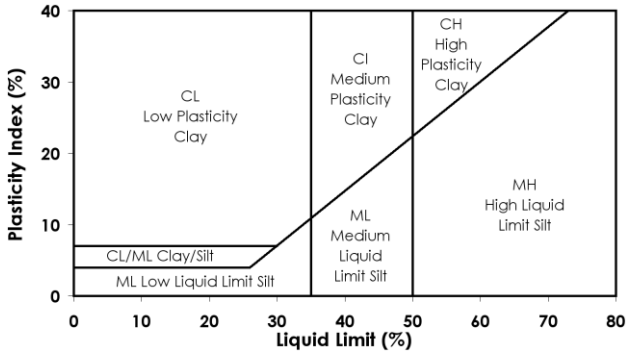
Particle Size

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

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

Plasticity Properties

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



Moisture Condition

Dry — Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist — Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet — As for moist but with free water forming on hands when handled.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

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

Density of Granular Soils

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

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

Minor Components

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

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

Soil Data

Explanation of Terms (2 of 3)

Soil Agricultural Classification Scheme

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

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

Soil Data

Explanation of Terms (3 of 3)

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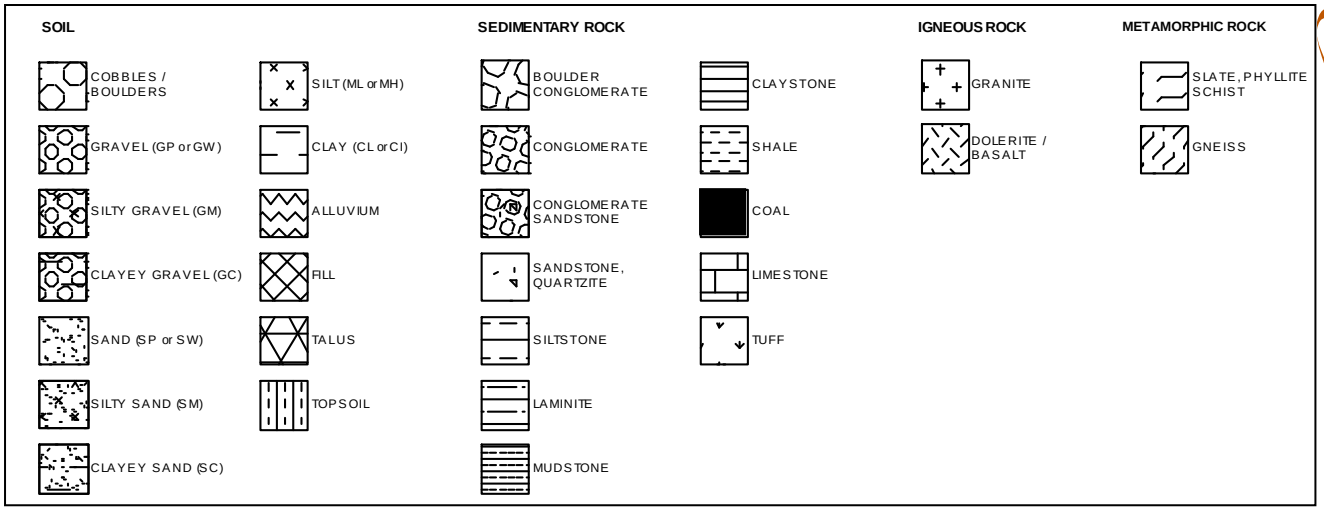
Symbols for Soil and Rock



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

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)	IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
		DRY STRENGTH (Crushing Characteristics)	DILATANCY	TOUGHNESS	DESCRIPTION	USCS	Primary Name
		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, gravely clays, sandy clays, silty clays, lean clays	CL	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

Low Plasticity – Liquid Limit W_L < 35 % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit W_L > 60 %

Rock Data

Explanation of Terms (1 of 2)

Definitions

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

Rock Substance — In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot, unless extremely weathered, be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Rock substance is effectively homogeneous and may be isotropic or anisotropic.

Rock Defect — Discontinuity or break in the continuity of a substance or substances.

Rock Mass — Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

Degree of Weathering

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

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

Rock Strength

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

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

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

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

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

Rock Core Recovery

TCR = Total Core Recovery

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

SCR = Solid Core Recovery

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

RQD = Rock Quality Designation

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

Rock Strength Tests

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

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)

BP	Bedding plane parting
X	Foliation
L	Cleavage
JT	Joint
F	Fracture
SZ	Sheared zone (Fault)
CS	Crushed seam
DS	Decomposed seam
IS	Infilled seam
V	Vein

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Fe	Iron Oxide

Planarity

Cu	Curved
Ir	Irregular
Pl	Planar
St	Stepped
Un	Undulating

Roughness

Po	Polished
Ro	Rough
Sl	Slickensided
Sm	Smooth
Vr	Very rough

Inclination

The inclination of defects are measured from perpendicular to the core axis.

Test Methods

Explanation of Terms (1 of 2)

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Sampling

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

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

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

Drilling Methods

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

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

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

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

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

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

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

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

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

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

Standard Penetration Tests

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

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

The test results are reported in the following form:

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

as 4, 6, 7
N = 13

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

as 15, 30/40 mm.

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

CONE PENETROMETER TESTING AND INTERPRETATION

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

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

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

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

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

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

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

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

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

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

q_c = (12 to 18) c_u

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

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

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

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

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

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

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

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

In low permeability soils, ground water although present, may enter the hole slowly, or perhaps not at all during the time it is left open.
A localised perched water table may lead to an erroneous indication of the true water table.
Water table levels will vary from time to time with seasons or recent prior weather changes. They may not be the same at the time of construction as are indicated in the report.
The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

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