Hanson Construction Materials

martens consulting engineers

Geotechnical Assessment:

Concept plan for the redevelopment of Lot 11 DP 558723, Lot 1 DP 200697 and Lot 2 DP262213 Eastern Creek

ENVIRONMENTAL

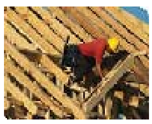
WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT



P0601396JR01-V3
October 2006

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to provide a geotechnical assessment in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and On-Site Hanson Australia Pty Ltd (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Martens & Associates Pty Ltd derived the data in this report primarily from a number of sources which may include for example site inspections, correspondence regarding the proposal, examination of records in the public domain, interviews with individuals with information about the site or the project, and field explorations conducted on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further examination / exploration of the site and subsequent data analyses, together with a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Martens & Associates Pty Ltd may have relied upon and presumed accurate certain information (or absence thereof) relative to the site. Except as otherwise stated in the report, Martens & Associates Pty Ltd has not attempted to verify the accuracy of completeness of any such information (including for example survey data supplied by others).

The findings, observations and conclusions expressed by Martens & Associates Pty Ltd in this report are not, and should not be considered an opinion concerning the completeness and accuracy of information supplied by others. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings and conclusions are based solely upon site conditions, information and drawings supplied by the Client *etc*. in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Martens & Associates Pty Ltd and the Client. Martens & Associates Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

Head Office
Unit 6 / 37 Leighton Place
Hornsby, NSW 2077, Australia
ACN 070 240 890 ABN 85 070 240 890
Phone: +61-2-9476 8777
Fax: +61-2-9476 8767
Email: mail@martens.com.au
Web: www.martens.com.au

Document and Distribution Status									
Author(s)			**Reviewer(s)**		**Project Manager**		**Signature**		
Mr G. Taylor/ Dr D. Martens			Dr D. Martens		Dr D. Martens				
			Document Location						
Revision No.	**Status**	**Release Date**	File Copy	MA Library	Hanson Australia Pty Ltd				
1	Pre-draft	7.9.2006	1E, 1P, 1H	1H	1P				
2	Draft	21.7.2006	1E, 1P, 1H	1H	1P				
3	Final	4.10.2006	1E, 1P, 1H	1H	1P				

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

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

Contents

1 Background and Scope of Works

This report provides the findings of a geotechnical investigation and sub-surface exploration of a proposed road alignment adjacent to the Hanson Quarry located at Eastern Creek, NSW. Field investigations were undertaken on the 2nd and 9th of July 2006.

Our understanding of the proposal is that the proposed road alignment, which may ultimately become a dedicated public road with significant through traffic, will generally be consistent with the existing Quarry right of way and that in time may become (Attachment A).

Our scope of works have been to assess the stability and suitability of the propose road alignment which we understand is somewhat to the north of the alignment nominated on local development precinct plans. Specifically, this includes:

1. Investigation of sub-surface soil and rock properties using site drilling along the existing haul road alignment to provide a 'worst case' stability assessment given that this is closest to the open cut mine.

2. Soil and rock strength testing to determine preliminary properties required for stability analysis.

3. Undertake preliminary stability analysis for both existing conditions and for the proposed road development with suitably allowance working surcharge loads imposed by the road (both during construction and in operation). An assessment of the impact of traffic and earthquake loads was also undertaken.

Our report has been prepared in accordance with:

- Australian Geomechanics Society (AGS 2000)
- Australian Standards 1726 (1993) and 1289.6.3.1 (2004)

2 Site Description

2.1 Field Investigations

Two site inspections were undertaken on 2nd and 9th of July 2006. All field inspections were carried out on a Sunday due to less traffic on the haul road and the shut down of all quarry plant. Works conducted during field investigations include:

- General walkover inspection of the site and surrounding areas to examine local geology, slope stability and sedimentology.
- Completion of 5 test holes to a depth of 2-10m involving detailed sub-surface investigations including soil and continuous core diamond drilling of rock (NMLC).
- Soil overburden sampling and rock coring sampling.
- Penetration testing of soil overburden material with Standard Penetration Test (SPT).

2.2 Location of Existing Road

The existing road is located on the southern side of the Quarry. Various material stockpiles and the Pioneer asphalt plant occur to the south of the existing road with the quarry located to the north (Figure 1). The existing road forms part of the quarry haul road as well as being the main road for vehicle access to the asphalt plant, stockpile areas and provides site access to areas west and north of the quarry.

Attachment A indicates locations of the proposed road with respect to the precinct road alignment and test boreholes undertaken. Vertical and horizontal road alignments for the proposed road and Precinct plan roads are provided in Attachment A.

Figure 1: Eastern Creek Quarry and the existing road and investigation area (Google Earth).

2.3 Condition of Existing Road

Preliminary site inspections indicate that below the surface pavement materials (predominantly gravel and clay materials), a residual clay mantle exists overlying generally moderately weathered to fresh bedrock. Depth of the mantle varies between 1.5m the west (BH2) to 2.5 m (BH4) in the east. Fill depths over the clay mantle varied and consisted of primarily general clay based fill and road-base materials.

The amount of sub-surface soil or soil overburden (fill, road base and natural clays) above rock varied along the road. More generally, the western portion of the current road has been cut into the natural materials (Plates 1 and 2) while the eastern portion was on fill (Plates 3, 4 and 5). The road is in a serviceable condition with no obvious signs of excessive wear and tear or sub-surface stress. No evidence of past or recent slope instability was observed along the investigation transect. These observations suggest that sub-surface conditions are stable and suitable for heavy load traffic (which indeed has been the usage to recent times).

2.4 Geology

The 1:100 000 Sydney geological sheet (NSW Mineral Resources, 1991) indicates that the quarry area is a basalt / andesite intrusion within local Wianamatta Shale materials (Bannerman *et al.,* 1990).

Site borehole investigations indicate that the existing road is underlain by andesite / basaltic rock materials. These are generally only moderately weathered to approximately 3-4 m below the clay mantle, and then grade to fresh bedrock at greater depths.

Our testing (including field strength testing and point load testing) indicates that the moderately weathered rock materials are generally of moderate strength with fresh bedrock strength being moderate to high.

2.5 Geological Section

A site geological section was prepared on the basis of bore-hole test data. This is provided in Attachment B.

3 Geotechnical Risk Assessment

3.1 Geotechnical Risk Management Guidelines

A geotechnical risk assessment for the proposed road alignment has been undertaken in accordance with the principles outlined in the AGS (2000) guidelines for landslide risk management. The assessment employs the qualitative risk assessment matrices in Appendix G of the AGS (2000) guidelines to determine the level of risk to life and property arising from the proposed road.

The risk assessment includes the following site features in determining site geotechnical risk classification.

- Site geological and topographical setting
- Site stormwater and sub-surface drainage
- Sub-subsurface soil and strength profiles
- Strength properties of rock materials
- Site gradient and slope instability
- Relative site position in landscape.

Each of these features is described in the followng sections.

3.2 Site Physical Features

3.2.1 Site Drainage

Existing site drainage associated with the existing road conveys runoff to adjacent drains running parallel with the road.

No natural drainage lines were noted along the road. No surface dampness or groundwater was encountered during inspection.

3.2.2 Groundwater

Groundwater was not observed during sub-surface investigations to a depth of 10 m. On the basis of site and local geology and topography, it is expected that ephemeral groundwater may be present at the soil rock interface (>2.0 - 4.0 m below ground level) after periods of substantial and extended rainfall. More permanent groundwater is likely to be > 10 m in depth. Further to this, we note that considerable groundwater dewatering has occurred in the local area in association with the mine excavation site.

3.2.3 Soil Profile

Five test bore sites (Attachments A, B and C) and standard penetration testing (Attachment D) were used to determine the site sub-surface conditions in the vicinity of the proposed road works. A summary of soil conditions is provided in Table 1.

Table 1: Depth to bedrock at test locations.

Layer (m)	Depth Range (m BGL)	Consistency	Undrained Shear Strength (kN/m^2)
Pavement Material	0.5 -1.0	Very Stiff	160
Upper clays	0.5 – 2.0	Stiff	60
Lower Clays	2.0 – 4.0	Very Stiff - Hard	310

Note: BGL = metres below ground level.

3.2.4 Rock Strength Testing

Preliminary rock strength testing was undertaken in the field as rock cores were logged. More detailed testing was undertaken later using the Point load test method. Point load test results are provided in Attachment D with a summary of average rock strengths at each borehole provided in Table 2. These show that rock strength was generally consistent between each of the various boreholes. Further to this, strength data generally show increase with depth. This is particularly so at BH1, BH3. Strength testing data, together with borehole data were used to estimate net *in-situ* rock properties such as internal angle of friction and cohesion for use in instability analysis.

Table 2: Summary of borehole rock properties.

Bore Hole No.	Is50 (Mpa)	UCS (Mpa)
BH1	1.47	30.85
BH2	1.33	27.84
BH3	1.33	27.92
BH4	1.39	29.09
BH5	No sample	No sample

Note: Is50 = Corrected point load strength, UCS = Unconfined compressive strength.

3.3 Stability Analysis

3.3.1 Modelling Approach

A slope stability analysis was undertaken using the SLIDE 5.0 modelling package. This allows for the assessment of Factor of Safety (FOS) against sliding under a range of development scenarios include any soil reinforcements and loading scenarios. Two scenarios were modelled:

1. Existing conditions. This included current pavement construction and current heavy vehicular loadings.

2. Proposed development. This included replacement of the current pavement with a new rigid or semi-rigid pavement and expected vehicular loadings.

3.3.2 Ground Vibrations

The impact of ground vibrations was included as part of the stability assessment. At present, very heavy vehicles utilise the existing road which is constructed of a mixture of gravel and clay fill. Road corrugations are substantial and considerable noise and ground vibrations occur in relation to local heavy vehicle traffic.

Following redevelopment, a new smooth pavement will replace the existing pavement and heavy vehicle traffic will be considerably reduced given the cessation of mining activities. On this basis, we estimate the following ground vibration parameters for instability modelling.

Table 3: Ground vibration parameters used for modelling.

Bore Hole No.	Existing Conditions	Developed Conditions
Peak Particle Velocity (m/s)[1]	2.0	0.6
Peak Ground Acceleration (m/s^2)	0.188	0.057
Dominant Vibration Frequency (Hz)	15	15
Acceleration Coefficient (g)	0.019	0.006

Note: [1]. Estimate based on literature.

3.3.3 Pavement Conditions

Assumptions for existing pavement conditions were based on site testing. Pavement varied along the investigation transect from a 0.3 m thick layer of road base gravels (BH1) to stiff to very stiff clays approximately 1.0 – 1.5 m thick (BH2, BH3 and BH4). On the basis of borehole and SPT test data, undrained shear strengths of 160 KPa for the existing pavement have been utilised for instability modelling.

Given that final designs for the proposed pavement have not yet been determined, we have assumed that a 600 mm thick 32 MPa rigid pavement will be provided.

3.3.4 Vehicular Loads

The impact of vehicular traffic load has been incorporated into the instability analysis. Factors used for modelling are provided in Table 4.

Table 4: Traffic induced distributed loads.

Factor	Existing Conditions	Developed Conditions
Maximum Vehicular Mass (tonnes)[1]	88	68
Likely Maximum Distributed Load (KPa)	24.4	10.7
Assumed Distributed Load (KPa)	30	15

Note: [1]. Data sourced from National Transport Commission Australia on-line database (2006) and Caterpillar Australia on-line vehicular fact sheets (2006)

3.3.5 Earthquake Forces

Australia is located entirely within a tectonic plate and experiences low to moderate levels of seismic activity compared with say Japan, New Zealand and California. Peak ground acceleration (PGA) is an estimate of the maximum horizontal acceleration experienced by a solid mass at the soil surface in an earthquake. The 5–point 'peril scale' (Table 5) is based on PGA from the Global Seismic Hazard Assessment Program (GSHAP, 1999). This scale gives peak ground accelerations in bedrock having a 10% chance of exceedance in 50 years (equivalent to a 475 ARI).

Table 5: Global seismic hazard assessment program 'Peril Scale'.

Risk Rating	Peak Ground Acceleration (m/s^2)
Very High	> 4
High	2.4 – 4.0
Medium	0.8 – 2.4
Low	0.2 – 0.8
Negligible	< 0.2

Note: [1]. Estimate based on literature.

Further to the above, actual ground-shaking intensity felt at ground level can be strongly modulated by the response of the soils and weathered material overlying basal rocks. This tendency to amplify ground motions is given by a five-point ground zonation developed by Blong *et al*. (2000). An overview of this zonation is provided in Table 6. Site materials within the existing access road fall within category 4 (Table 6). On this basis, high transfer rate of earthquake loads would be expected at the development site for both existing and developed conditions.

Table 6: Global seismic hazard assessment program 'Peril Scale'.

Zone	Material
1	Unconsolidated and swampy soils
2	Variable alluvial, estuarine and wind-blown deposits, including sands, organic materials and unconsolidated clays
3	Thicker soils and sediments of older river terraces and valley fills, well-drained coastal and inland sand dunes
4	Competent bedrocks but subsoils may be plastic or have high shrink-swell potential leading to cracking of structures
5	Shallow soils on competent bedrock

On the basis of data contained within AS 1170.4 (1993), the acceleration coefficient for Sydney is 0.08. The acceleration coefficient agrees with data published by Geosciences Australia (Australian Government, 2006) and can be interpreted with reference to the 'Peril scale' (ie. 10% chance of exceedance in 50 years).

3.3.6 *Modelling Scenario Summary*

Modelling scenarios evaluated in the stability assessment are described in Table 7. We note that earthquake accelerations were included for both pre- and post-development conditions in order that 'worst case' adverse site conditions could be considered.

Table 7: Summary of modelling scenarios evaluated.

Scenario	Description
1	Existing conditions
2	Existing with earthquake loads
3	Proposed development
4	Proposed development with earthquake loads

3.3.7 *Modelling Results*

Detailed results of modelling are provided in Attachment F and summarised below in Table 8. This describes the Factor of Safety (FOS) against sliding. Values > 1 represent stability, with a value of > 1.5 being generally acceptable.

Table 8: Summary of modelling Factor of Safety (FOS) results.

Scenario	Existing Conditions	Developed Conditions
No Earthquake Load	6.541	7.265
With Earthquake Load	5.929	5.929

Results show that the FOS against sliding is considerably greater than 1.5 for all modelled scenarios, even under design earthquake loads. In fact, modelling indicates that the FOS actually improves under the developed conditions in association with reduced ground vibrations and reduced traffic load due to removal of mining machinery.

3.3.8 *Assessment of Road Alignments*

We have undertaken an assessment of the proposed road alignment in relation to the NSW RTA road design guidelines. Our assessment is that the vertical and horizontal alignment complies with the requirements for a 60 km speed limit. Should the speed limit be increased to 70 km/hour, only minor horizontal road re-alignment may be required. Our view is that such realignment, where this would be required, would not adversely affect road stability or alter the outcomes and recommendations of this report.

3.4 Recommendations

It is our view that there are no geotechnical conditions along the proposed alignment that would preclude consent for such a road proposal. The proposed road will not detrimentally affect local slope stability. Historically the usage of heavy mining machinery at the site and along the Quarry road has demonstrated this stability without a more formal road pavement.

4 References

Australian Standard 1796 (1993) Geotechnical Site Investigations

Australian Standard 1170.4 (1993) SAA Loading Code Part 4: Earthquake Loads

Australian Standard 1289.6.3.1 (2004) *Methods of testing soils for engineering purposes - Soil strength and consolidation tests - Determination of the penetration resistance of a soil - Standard penetration test (SPT)*

Australian Geomechanics Society, Sub-Committee on Landslide Risk Management (March 2000) Landslide Risk Management Concepts and Guidelines, *Australian Geomechanics* 35 (1), p 49 – 92

Bannerman S.M. and Hazelton, P.A. (1990) *Soil landscapes of the Penrith 1:100,000 sheet*, Soil Conservation Service of NSW, Sydney

Blong, R, Sinai, D, and C. Packham (2000) *Natural Perils in Australia and New Zealand,* Swiss Re Australia Ltd

Australian Government (2006) Geosciences Australia Earthquake Hazard map, *National Geoscience Datasets*

NSW Department of Mineral Resources (1991) *Sydney Geological Series* 9030 Map Sheet

NSW Roads and Transit Authority (2002) Road Design Guide

State of California Department of Transportation (1990), *Trenching and Shoring Manual*

The Global Seismic Hazard Assessment Program (GSHAP) (1999) http://www.seismo.ethz.ch/GSHAP/

5 Attachment A – Site plan with road alignments, borehole locations and road sections

PROPOSED INTERNAL ACCESS ALIGNMENT

ACCESS ALIGNMENT ON PRECINCT PLAN

N
W E
S

UNITS – METRES
SCALE – 1:1000 @ A1 1:2000 @ A3

martens
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777
Fax: (02) 9476 8767
Email: mail@martens.com.au
Internet: http://www.martens.com.au

MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers

CLIENT/PROJECT
HANSON
EASTERN CREEK, SYDNEY

THIS PLAN MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS APPROVED BY PRINCIPAL CERTIFYING AUTHORITY
All measurements in mm unless otherwise specifiec.

TITLE
SITE PLAN, ROAD ALIGNMENTS AND BOREHOLE LOCATIONS

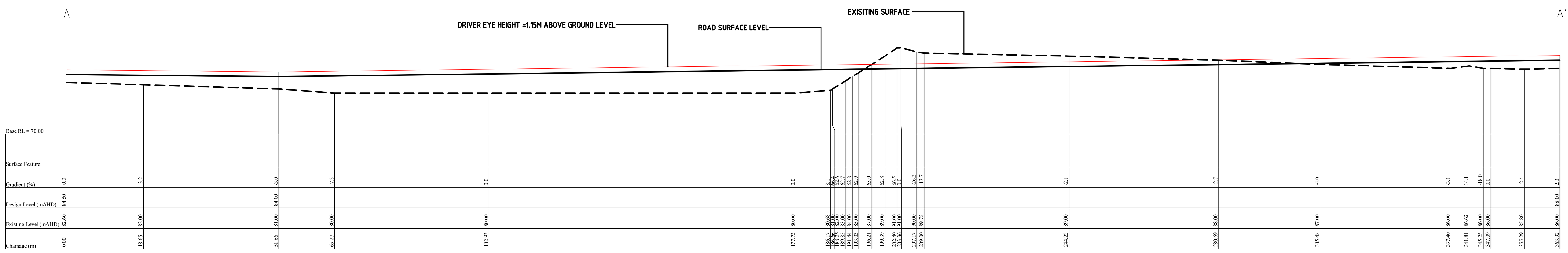
PROJECT MANAGER: DR D. MARTENS

DRAWING NUMBER: P0601396JD08-V1 SHEET 1

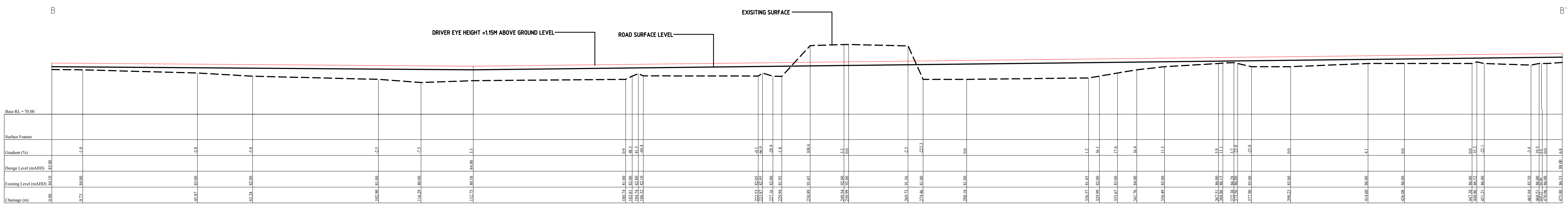
DESIGNED: DMM	DATUM: mAHD	SHEET 1 OF 1 SHEETS	
DRAWN: DMM	HORIZONTAL RATIO: 1:1000 @ A1 1:2000 @ A3		
REVIEWED: GMT	VERTICAL RATIO: 1:1000 @ A1 1:2000 @ A3	PAPER SIZE: A1 / A3	

REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	18.9.2006	DMM
1.0	FINAL	4.10.2006	DMM

COLLECTOR ROAD LONG SECTION



PROPOSED ROAD LONG SECTION



martens
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777
Fax: (02) 9476 8767
Email: mail@martens.com.au
Internet: http://www.martens.com.au

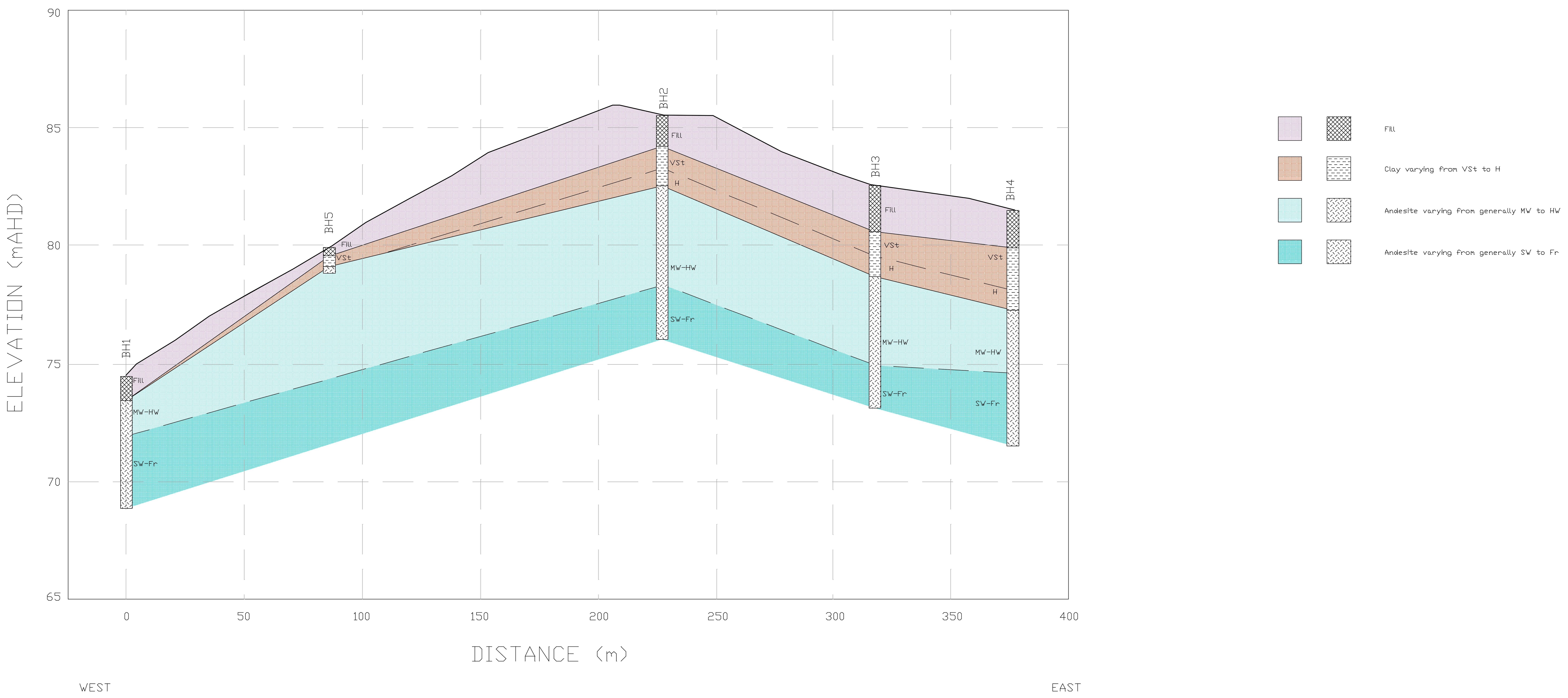
MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers

CLIENT/ PROJECT	HANSON EASTERN CREEK, SYDNEY
TITLE	LONGITUDINAL LONG SECTION OF COLLECTOR ROAD AND PROPOSED ROAD
DESIGNED:	DMM
DRAWN:	DMM
REVIEWED:	GMT
DATUM:	mAHD
HORIZONTAL RATIO:	1:1000 @ A1 1:2000 @ A3
VERTICAL RATIO:	1:1000 @ A1 1:2000 @ A3
SHEET	1 OF 1 SHEETS
PAPER SIZE:	A1 / A3
PROJECT MANAGER:	DR D. MARTENS
DRAWING NUMBER:	P0601396JD08-V1 SHEET 3

THIS PLAN MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS APPROVED BY PRINCIPAL CERTIFYING AUTHORITY
All measurements in m unless otherwise specified.

REV.	DESCRIPTION	DATE	ISSUED
1.0	GEOTECHNICAL REPORT	3.10.2006	DMM

6 Attachment B – Geological Section Through Study Area



martens
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777
Fax: (02) 9476 8767
Email: mail@martens.com.au
Internet: http://www.martens.com.au

MARTENS & ASSOCIATES PTY LTD
Sustainable Solutions
Environmental - Geotechnical - Civil
Hydraulic - Wastewater Engineers

CLIENT/PROJECT
HANSON
EASTERN CREEK, SYDNEY

THIS PLAN MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS APPROVED BY PRINCIPAL CERTIFYING AUTHORITY
All measurements in mm unless otherwise specified.

TITLE
GEOLOGICAL SECTION OF EXISTING ROAD

PROJECT MANAGER: DR D. MARTENS

DRAWING NUMBER: P0601396JD08-V1 SHEET 2

DESIGNED: DMM	DATUM: mAHD	SHEET 1
DRAWN: DMM	HORIZONTAL RATIO: 1:500 @ A1, 1:1000 @ A3	OF 1 SHEETS
REVIEWED: GMT	VERTICAL RATIO: 1:50 @ A1, 1:100 @ A3	PAPER SIZE: A1 / A3

REV.	DESCRIPTION	DATE	ISSUED
1.0	DRAFT	18.9.2006	DMM

7 Attachment C – Borehole Logs


EASTERN CREEK 44103 BH-1 START - 1.0 M
1
2
3
4
6
7
8
9

CLIENT	HANSON Pty Ltd	COMMENCED	2/7/06	COMPLETED	2/7/06	REF	BH1
PROJECT	Geotechnical Assessment	LOGGED	GT	CHECKED	DM	Sheet 1 of 1	
SITE	Eastern Creek Quarry	GEOLOGY		VEGETATION	None	PROJECT NO.	P0601396
EQUIPMENT	Auger/Rotary Drill	EASTING	150 49 41 (Deg/Min/Sec) E	RL SURFACE	74.5 m AHD		
DRILLING FLUID	Water	NORTHING	33 47 58 (Deg/Min/Sec) S	ASPECT	West	SLOPE	0-5%

DRILLING DATA / MATERIAL DATA / SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	GRAPHIC LOG	DESCRIPTION OF STRATA Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EW VW W MS S VS ES 0.03 0.1 0.3 1 3 10	DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS	AVERAGE DEFECT SPACING (mm) 10 30 100 300 1000 3000
A	N					FILL - ROADBASE/GRAVELS				
A	N			0.5m		FILL - Brown/Grey weathered Basalt START of CORING at 1.0m				
NMLC	N	100% (100%)	14.3% (44.9%)	1.0m 1.5m 2.0m		ANDESITE - Light Grey	MW EW MW HW MW		1.00 - F 80° Un, Ro, Ct 1.05 - F 10° Ir, Ro, Ct 1.12 - CS 10° Ir, Ro, Ct 1.22 - F 10° Un, Ro, Sn 1.30 - F 5° Pl, Ro, Sn 1.38 - F 5° Pl, Ro, Sn 1.39 - Cu 5° Pl, Ro, Sn 1.46 - F 10° Ir, Ro, Ct 1.59 - F 5° Pl, Ro, Ct 1.67 - F 25° Ir, Ro, Ct 1.69 - F 35° Ir, Ro, Ct 1.72 - F 10° Ir, Ro, Sn 1.83 - F 30° Ir, Ro, Sn 1.92 - F 5° Ir, Ro, Sn 1.95 - F 5° Pl, Ro, Sn 2.00 - F 5° Pl, Ro, Sn 2.05 - F 30° Ir, Sm, Ct 2.10 - Cu 10° Ir, Ro, Ct 2.12 - F 10° Pl, Ro, Ct 2.15 - Cu 10° Ir, Ro, Ct 2.18 - F 15° Ir, Ro, Ct	
						ANDESITE - Light Grey	HW MW		2.23 - F 30° Pl, Ro, Ct 2.30 - Cu 25° Pl, Ro, Ct 2.34 - F 25° Pl, Ro, Ct 2.35 - Cu 25° Pl, Ro, Ct 2.39 - F 15° Ir, Ro, Ct 2.40 - Cu 5° Ir, Ro, Ct	
NMLC	N	100% (100%)	62% (44.9%)	2.5m 3.0m		ANDESITE - Dark Grey	Fr HW		2.51 - F 15° Ir, Ro, Ct 2.52 - Cu 15° Ir, Ro, Ct 2.57 - F 5° Pl, Ro, Ct 2.60 - F 5° Pl, Ro, Ct 2.61 - Cu 5° Ir, Ro, Ct 2.86 - F 10° Pl, Sm, Ct 2.94 - F 15° Pl, Sm, Fe 3.04 - F 35° Pl, Sm, Fe 3.09 - F 25° Ir, Sm, Fe 3.14 - F 20° Un, Ro, Fe 3.21 - F 30° Ir, Ro, Sn 3.24 - F 45° Ir, Ro, Sn 3.42 - F 25° Pl, Ro, Sn 3.47 - F 5° Pl, Ro, Ct	
				3.5m 4.0m 4.5m 5.0m		ANDESITE - Light Grey with yellowish tinge	Fr MW Fr		3.54 - F 35° Pl, Ro, Fe 3.78 - F 60° Pl, Ro, Sn 3.84 - F 15° Ir, Ro, Sn 3.89 - F 15° Ir, Ro, Sn 4.10 - F 20° Ir, Ro, Ct 4.28 - F 5° Un, Ro, Ct 4.31 - F 10° Ir, Ro, Ct 4.43 - F 25° Pl, Ro, Fe 4.47 - F 45° Pl, Ro, Sn 4.55 - F 20° Un, Ro, Sn 4.58 - F 10° Pl, Ro, Sn 4.66 - F 10° Cu, Ro, Fe 4.68 - F 5° Pl, Ro, Sn 4.89 - F 35° Pl, Ro, Fe 5.22 - F 50° Pl, Ro, Cn 5.27 - F 35° Pl, Ro, Cn 5.31 - F 10° Pl, Ro, Cn	
				5.5m 6.0m 6.5m 7.0m 7.5m 8.0m 8.5m 9.0m		END of CORED BOREHOLE at 5.5m				

EQUIPMENT / METHOD
- N Natural exposure
- X Existing excavation
- HQ Diamond Core - 63 mm
- NMLC Diamond Core - 52 mm
- NQ Diamond Core - 47 mm
- A Auger

WATER
- N None observed
- X Not measured
- Water level
- Water outflow
- Water inflow

WEATHERING
- Rs Residual Soil
- EW Extremely Weathered
- HW Highly Weathered
- MW Moderately Weathered
- SW Slightly Weathered
- Fr Fresh Rock

CORE DATA
- TCR Total Core Recovery (%)
- RQD Rock Quality Designation (%)
- SCR Solid Core Recovery (%)

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

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole


0m EASTERN CREEK
1m 44103 BORE HOLE-2
2m START core RUN 3.0M
3
4
5
6
7
8
9

CLIENT	**HANSON Pty Ltd**	**COMMENCED**	2/7/06	**COMPLETED**	2/7/06	**REF**	**BH2**
PROJECT	**Geotechnical Assessment**	**LOGGED**	GT	**CHECKED**	DM	**Sheet** 1 **of** 2	
SITE	**Eastern Creek Quarry**	**GEOLOGY**		**VEGETATION**	None	**PROJECT NO.**	P0601396
EQUIPMENT	Auger/Rotary Drill	**EASTING**	150 49 41 (Deg/Min/Sec) E	**RL SURFACE**	85.5 m AHD		
DRILLING FLUID	Water	**NORTHING**	33 47 58 (Deg/Min/Sec) S	**ASPECT**	West	**SLOPE**	0-5%

DRILLING DATA | MATERIAL DATA | SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	DESCRIPTION OF STRATA (Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.)
A	N				FILL - ROADBASE/GRAVELS
A	N			0.5m	CLAY- Grey, silty gravels, stiff to very stiff (FILL)
A	N			1.0m	CLAY- Brown/Grey, gravels 1-15mm approx 15%, firm (FILL)
A	N			1.5m – 2.5m	CLAY- Brown/Grey with red mottling, gravels 1-15mm approx 15%, Stiff grading to hard at base (NATURAL SOILS)
					START of CORING at 3.0m
NMLC	N	94 %	71 %	3.0m – 5.0m	ANDESITE - Light Grey
				5.0m	ANDESITE - Dark Grey
				5.5m	ANDESITE - Light Grey
					ANDESITE - Dark Grey
				6.0m – 9.0m	ANDESITE - Light Grey

WEATHERING (3.0m – 9.0m, in order down the log): SW, HW, SW, MW, SW, MW, SW, MW, SW, MW, SW, Fr, MW, SW, Fr

INFERRED STRENGTH $Is_{(50)}$ MPa: EW - 0.03, VW - 0.1, W - 0.3, MS - 1, S - 3, VS - 10, ES

AVERAGE DEFECT SPACING (mm): 10, 30, 100, 300, 1000, 3000

DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS

3.00
3.02 - F 5° Pl, Sm, Fe
3.10 - F 55° Pl, Sm, Cn
3.45 - F 5° Or, Ro, Sn
3.52 - F 90° Pl, Ro, Ct
3.53 - Cu 5° Ir, Ro, Ct
3.62 - F 5° Pl, Sm, Ct
3.68 - F 5° Pl, Sm, Sn
4.14 - F 5° Pl, Sm, Fe
4.18 - F 10° Ir, Ro, Ct
4.22 - F 5° Pl, Ro, Ct
4.24 - F 5° Pl, Sm, Sn
4.30 - F 0° Cu, Sm, Ct
4.35 - F 5° Pl, Sm, Ct
4.47 - F 0° Pl, Sm, Cn
4.70 - F 10° Cu, Sm, Ct
4.94 - F 0° Pl, Sm, Fe
5.00 - F 90° Pl, Ro, Cn
5.04 - F 0° Pl, Sm, Cn
5.30 - F 0° Pl, Sm, Cn
5.64 - F 0° Pl, Sm, Ct
5.74 - F 0° Pl, Sm, Cn
5.91 - F 0° Ir, Ro, Cn
6.00 - F 5° Ir, Ro, Ct
6.02 - F 10° Pl, Sm, Ct
6.07 - F 5° Pl, Sm, Cn
6.40 - F 0° Pl, Sm, Cn
6.59 - F 10° Pl, Ro, Cn
6.70 - F 0° Pl, Ro, Cn
6.78 - F 5° Ir, Sm, Ct
6.82 - F 15° Ir, Sm, Ct
6.96 - F 85° Pl, Sm, Fe
6.98 - F 15° Ir, Sm, Ct
7.12 - F 10° Cu, Ro, Cn
7.19 - F 5° Pl, Sm, Cn
7.21 - F 5° Pl, Sm, Cn
7.35 - F 0° Pl, Ro, Cn
7.42 - F 0° Pl, Ro, Cn
7.53 - F 0° Pl, Ro, Cn
7.71 - F 0° Pl, Ro, Cn
7.81 - F 0° Pl, Ro, Sn
7.82 - F 15° Ir, Ro, Ct
7.92 - F 5° Pl, Ro, Cn
8.03 - F 0° Pl, Ro, Cn
8.52 - F 5° Pl, Ro, Cn
8.65 - F 5° Ir, Sm, Fe
8.69 - F 15° Ir, Sm, Fe
8.75 - F 15° Pl, Sm, Fe
8.78 - F 15° Pl, Ro, Cn

EQUIPMENT / METHOD
- N Natural exposure
- X Existing excavation
- HQ Diamond Core - 63 mm
- NMLC Diamond Core - 52 mm
- NQ Diamond Core - 47 mm
- A Auger

WATER
- N None observed
- X Not measured
- Water level
- Water outflow
- Water inflow

WEATHERING
- Rs Residual Soil
- EW Extremely Weathered
- HW Highly Weathered
- MW Moderately Weathered
- SW Slightly Weathered
- Fr Fresh Rock

CORE DATA
- TCR Total Core Recovery (%)
- RQD Rock Quality Designation (%)
- SCR Solid Core Recovery (%)

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

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole

CLIENT	**HANSON Pty Ltd**	**COMMENCED**	2/7/06	**COMPLETED**	2/7/06	**REF**	**BH2**
PROJECT	**Geotechnical Assessment**	**LOGGED**	GT	**CHECKED**	DM	**Sheet** 2 **of** 2	
SITE	**Eastern Creek Quarry**	**GEOLOGY**		**VEGETATION**	None	**PROJECT NO.**	P0601396
EQUIPMENT	Auger/Rotary Drill	**EASTING**	150 49 41 (Deg/Min/Sec) E	**RL SURFACE**	85.5 m AHD		
DRILLING FLUID	Water	**NORTHING**	33 47 58 (Deg/Min/Sec) S	**ASPECT**	West	**SLOPE**	0-5%

DRILLING DATA / MATERIAL DATA / SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	GRAPHIC LOG	DESCRIPTION OF STRATA Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EW VW W MS S VS ES (0.03, 0.1, 0.3, 1, 3, 10)	DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS	AVERAGE DEFECT SPACING (mm) 10, 30, 100, 300, 1000, 3000
				9.5m		ANDESITE - Light Grey	Fr SW		9.12 - V 25° Ir, Sm, Cn 9.36 - F 20° Pl, Ro, Ct 9.52 - F 20° Ir, Ro, Ct	
						CORE LOSS				
				10.0m		END of CORED BOREHOLE at 10.00				
				10.5m						
				11.0m						
				11.5m						
				12.0m						
				12.5m						
				13.0m						
				13.5m						

EQUIPMENT / METHOD
- N Natural exposure
- X Existing excavation
- HQ Diamond Core - 63 mm
- NMLC Diamond Core - 52 mm
- NQ Diamond Core - 47 mm
- A Auger

WATER
- N None observed
- X Not measured
- Water level
- Water outflow
- Water inflow

WEATHERING
- Rs Residual Soil
- EW Extremely Weathered
- HW Highly Weathered
- MW Moderately Weathered
- SW Slightly Weathered
- Fr Fresh Rock

CORE DATA
- TCR Total Core Recovery (%)
- RQD Rock Quality Designation (%)
- SCR Solid Core Recovery (%)

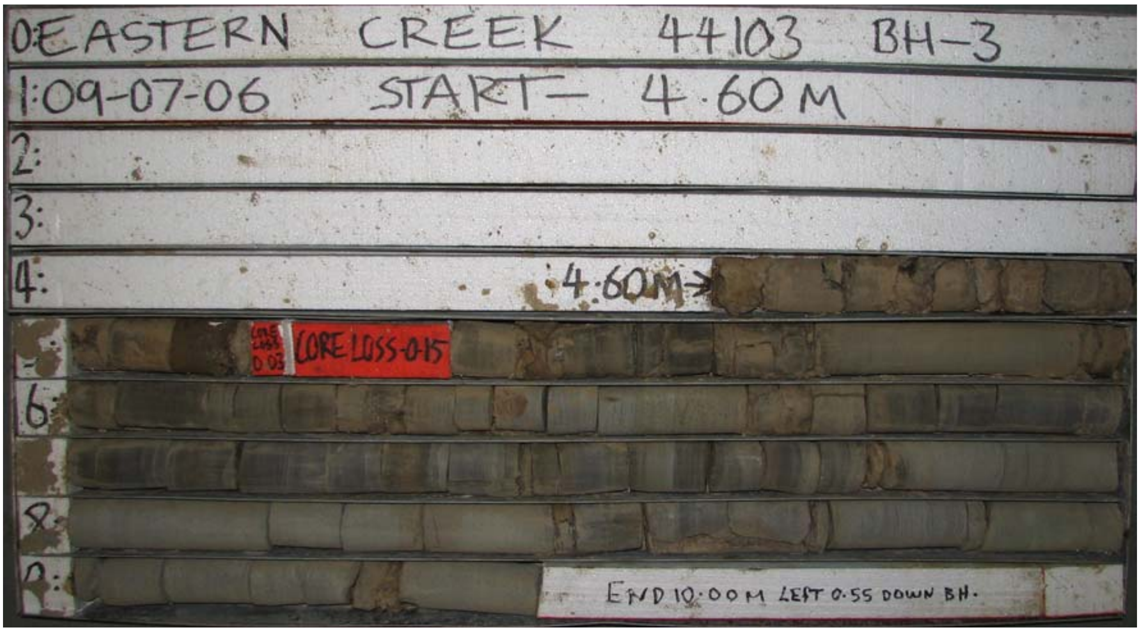
ROCK STRENGTH TEST RESULTS
- ▼ Point load strength Index (Is50) - axial test (MPa)
- ▶ Point load strength Index (Is50) - diametrall test (MPa)
- ● Unconfined compressive strength (UCS) (MPa)

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole


0: EASTERN CREEK 44103 BH-3
1: 09-07-06 START - 4.60 M
2:
3:
4: 4.60M→
CORE LOSS 0.15
6
8
END 10.00M LEFT 0.55 DOWN BH.

CLIENT	**HANSON Pty Ltd**	COMMENCED	9/7/06	COMPLETED	9/7/06	**REF**	**BH3**
PROJECT	**Geotechnical Assessment**	LOGGED	GT	CHECKED	DM	Sheet 1 of 2	
SITE	**Eastern Creek Quarry**	GEOLOGY		VEGETATION	None	PROJECT NO.	P0601396
EQUIPMENT	Auger/Rotary Drill	EASTING	150 49 41 (Deg/Min/Sec) E	RL SURFACE	82.6 m AHD		
DRILLING FLUID	Water	NORTHING	33 47 58 (Deg/Min/Sec) S	ASPECT	West	SLOPE	0-5%

DRILLING DATA / MATERIAL DATA / SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	DESCRIPTION OF STRATA Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.	WEATHERING	DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS
A	N			0.0–0.5m	ROADBASE/GRAVELS (FILL)		
A	N			0.5m–2.0m	CLAY-Red/orange with gravels, 5-20mm, approx 15%, firm to very stiff at depth. (FILL)		
A	N			2.0m–4.0m	CLAY-Grey/Brown, Stiff with gravels, 5-10mm, approx 15%, very stiff to hard at depth (NATURAL SOILS).		
				4.0m–4.65m	ANDESITE- EXTREMELY WEATHERED, with soil properties. START CORING at 4.65m		
NMLC	N	100 % (86.3%)	0 % (36.4%)	4.65m–5.1m	ANDESITE - Light Brown/Grey extremely weathered, shale/soil like properties	EW EW	4.65 4.73 - F 80° Un, Ro, Ct 4.80 - F 15° Un, Ro, Ct 4.85 - F 5° Ir, Ro, Ct 4.88 - Cu 10° Ir, Ro, Ct 4.92 - F 5° Pl, Sm, Ct 4.97 - F 0° Pl, Sm, Ct 4.99 - F 0° Ir, Ro, Ct 5.04 - F 5° Cu, Sm, Ct
					CORELOSS		5.10 - F 15° Ir, Sm, Ct 5.18 - CS 15° Pl, Sm, Ct
NMLC	N	88.2 % (86.3%)	42.1 % (36.4%)	5.2m–6.4m	ANDESITE - Grey with brown staining	HW EW HW SW MW	5.36 - Core loss 5.42 - F 5° Pl, Sm, Ct 5.46 - Cu 5° Ir, Sm, Ct 5.53 - F 5° Pl, Sm, Ct 5.56 - F 10° Ir, Sm, Ct 5.60 - F 5° Pl, Sm, Ct 5.70 - CS 5° Cu, Sm, Ct 5.96 - F 5° Pl, Sm, Ct 5.98 - Cu 15° Ir, Sm, Ct 5.98 - Cu 15° Ir, Sm, Ct 5.98 - Cu 15° Ir, Sm, Ct 6.00 - F 5° Pl, Sm, Ct 6.05 - F 5° Pl, Sm, Ct 6.14 - F 0° Pl, Sm, Cn 6.16 - F 5° Pl, Sm, Cn 6.20 - F 5° Pl, Sm, Cn 6.26 - F 5° Ir, Sm, Ct 6.29 - F 5° Ir, Sm, Ct 6.32 - F 5° Ir, Sm, Ct 6.37 - F 5° Ir, Sm, Ct
				6.4m–6.75m	ANDESITE - Light Grey	SW EW	6.40 - F 0° Cu, Sm, Ct 6.45 - F 5° Pl, Sm, Cn 6.50 - F 5° Pl, Sm, Cn 6.64 - F 5° Pl, Sm, Cn 6.70 - Cu 5° Ir, Sm, Ct
				6.75m–7.75m	ANDESITE - Grey with Light Grey bands	MW	6.75 - F 90° Pl, Sm, Ct 6.82 - F 5° Pl, Sm, Ct 6.96 - F 5° Pl, Sm, Ct 7.03 - F 5° Pl, Sm, Ct 7.16 - F 10° Pl, Sm, Cn 7.24 - F 10° Pl, Sm, Cn 7.30 - F 5° Pl, Sm, Cn 7.36 - F 5° Pl, Sm, Cn 7.42 - F 90° Ir, Ro, Cn 7.43 - F 5° Pl, Sm, Cn 7.46 - F 5° Pl, Sm, Cn 7.52 - F 5° Pl, Sm, Sn 7.60 - F 5° Pl, Sm, Sn 7.65 - F 5° Pl, Sm, Sn 7.70 - F 0° Pl, Sm, Sn
NMLC	N	80 % (86.3%)	47.6 % (36.4%)	7.75m–9.0m	ANDESITE - Light Grey	Fr EW SW	7.75 - F 5° Ir, Sm, Ct 7.77 - F 10° Ir, Sm, Ct 7.88 - F 0° Pl, Sm, Cn 8.19 - F 0° Pl, Sm, Cn 8.33 - F 0° Ir, Sm, Sn 8.45 - F 5° Ir, Sm, Ct 8.47 - Cu 5° Ir, Sm, Ct 8.54 - F 5° Ir, Sm, Ct 8.69 - F 90° Ir, Ro, Sn 8.71 - F 5° Pl, Sm, Cn 8.85 - F 10° Pl, Ro, Sn 8.87 - F 10° Ir, Ro, Ct 8.98 - F 10° Pl, Ro, Cn

INFERRED STRENGTH $Is_{(50)}$ MPa: EW 0.03, VW 0.1, W 0.3, MS 1, S 3, VS 10, ES

AVERAGE DEFECT SPACING (mm): 10, 30, 100, 300, 1000, 3000

EQUIPMENT / METHOD
- N Natural exposure
- X Existing excavation
- HQ Diamond Core - 63 mm
- NMLC Diamond Core - 52 mm
- NQ Diamond Core - 47 mm
- A Auger

WATER
- N None observed
- X Not measured
- Water level
- Water outflow
- Water inflow

WEATHERING
- Rs Residual Soil
- EW Extremely Weathered
- HW Highly Weathered
- MW Moderately Weathered
- SW Slightly Weathered
- Fr Fresh Rock

CORE DATA
- TCR Total Core Recovery (%)
- RQD Rock Quality Designation (%)
- SCR Solid Core Recovery (%)

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

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole

CLIENT	HANSON Pty Ltd	COMMENCED	9/7/06	COMPLETED	9/7/06	REF BH3
PROJECT	Geotechnical Assessment	LOGGED	GT	CHECKED	DM	Sheet 2 of 2
SITE	Eastern Creek Quarry	GEOLOGY		VEGETATION	None	PROJECT NO. P0601396
EQUIPMENT	Auger/Rotary Drill	EASTING	150 49 41 (Deg/Min/Sec) E	RL SURFACE	82.6 m AHD	
DRILLING FLUID	Water	NORTHING	33 47 58 (Deg/Min/Sec) S	ASPECT	West	SLOPE 0-5%

DRILLING DATA | MATERIAL DATA | SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	GRAPHIC LOG	DESCRIPTION OF STRATA Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa EW - 0.03, VW - 0.1, W - 0.3, MS - 1, S - 3, VS - 10, ES	DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS	AVERAGE DEFECT SPACING (mm) 10, 30, 100, 300, 1000, 3000
						ANDESITE - Light Grey	SW EW Fr		9.02 - F 10° Ir, Ro, Cn 9.09 - F 5° Pl, Sm, Cn 9.17 - F 5° Pl, Sm, Cn 9.22 - F 5° Pl, Sm, Cn 9.27 - F 15° Ir, Ro, Cn 9.29 - F 15° Ir, Ro, Cn 9.31 - Cu 5° Pl, Ro, Ct	
				9.5m		END of CORED BOREHOLE at 9.45m			9.45 - F 5° Pl, Sm, Cn	
				10.0m						
				10.5m						
				11.0m						
				11.5m						
				12.0m						
				12.5m						
				13.0m						

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
HQ Diamond Core - 63 mm
NMLC Diamond Core - 52 mm
NQ Diamond Core - 47 mm
A Auger

WATER
N None observed
X Not measured
Water level
Water outflow
Water inflow

WEATHERING
Rs Residual Soil
EW Extremely Weathered
HW Highly Weathered
MW Moderately Weathered
SW Slightly Weathered
Fr Fresh Rock

CORE DATA
TCR Total Core Recovery (%)
RQD Rock Quality Designation (%)
SCR Solid Core Recovery (%)

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

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole


0: EASTERN CREEK BH-4 44103
1: START CORING AT 4.60M
2:
3:
4: 4.60
5
6
7
8
9
END 10M LEFT 0.10 DOWN BK

CLIENT	HANSON Pty Ltd	COMMENCED	9/7/06	COMPLETED	9/7/06	REF BH4
PROJECT	Geotechnical Assessment	LOGGED	GT	CHECKED	DM	Sheet 2 of 2
SITE	Eastern Creek Quarry	GEOLOGY		VEGETATION	None	PROJECT NO. P0601396
EQUIPMENT	Auger/Rotary Drill	EASTING	150 49 41 (Deg/Min/Sec) E	RL SURFACE	81.5 m AHD	
DRILLING FLUID	Water	NORTHING	33 47 58 (Deg/Min/Sec) S	ASPECT	West	SLOPE 0-5%

DRILLING DATA / MATERIAL DATA / SAMPLING & DEFECT DATA

METHOD	WATER	TCR	RQD (SCR)	DEPTH (M)	GRAPHIC LOG	DESCRIPTION OF STRATA Type, texture, structure, mottling, colour, oxidation, particle characteristics, organics, secondary & minor components, fill, contamination, odour.	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (EW - 0.03, VW - 0.1, W - 0.3, MS - 1, S - 3, VS - 10, ES)	DEFECT DESCRIPTIONS AND ADDITIONAL OBSERVATIONS	AVERAGE DEFECT SPACING (mm) (10, 30, 100, 300, 1000, 3000)
						ANDESITE - Light Grey			9.05 - F 5° Pl, Ro, Cn 9.20 - F 10° Pl, Ro, Cn 9.21 - F 10° Pl, Ro, Cn 9.28 - F 5° Cu, Ro, Cn 9.28 - F 75° Cu, Ro, Fe 9.48 - F 5° Pl, Ro, Cn	
				9.5m		ANDESITE - Dark Grey	Fr		9.57 - F 5° Pl, Ro, Cn 9.63 - F 5° Pl, Ro, Cn 9.71 - F 5° Pl, Ro, Cn 9.75 - F 5° Pl, Ro, Cn 9.82 - F 10° Pl, Ro, Cn 9.85 - F 70° Un, Ro, Cn 9.90 - F 5° Pl, Ro, Cn	
						CORE LOSS				
				10.0m		END of CORED BOREHOLE at 10.00m				
				10.5m						
				11.0m						
				11.5m						
				12.0m						
				12.5m						
				13.0m						
				13.5m						

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
HQ Diamond Core - 63 mm
NMLC Diamond Core - 52 mm
NQ Diamond Core - 47 mm
A Auger

WATER
N None observed
X Not measured
Water level
Water outflow
Water inflow

WEATHERING
Rs Residual Soil
EW Extremely Weathered
HW Highly Weathered
MW Moderately Weathered
SW Slightly Weathered
Fr Fresh Rock

CORE DATA
TCR Total Core Recovery (%)
RQD Rock Quality Designation (%)
SCR Solid Core Recovery (%)

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

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

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Cored Borehole

CLIENT	HANSON	COMMENCED	9/9/06	COMPLETED	9/9/06	REF BH5
PROJECT	GEOTECHNICAL ASSESSMENT	LOGGED	GT	CHECKED	DM	Sheet of
SITE	HANSON QUARRY, EASTERN CREEK	GEOLOGY		VEGETATION	None	PROJECT NO. P0601396
EQUIPMENT	ROTARY AUGER	EASTING	150°49 41 (Deg/Min/Sec)	RL SURFACE	80.0 m AHD	
EXCAVATION DIMENSIONS	DIA: 200MM DEPTH: 1.5M	NORTHING	33° 47 58 (Deg/Min/Sec)	ASPECT	WEST	SLOPE 5%

EXCAVATION DATA / MATERIAL DATA / SAMPLING & TESTING

METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION RESISTANCE (L M H R)	GRAPHIC LOG	CLASSIFICATION	DESCRIPTION OF STRATA Soil type, texture, structure, mottling, colour, plasticity, rocks, oxidation, particle characteristics, organics, secondary and minor components, fill, contamination, odour.	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	RESULTS AND ADDITIONAL OBSERVATIONS
A	N	N	D	0.5			XX	ROADBASE/FILL - Black	St		SPT	0.5	
A	N	N	D	0.7			CL	CLAY (FILL) - Black/Grey, gravels.	St				
A	N	N	M	1.0			CH	CLAY - Orange/yellow, fine sands, gravels (5-10mm approx 10%)	VSt		A SPT	0.7 1.0	1.0
A	N	N	M	1.5			CH	CLAY- Grey/Orange	VSt		A	1.5	
				2.0				Borehole terminated at 1.5m on extremely weathered Andesite			SPT SPT	2.0 2.5	2.0
				3.0									3.0
				4.0									4.0

EQUIPMENT / METHOD
N Natural exposure
X Existing excavation
BH Backhoe bucket
E Excavator
HA Hand auger
S Hand spade
PT Push tube
A Auger

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

martens

MARTENS & ASSOCIATES PTY LTD
6/37 Leighton Place
Hornsby, NSW 2077 Australia
Phone: (02) 9476 8777 Fax: (02) 9476 8767
mail@martens.com.au WEB: http://www.martens.com.au

Engineering Log - Excavation / Borehole

8 Attachment D- Standard Penetration Testing Summary

Depth	TB2	N	TB3	N	TB4	N	TB5	N
0.50	-		-		-		-	
0.65	19		7		11		21	
0.80	7		7		16		15	
0.95	12	19	10	17	15	31	12	27
1.00	-		-		-		-	
1.15	4		2		6		8	
1.30	6		2		4		25/80[3]	
1.45	7	13	3	5	5	9	-	-
2.00	-		-		-		-	
2.15	22		2		8		25/30[4]	
2.30	23		3		26		-	
2.45	25/100[1]	-	4	7	23	49	-	-
3.00	-		-		-		-	
3.15	-		6		16		-	
3.30	-		6		17		-	
3.45	-		11	17	32	49	-	
4.00	-		-		-		-	
4.15	-		11		5		-	
4.30	-		26		13		-	
4.45	-		25/90[2]	-	30	43	-	

NOTES: [1] SPT terminated at 2.4m. [2] SPT terminated at 4.39m. [3] SPT terminated at 1.23m. [4] SPT terminated at 2.03m

9 Attachment E- Point Load Testing Data

martens
consulting engineers since 1989

POINT LOAD STRENGTH INDEX TEST REPORT

Client	Hanson Australia Pty Ltd	**Address**	Level 6, 35 Clarence Street, Sydney	**Page No.**	1 of 4
Project	Hanson Quarry Road stability assessment - BH1				

Sample Ref	Client Ref	Lithology	D (mm)	W (mm)	P (kN)	Test Type	Is (Mpa)	Is50 (Mpa)	UCS (Mpa)	Class	Interpretation
BH1-1.30-A	P0601396	Andesite	52	45	1.0	D	0.37	0.38	7.9	M	Medium Strength
BH1-1.30-B	P0601396	Andesite	52	45	2.0	O	0.67	0.70	14.7	M	Medium Strength
BH1-2.80-A	P0601396	Andesite	52	50	6.0	D	2.22	2.26	47.4	H	High Strength
BH1-2.80-B	P0601396	Andesite	52	50	5.5	O	1.66	1.77	37.2	H	High Strength
BH1-4.05-A	P0601396	Andesite	52	100	7.5	D	2.77	2.82	59.3	H	High Strength
BH1-4.05-B	P0601396	Andesite	52	100	9.0	O	1.36	1.69	35.5	H	High Strength
BH1-4.05-A1	P0601396	Andesite	52	115	8.0	D	2.96	3.01	63.2	VH	Very High Strength
BH1-4.05-B1	P0601396	Andesite	52	115	8.5	O	1.12	1.43	30.1	H	High Strength

Test Device	Shambhavi PIT-01 Point Load Tester	**Sample Received**	9.7.2006
Sample History	Unsoaked	**Sample Tested**	5.9.2006
Sampled By	GMT	**Test Method**	AS 4133.4.1 1993
Job Number	P0601396		
Laborator Officer	G. Taylor	**Officer Signature**	

NOTES

Terms - D = Platen Separation (mm), W = Avg Sample Width (mm), P = Failure Load (KN), I_s = Point Load Strength (Mpa), I_s50 = Corrected Point Load Strength (Mpa), UCS = Unconfined Compressive Strength estimate (Mpa)

Test Types - D = Diametral, O = Axial / Block | UCS K factor | 21

Head Office
Unit 6 / 37 Leighton Place
Hornsby NSW 2077, Australia
Ph 02 9476 8777 **Fax** 02 9476 8767

> mail@martens.com.au
www.martens.com.au
MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

martens
consulting engineers since 1989

POINT LOAD STRENGTH INDEX TEST REPORT

Client	Hanson Australia Pty Ltd	**Address**	Level 6, 35 Clarence Street, Sydney	**Page No.**	2 of 4
Project	Hanson Quarry Road stability assessment - BH2				

Sample Ref	Client Ref	Lithology	D (mm)	W (mm)	P (kN)	Test Type	Is (Mpa)	Is50 (Mpa)	UCS (Mpa)	Class	Interpretation
BH2-4.10-A	P0601396	Andesite	52	35	5.0	D	1.85	1.88	39.5	H	High Strength
BH2-4.10-B	P0601396	Andesite	52	35	5.0	O	2.16	2.12	44.5	H	High Strength
BH2-5.60-A	P0601396	Andesite	52	42	2.5	D	0.92	0.94	19.8	M	Medium Strength
BH2-5.60-B	P0601396	Andesite	52	42	4.0	O	1.44	1.47	30.9	H	High Strength
BH2-8.50-A	P0601396	Andesite	52	70	3.0	D	1.11	1.13	23.7	H	High Strength
BH2-8.50-B	P0601396	Andesite	52	70	3.5	O	0.76	0.87	18.2	M	Medium Strength

Test Device	Shambhavi PIT-01 Point Load Tester	**Sample Received**	9.7.2006
Sample History	Unsoaked	**Sample Tested**	5.9.2006
Sampled By	GMT	**Test Method**	AS 4133.4.1 1993
Job Number	P0601396		
Laborator Officer	G. Taylor	**Officer Signature**	

NOTES

Terms - D = Platen Separation (mm), W = Avg Sample Width (mm), P = Failure Load (KN), I_s = Point Load Strength (Mpa), I_s50 = Corrected Point Load Strength (Mpa), UCS = Unconfined Compressive Strength estimate (Mpa)

Test Types - D = Diametral, O = Axial / Block | UCS K factor | 21

Head Office
Unit 6 / 37 Leighton Place
Hornsby NSW 2077, Australia
Ph 02 9476 8777 **Fax** 02 9476 8767

> mail@martens.com.au
www.martens.com.au
MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

martens
consulting engineers since 1989

POINT LOAD STRENGTH INDEX TEST REPORT

Client	Hanson Australia Pty Ltd	Address	Level 6, 35 Clarence Street, Sydney	Page No.	3 of 4
Project	Hanson Quarry Road stability assessment - BH3				

Sample Ref	Client Ref	Lithology	D (mm)	W (mm)	P (kN)	Test Type	Is (Mpa)	Is50 (Mpa)	UCS (Mpa)	Class	Interpretation
BH3-6.10-A	P0601396	Andesite	52	45	2.5	D	0.92	0.94	19.8	M	Medium Strength
BH3-6.10-B	P0601396	Andesite	52	45	3.5	O	1.17	1.22	25.7	H	High Strength
BH3-7.90-A	P0601396	Andesite	52	40	3.5	D	1.29	1.32	27.7	H	High Strength
BH3-7.90-B	P0601396	Andesite	52	40	5.0	O	1.89	1.91	40.2	H	High Strength
BH3-9.10-A	P0601396	Andesite	52	50	3.5	D	1.29	1.32	27.7	H	High Strength
BH3-9.10-B	P0601396	Andesite	52	50	4.5	O	1.36	1.45	30.4	H	High Strength

Test Device	Shambhavi PIT-01 Point Load Tester	**Sample Received**	9.7.2006
Sample History	Unsoaked	**Sample Tested**	5.9.2006
Sampled By	GMT	**Test Method**	AS 4133.4.1 1993
Job Number	P0601396		
Laborator Officer	G. Taylor	**Officer Signature**	

NOTES

Terms - D = Platen Separation (mm), W = Avg Sample Width (mm), P = Failure Load (KN), I_s = Point Load Strength (Mpa), I_s50 = Corrected Point Load Strength (Mpa), UCS = Unconfined Compressive Strength estimate (Mpa)

Test Types - D = Diametral, O = Axial / Block | UCS K factor | 21

Head Office
Unit 6 / 37 Leighton Place
Hornsby NSW 2077, Australia
Ph 02 9476 8777 **Fax** 02 9476 8767

> mail@martens.com.au
www.martens.com.au
MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

martens
consulting engineers since 1989

POINT LOAD STRENGTH INDEX TEST REPORT

Client	Hanson Australia Pty Ltd	**Address**	Level 6, 35 Clarence Street, Sydney	**Page No.**	4 of 4
Project	Hanson Quarry Road stability assessment - BH4				

Sample Ref	Client Ref	Lithology	D (mm)	W (mm)	P (kN)	Test Type	Is (Mpa)	Is50 (Mpa)	UCS (Mpa)	Class	Interpretation
BH4-5.60-A	P0601396	Andesite	52	55.0	5.5	D	2.03	2.07	43.5	H	High Strength
BH4-5.60-B	P0601396	Andesite	52	55	6.0	O	1.65	1.79	37.7	H	High Strength
BH4-7.70-A	P0601396	Andesite	52	50	2.5	D	0.92	0.94	19.8	M	Medium Strength
BH4-7.70-B	P0601396	Andesite	52	50	5.5	O	1.66	1.77	37.2	H	High Strength
BH4-8.60-A	P0601396	Andesite	52	40	3.5	D	1.29	1.32	27.7	H	High Strength
BH4-8.60-B	P0601396	Andesite	52	40	3.0	O	1.13	1.15	24.1	H	High Strength
BH4-9.70-A	P0601396	Andesite	52	25	2.0	D	0.74	0.75	15.8	M	Medium Strength
BH4-9.70-B	P0601396	Andesite	52	25	3.5	O	2.11	1.93	40.5	H	High Strength

Test Device	Shambhavi PIT-01 Point Load Tester	**Sample Received**	9.7.2006
Sample History	Unsoaked	**Sample Tested**	5.9.2006
Sampled By	GMT	**Test Method**	AS 4133.4.1 1993
Job Number	P0601396		
Laborator Officer	G. Taylor	**Officer Signature**	

NOTES

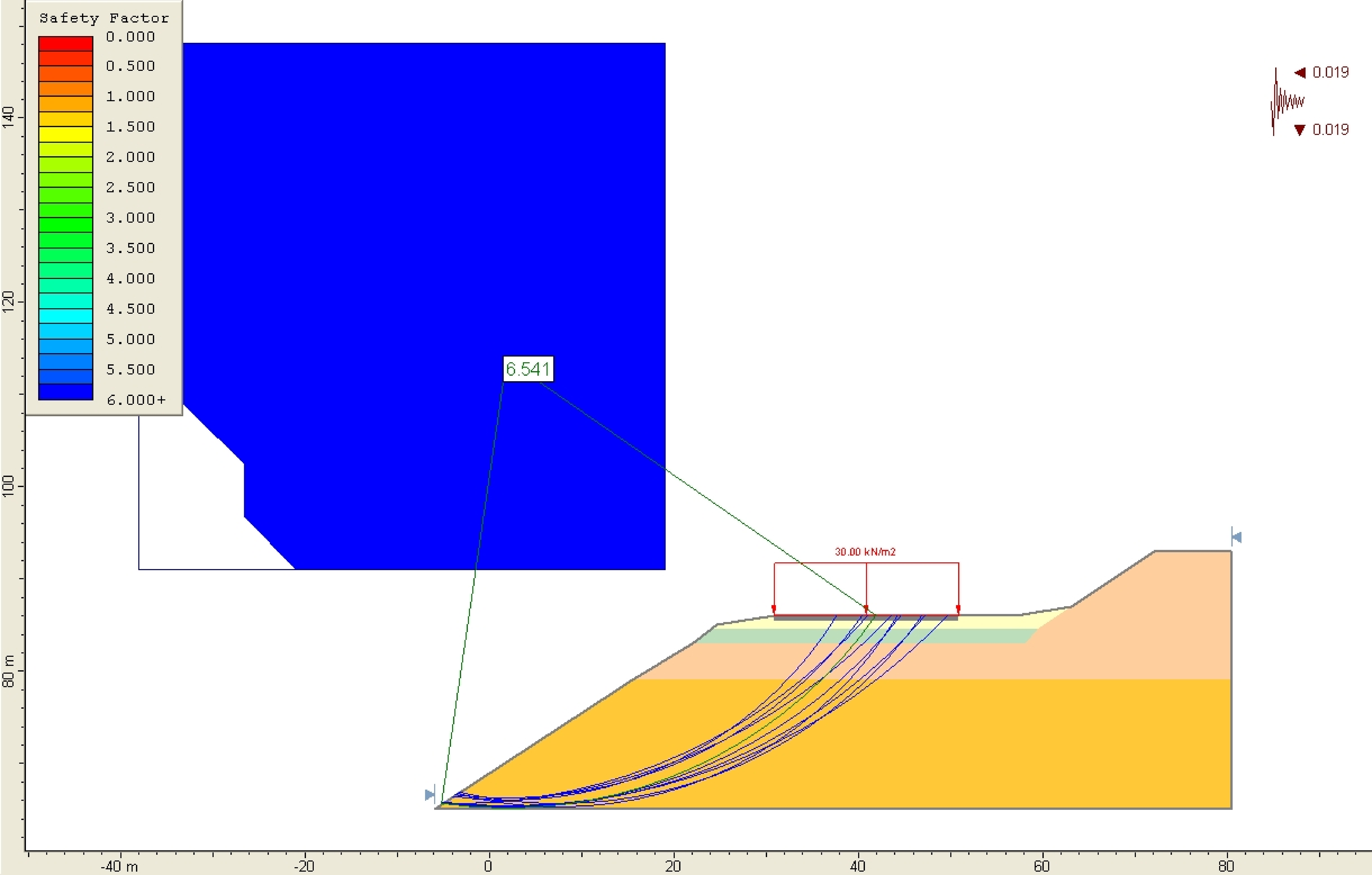
Terms - D = Platen Separation (mm), W = Avg Sample Width (mm), P = Failure Load (KN), I_s = Point Load Strength (Mpa), I_s50 = Corrected Point Load Strength (Mpa), UCS = Unconfined Compressive Strength estimate (Mpa)

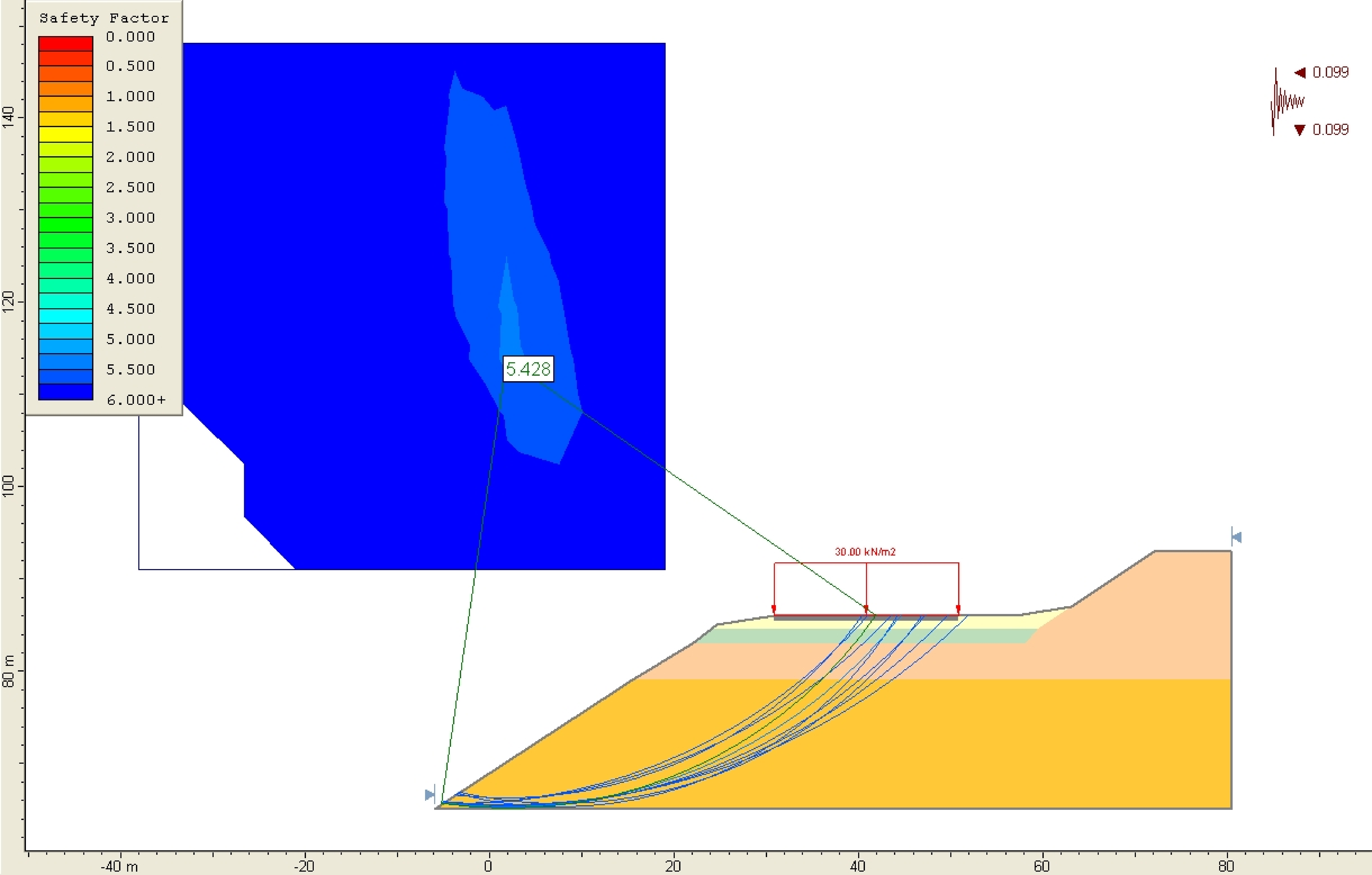
Test Types - D = Diametral, O = Axial / Block — UCS K factor: 21

Head Office
Unit 6 / 37 Leighton Place
Hornsby NSW 2077, Australia
Ph 02 9476 8777 **Fax** 02 9476 8767

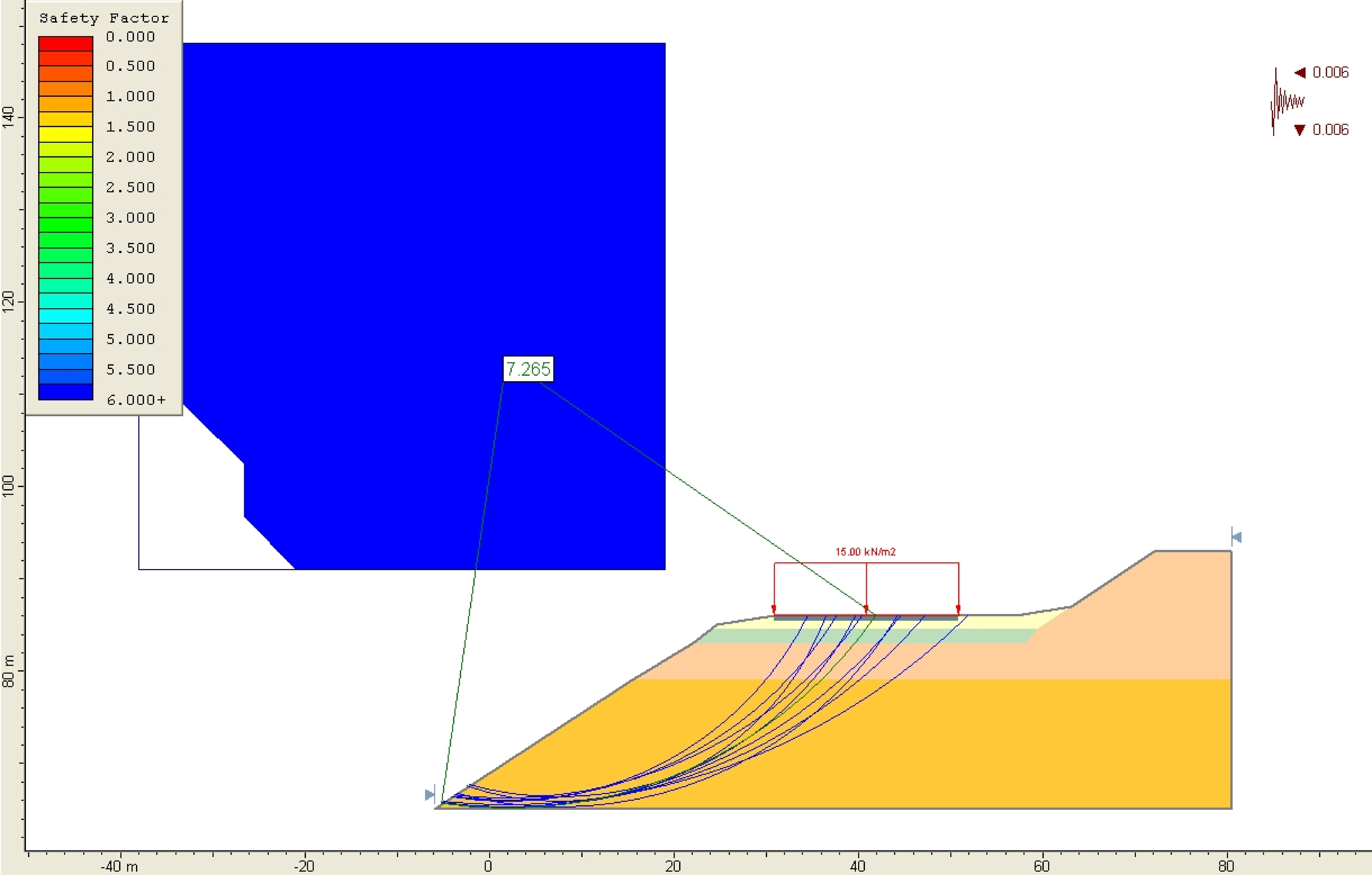
> mail@martens.com.au
www.martens.com.au
MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

10 Attachment F - Slope Instability Analysis

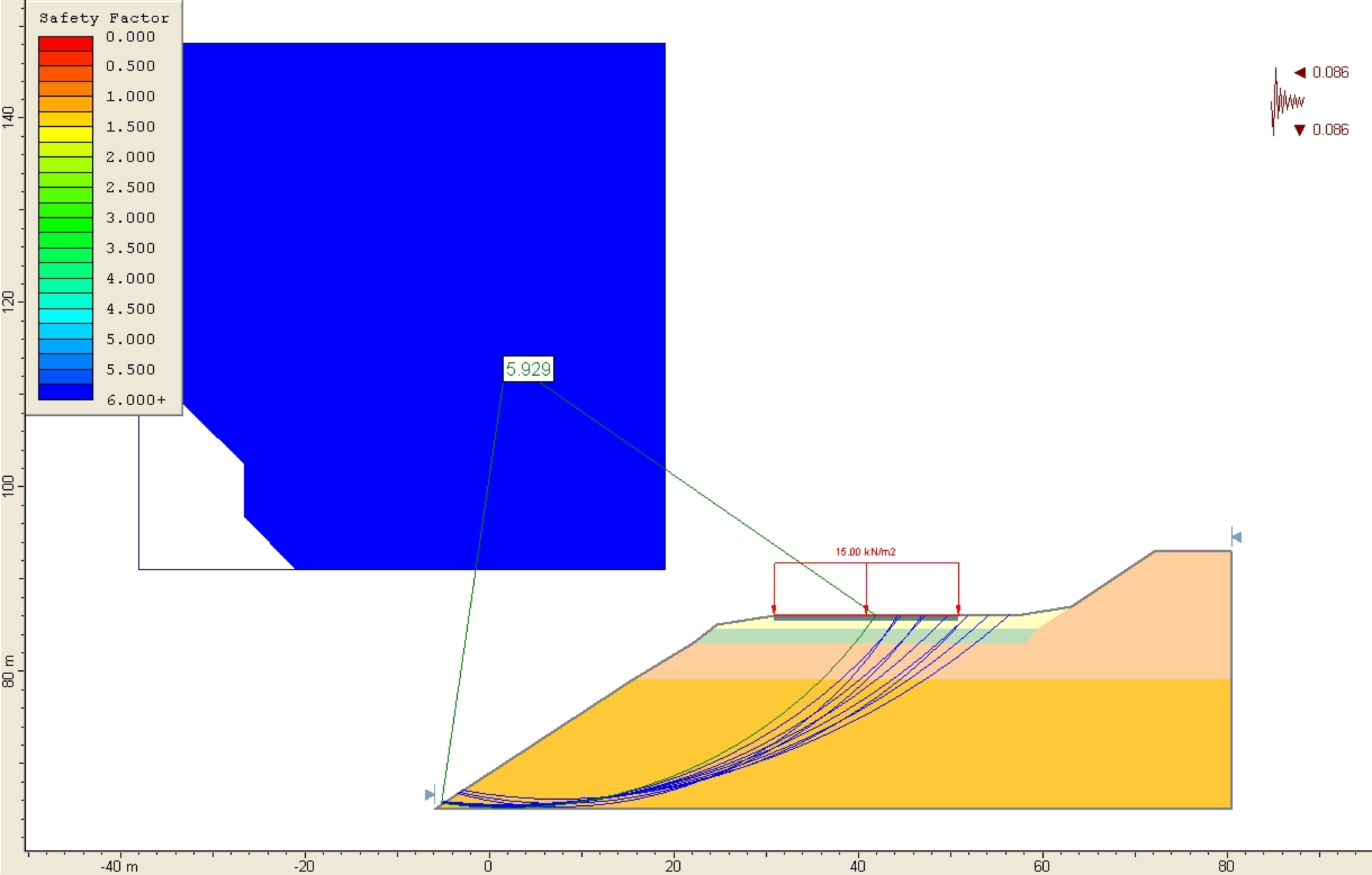

Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
6.541
30.00 kN/m2
0.019
0.019
140
120
100
80 m
-40 m
-20
0
20
40
60
80



Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
5.428
30.00 kN/m2
0.099
0.099
140
120
100
80 m
-40 m
-20
0
20
40
60
80



Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
7.265
15.00 kN/m2
0.006
0.006
140
120
100
80 m
-40 m
-20
0
20
40
60
80



Safety Factor
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
5.500
6.000+
5.929
15.00 kN/m2
0.086
0.086
140
120
100
80 m
-40 m
-20
0
20
40
60
80

11 Attachment G - Plates

Plate 1: View looking west from Test Bore 1 at road and cut in local rock.

Plate 2: View looking east from Test Bore 1 at cut running adjacent to road.

Plate 3: View looking west from Test Bore 3 at stockpiles.

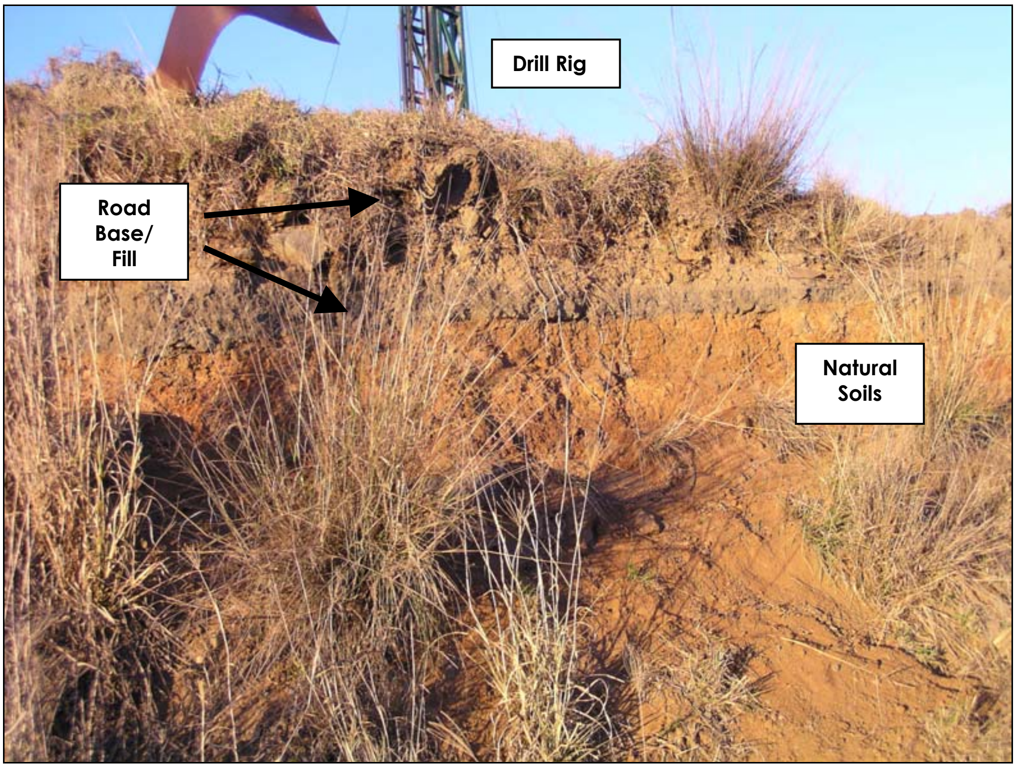


Plate 4: View looking south at profile of bank down slope (approximately 2-3m below Test Bore 3 surface R.L) showing fill and road base above natural soils.

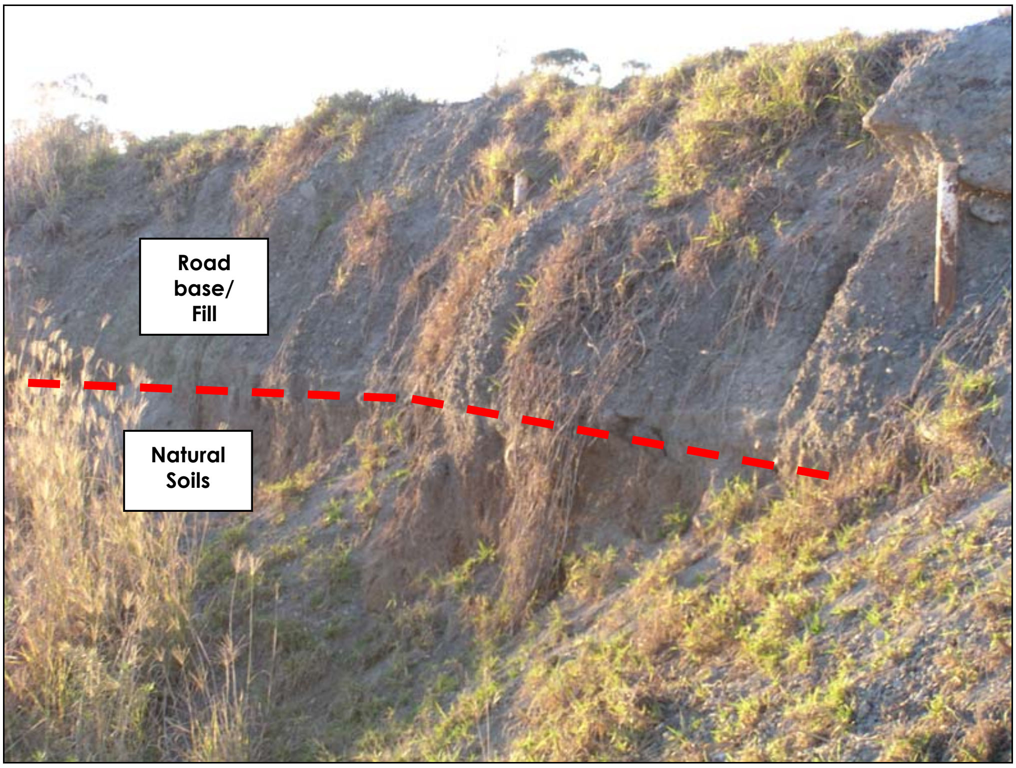


Plate 5: View looking east at bank adjacent to road showing fill and road base above natural soils.

12 Attachment H - Notes Relating to This Report

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.

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.

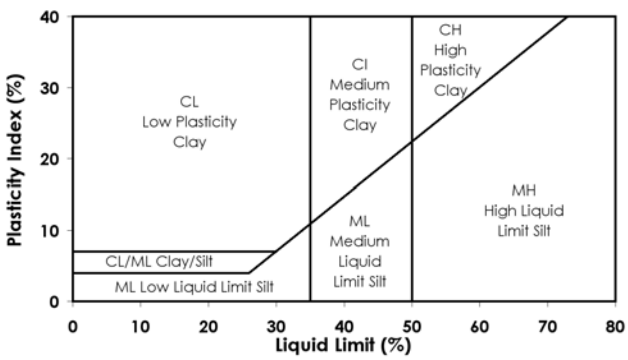
Particle Size

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)	Approx SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	2 to 4	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail.
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 %

martens consulting engineers

Soil Agricultural Classification Scheme

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

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

Soil Data

Explanation of Terms (3 of 3)

martens consulting engineers

Symbols for Soil and Rock

SOIL

- 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)
- CLAY (CL or CI)
- ALLUVIUM
- FILL
- TALUS
- TOPSOIL

SEDIMENTARY ROCK

- BOULDER CONGLOMERATE
- CONGLOMERATE
- CONGLOMERATE SANDSTONE
- SANDSTONE, QUARTZITE
- SILTSTONE
- LAMINITE
- MUDSTONE
- CLAYSTONE
- SHALE
- COAL
- LIMESTONE
- TUFF

IGNEOUS ROCK

- GRANITE
- DOLERITE / BASALT

IGNEOUS ROCK

- SLATE, PHYLLITE SCHIST
- GNEISS

Unified Soil Classification Scheme (USCS)

<table>
<tr><th colspan="7">FIELD IDENTIFICATION PROCEDURES
(Excluding particles larger than 63 mm and basing fractions on estimated mass)</th><th>USCS</th><th>Primary Name</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOILS
More than 50 % of material less than 63 mm is larger than 0.075 mm</td><td rowspan="16">(A 0.075 mm particle is about the smallest particle visible to the naked eye)</td><td rowspan="4">GRAVELS
More than half of coarse fraction is larger than 2.0 mm.</td><td rowspan="2">CLEAN GRAVELS (Little or no fines)</td><td colspan="3">Wide range in grain size and substantial amounts of all intermediate particle sizes.</td><td>GW</td><td>Gravel</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with more intermediate sizes missing</td><td>GP</td><td>Gravel</td></tr>
<tr><td rowspan="2">GRAVELS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below)</td><td>GM</td><td>Silty Gravel</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>GC</td><td>Clayey Gravel</td></tr>
<tr><td rowspan="4">SANDS
More than half of coarse fraction is smaller than 2.0 mm</td><td rowspan="2">CLEAN SANDS (Little or no fines)</td><td colspan="3">Wide range in grain sizes and substantial amounts of intermediate sizes missing.</td><td>SW</td><td>Sand</td></tr>
<tr><td colspan="3">Predominantly one size or a range of sizes with some intermediate sizes missing</td><td>SP</td><td>Sand</td></tr>
<tr><td rowspan="2">SANDS WITH FINES (Appreciable amount of fines)</td><td colspan="3">Non-plastic fines (for identification procedures see ML below)</td><td>SM</td><td>Silty Sand</td></tr>
<tr><td colspan="3">Plastic fines (for identification procedures see CL below)</td><td>SC</td><td>Clayey Sand</td></tr>
<tr><td rowspan="8">FINE GRAINED SOILS
More than 50 % of material less than 63 mm is smaller than 0.075 mm</td><td colspan="7">IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM</td></tr>
<tr><td>DRY STRENGTH (Crushing Characteristics)</td><td>DILATANCY</td><td>TOUGHNESS</td><td colspan="2">DESCRIPTION</td><td>USCS</td><td>Primary Name</td></tr>
<tr><td>None to Low</td><td>Quick to Slow</td><td>None</td><td colspan="2">Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity</td><td>ML</td><td>Silt</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Medium</td><td colspan="2">Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays</td><td>CL</td><td>Clay</td></tr>
<tr><td>Low to Medium</td><td>Slow to Very Slow</td><td>Low</td><td colspan="2">Organic slits and organic silty clays of low plasticity</td><td>OL</td><td>Organic Silt</td></tr>
<tr><td>Low to Medium</td><td>Slow to Very Slow</td><td>Low to Medium</td><td colspan="2">Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts</td><td>MH</td><td>Silt</td></tr>
<tr><td>High</td><td>None</td><td>High</td><td colspan="2">Inorganic clays of high plasticity, fat clays</td><td>CH</td><td>Clay</td></tr>
<tr><td>Medium to High</td><td>None</td><td>Low to Medium</td><td colspan="2">Organic clays of medium to high plasticity</td><td>OH</td><td>Organic Silt</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td colspan="5">Readily identified by colour, odour, spongy feel and frequently by fibrous texture</td><td>Pt</td><td>Peat</td></tr>
<tr><td colspan="9">Low Plasticity – Liquid Limit W_L < 35 %   Medium Plasticity – Liquid limit W_L 35 to 60 %   High Plasticity - Liquid limit W_L > 60 %</td></tr>
</table>

Rock Data

Explanation of Terms (1 of 2)

Definitions

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

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

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

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

Degree of Weathering

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

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

Rock Strength

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

Term	Is (50) MPa	Field Guide	Symbol
Extremely weak	< 0.03	Easily remoulded by hand to a material with soil properties.	EW
Very weak	0.03 - 0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VW
Weak	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.	W
Medium strong	0.3 - 1	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	MS
Strong	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.	S
Very Strong	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.	VS
Extremely strong	> 10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	ES

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

Roughness

Po	Polished
Ro	Rough
Sl	Slickensided
Sm	Smooth
Vr	Very rough

Planarity

Cu	Curved
Ir	Irregular
Pl	Planar
St	Stepped
Un	Undulating

Inclination

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

Test Methods

martens consulting engineers

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:

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

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

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

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

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

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

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

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

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

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

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