ENVIRONMENTAL INVESTIGATION SERVICES

REPORT

TO

CARDNO (NSW/ACT) PTY LTD

ON

PRELIMINARY ENVIRONMENTAL SITE ASSESSMENT AND MANAGEMENT PLAN

FOR

PROPOSED ACCESS UPGRADES

AT

WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

8 AUGUST 2014 **REF: E26853KPrpt**

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a) EIS' proposal in respect of the work covered by the Report;
b) The limitations defined in the client's brief to EIS; and
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TABLE OF CONTENTS

1 INTRODUCTION

Cardno (NSW/ACT) Pty Ltd ('the client') commissioned Environmental Investigation Services (EIS)[1] to undertake a preliminary Environmental Site Assessment (ESA) and prepare a management plan for the proposed access upgrades at Wentworthville Station, Wentworthville, NSW. The site location is shown on Figure 1. The ESA and management plan is limited to the site area shown on the attached Figure 2.

This report was prepared in accordance with an EIS proposal (Ref: EP8160KP) of 8 July 2014 and written acceptance from the client of 30 July 2014.

We understand the ESA and management plan have been requested for due diligence purposes.

A geotechnical investigation was previously undertaken at the site by JK Geotechnics[2] (Project Ref: 26853S). Relevant subsurface information from the JK investigation is discussed in this report.

1.1 Proposed Development Details

Based on the details provided, it is understood that the proposed access upgrades include the construction of four lifts adjacent to the existing footbridge. It is also proposed to widen the footbridge and construct new staircases and canopies.

We have assumed that the depth of excavation for the proposed lift overrun pits will not extend beyond 2m.

1.2 Aim and Objectives

The aim of the preliminary ESA and management plan is to provide information (based on a limited desktop assessment) with regards to potential soil contamination and soil waste classification.

The objectives of the preliminary ESA and management plan are to:

- Make a preliminary assessment of site conditions in relation to potential soil contamination;
- Provide a discussion of the subsurface conditions and potential soil contaminants of concern;
- Discuss the soil waste classifications that may apply to excavated material;

[1] Environmental consulting division of Jeffery & Katauskas Pty Ltd (J&K)

[2] Geotechnical consulting division of J&K

- Provide preliminary recommendations for the management and assessment of the soils with regards to waste disposal during the works;
- Provide an outline of the typical timeframes and costs for completing a soil waste classification for the proposed access upgrades works.

1.3 Scope of Work

The scope of work included:

- Review of the site location, setting and regional geology;
- Review of contaminated-related notices on the NSW EPA website;
- Review of the JK borehole logs;
- Assessment of the excavation and waste classification requirements; and
- Preparation of a report.

2 SITE INFORMATION AND PHYSICAL SETTING

2.1 Site Identification

Table 2-1: Site Identification Information

Lot & Deposited Plan:	Part Lot 100 in DP1042344
Current Land Use:	Rail corridor
Proposed Land Use:	Unchanged
Local Government Authority:	Holroyd
Site Area (m^2):	800
RL (AHD in m) (approx.):	25-27
Geographical Location (MGA) (approx.):	N: 6257393 E: 312306
Site Location Plan:	Figure 1
JK Borehole Location Plan:	Figure 2

2.2 Site Description

The site is located within a gently undulating regional topographic setting and the site itself slopes down towards the north at approximately 2°. The station is bounded by Wentworth Avenue to the north and The Kingsway to the south. The surrounding land use setting comprises commercial/retail areas to the south, and commercial and residential areas to the north.

The site was inspected by JK in June 2014. For the purposes of this site description we have assumed that the railway is oriented in an east-west direction. Wentworthville Station comprises two island platforms with brick walls and asphaltic concrete (AC) platform surfaces. Single storey station buildings of brick construction were located over the eastern portion of each platform. Access onto the platforms was via a steel and concrete footbridge and stairs located towards the western end of the platform.

The southern portion of the station appeared to have been partially cut into the slope. Shale bedrock was exposed at the base of the cutting adjacent to The Kingsway.

2.3 NSW EPA Records

The NSW EPA records available online were reviewed for the assessment. A summary of the relevant information is provided in the following table:

Table 2-2: Summary of NSW EPA Online Records

Source	Details
CLM Act 1997[3]	There were no notices for the site (or the rail corridor in the general vicinity) under Section 58 of the Act.
NSW EPA List of Contaminated Sites[4]	The site is not listed on the NSW EPA register.
POEO Register[5]	There were no notices for the site on the POEO register.

2.4 Regional Geology

A review of the regional geological map of Penrith (1991[6]) indicates that the site is underlain by Ashfield Shale of the Wianamatta Group, which typically consists of black to dark grey shale and laminite.

2.5 Acid Sulfate Soil (ASS) Risk Map

The site is not located in an ASS risk area as mapped by the Department of Land and Water Conservation (1997[7]).

2.6 Subsurface Conditions

A summary of the subsurface conditions encountered during the JK investigation is presented in the following table. Reference should be made to the borehole logs attached in the appendices for further details.

[3] http://www.epa.nsw.gov.au/prclmapp/searchregister.aspx, visited on 7 August 2014
[4] http://www.epa.nsw.gov.au/clm/publiclist.htm, visited on 7 August 2014
[5] http://www.epa.nsw.gov.au/prpoeoapp/, visited on 7 August 2014
[6] Department of Mineral Resources, (1991), *1:100,000 Geological Map of Penrith (Series 9030)*
[7] Department of Land and Water Conservation (1997), Acid Sulfate Soil Risk Map Series

Table 2-3: Summary of Subsurface Conditions Encountered during JK Investigation

Profile	Description[1]
Pavement	Asphaltic Concrete (AC) pavement was encountered at the surface in BH2 and BH3 (maximum thickness of approximately 0.08m).
Fill	Fill material was encountered from the surface in BH1 and BH4, and beneath the AC in BH2 and BH3. The fill soil typically comprised silty clay or sandy gravel with inclusions of shale, sandstone and igneous gravels, root, root fibres, glass, plastic, concrete, brick and slag fragments. The depth of the fill material ranged from approximately 0.3m in BH1, to over 2m in BH3. The fill depths are shown on the attached Figure 2.
Natural Soil	Residual silty clay soil was encountered beneath the fill material in BH1, BH2 and BH4.
Bedrock	Shale bedrock was encountered beneath the fill material in BH3, and beneath the residual soil in the remaining boreholes.

Note:
1 – Depths described in metres below ground level

3 POTENTIAL SOIL AND WASTE CONTAMINATION CONDITIONS

3.1 Potential Soil Contamination

The limited desktop review and observations made during the JK site inspection did not identify any obvious soil contamination issues or potential soil contamination sources at the site. Odours or obvious fragments of potential asbestos containing materials (ACM) were not encountered in the boreholes drilled by JK.

The fill soils contained various inclusions that may be indicative of potential contamination. The presence of demolition rubble such as brick, concrete and glass fragments is often a precursor to ACM. The presence of slag may indicate the presence of heavy metals, petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs).

Based on the above information and EIS experience with similar projects in the rail corridor, the following potential soil contaminants of concern (PCC) have been identified:

- Heavy metals (Arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc);
- Petroleum hydrocarbons (total recoverable hydrocarbons – TRHs);
- Monocyclic aromatic hydrocarbons (benzene, toluene, ethylbenzene and xylenes – BTEX);
- PAHs;
- Organochlorine and organophoshporous pesticides (OCP/OPPs);
- Polychlorinated biphenyls (PCBs); and
- Asbestos.

3.2 Potential Waste Classifications

The fill and natural soil will require a waste classification in accordance with the *Waste Classification Guidelines Part 1: Classifying Waste* (2009[8]), if surplus material is to be disposed off-site. The table below outlines the various waste classifications that may apply for the material to be excavated during the proposed access upgrades, along with approximate disposal rates.

Table 3-1: Waste Classification Information

Soil Type	Potential Classification[1]	Likelihood of this Waste Stream being Present	Typical Landfill Disposal Fees ($ per tonne)[2]
Fill	General Solid Waste (non-putrescible), suitable for recycling	Moderate	$80-100
Fill	General Solid Waste (non-putrescible)	High	$160
Fill	General Solid Waste (non-putrescible) containing asbestos	Moderate	$160
Fill	Restricted Solid Waste (non-putrescible)	Low to moderate	$440
Fill	Hazardous Waste	Low	POA
Natural Soil and Bedrock[3, 4]	Virgin Excavated Natural Material (VENM)	Moderate to High	$60-80 (if suitable, VENM can be re-used on other sites which would eliminate/reduce the disposal costs for this waste stream)

Note:

1 – Waste Classification Guidelines 2009

2 – These fees are indicative only and should be confirmed by the receiving facility

3 – Natural material impacted by contamination will fall within one of the fill classifications

4 – Natural material that is excavated and stockpiled prior to VENM assessment may require an Excavated Natural Material (ENM) classification

POA – Price on application (costs will vary based on type of contamination present in the soil)

8 NSW Department of Environment, Climate Change and Water (DECCW) 2009, *Waste Classification Guidelines Part 1: Classifying Waste* (Waste Classification Guidelines 2009)

4 MANAGEMENT AND ASSESSMENT OF SOIL

4.1 Preliminary Assessment of Fill Spoil Quantities

A preliminary assessment of fill spoil quantities for each of the proposed lift pits is provided in the following table. The estimates are based on the following assumptions:

- Each lift will require excavation of a 4m by 4m area and will extend to a depth of approximately 2m below the existing levels;
- Each $1m^3$ of in-situ fill soil equates to 1.8 tonnes; and
- The fill depth at each lift pit location will be approximately equal to that encountered in the JK borehole at that location.

Table 4-1: Fill Spoil Estimates for Lift Pit Excavations

Area (See JK borehole locations in Figure 2)	Approximate Fill Depth (m)	In-situ Fill Volume Estimate (m^3)	Fill Quantity Estimate (tonnes)
BH1	0.3	5	9
BH2	1.8	29	52
BH3	2.5	32[1]	58[1]
BH4	0.8	13	23

Note:
1 – Additional fill quantities may apply if all fill soils need to be excavated from this area (i.e. beyond a depth of 2m)

4.2 Assessment and Management of Excavated Material

The following key factors should be considered in relation to waste classification assessment and management of surplus materials:

- A waste classification can be completed in-situ or on stockpiled material;
- Care should be taken to ensure that the various waste streams and soil types (i.e. fill versus VENM) are kept separate. Mixtures of fill and natural material would be classified as fill (or possibly as ENM if assessed accordingly); and
- If a VENM assessment is not undertaken prior to excavation of the natural material, stockpiled natural material may need to be assessed in accordance with the *The Excavated Natural Material Exemption* (2012[9]).

The management requirements for the fill soils (in relation to waste disposal) will vary depending on when the waste classification assessment is completed. In the event that the waste classification is undertaken whilst the fill material is still in-situ, the material can be excavated and loaded directly into trucks for transport to landfill.

[9] Protection of the Environment Operations (Waste) Regulation 2005 – General Exemption Under Part 6, Clause 51 and 51A, The Excavated Natural Material Exemption, 2012 (ENM Exemption 2012)

Specific Work Health and Safety (WHS) requirements may apply to this process in the event that asbestos or other contaminants are identified during the waste classification assessment.

If the fill material is excavated and stockpiled prior to the waste classification assessment, an appropriate strategy should be implemented to limit the spread of dust during the excavation works, and limit erosion of the stockpiled material. As a minimum, the stockpile(s) should be covered with builders plastic and surface water should be directed around the stockpile(s) to avoid erosion and runoff.

Personnel should wear appropriate protective clothing, including gloves, long sleeve shirts, long trousers and steel cap boots. WHS requirements in relation to asbestos-related matters should be addressed in accordance with the relevant codes and standards.

4.3 Waste Classification Assessment

The in-situ waste classification (for fill and natural material) would ideally be completed once the construction contractors are established on-site. Assuming that all areas can be assessed concurrently, the in-situ waste classification assessment should include:

- Sampling and analysis of at least one fill sample per lift pit area. The samples should be analysed for the PCC identified in **Section 3.1**;
- Sampling and analysis of the natural material (as deemed necessary by the environmental consultant); and
- Preparation of a report.

The in-situ waste classification assessment would be expected to cost in the order of $4,000-$5,500 + gst, depending on the amount of laboratory testing, site time and turnaround time required. This assessment could be completed within two to five days.

Assuming that the stockpile assessment can be undertaken during a single visit, the waste classification should include:

- Sampling and analysis of at least three fill samples. The samples should be analysed for the PCC identified in **Section 3.1;**
- An assessment of the natural soils in accordance with the ENM Exemption 2012; and
- Preparation of a report.

The ENM assessment for stockpiled natural material would be expected to cost in the order of $4,000-$5,500 + gst. The waste classification assessment for stockpiled fill would be expected to cost in the order of $2,000-$3,000 + gst. Final costs for both assessments would depend on the amount of laboratory testing, site time and turnaround time required. This assessment could be completed within two to five days.

5 LIMITATIONS

The report limitations are outlined below:

- EIS accepts no responsibility for any unidentified contamination issues at the site. Any unexpected problems/subsurface features that may be encountered during development works should be inspected by an environmental consultant as soon as possible;
- Previous use of this site may have involved excavation for the foundations of buildings, services, and similar facilities. In addition, unrecorded excavation and burial of material may have occurred on the site. Backfilling of excavations could have been undertaken with potentially contaminated material that may be discovered in discrete, isolated locations across the site during construction work;
- This report has been prepared based on site conditions which existed at the time of the investigation; scope of work and limitation outlined in the EIS proposal; and terms of contract between EIS and the client (as applicable);
- The conclusions presented in this report are based on investigation of conditions at specific locations, chosen to be as representative as possible under the given circumstances, visual observations of the site and immediate surrounds and documents reviewed as described in the report;
- Subsurface soil and rock conditions encountered between investigation locations may be found to be different from those expected. Groundwater conditions may also vary, especially after climatic changes;
- The investigation and preparation of this report have been undertaken in accordance with accepted practice for environmental consultants, with reference to applicable environmental regulatory authority and industry standards, guidelines and the assessment criteria outlined in the report;
- Where information has been provided by third parties, EIS has not undertaken any verification process, except where specifically stated in the report;
- EIS has not undertaken any assessment of off-site areas that may be potential contamination sources or may have been impacted by site contamination, except where specifically stated in the report;
- EIS accept no responsibility for potentially asbestos containing materials that may exist at the site. These materials may be associated with demolition of pre-1990 constructed buildings or fill material at the site;
- EIS have not and will not make any determination regarding finances associated with the site;
- Additional investigation work may be required in the event of changes to the proposed development or landuse. EIS should be contacted immediately in such circumstances;
- Material considered to be suitable from a geotechnical point of view may be unsatisfactory from a soil contamination viewpoint, and vice versa; and

- This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose.

LIST OF IN-TEXT TABLES

IMPORTANT INFORMATION ABOUT THIS REPORT

These notes have been prepared by EIS to assist with the assessment and interpretation of this report.

The Report is Based on a Unique Set of Project Specific Factors:
This report has been prepared in response to specific project requirements as stated in the EIS proposal document which may have been limited by instructions from the client. This report should be reviewed, and if necessary, revised if any of the following occur:

- the proposed land use is altered;
- the defined subject site is increased or sub-divided;
- the proposed development details including size, configuration, location, orientation of the structures or landscaped areas are modified;
- the proposed development levels are altered, eg addition of basement levels; or
- ownership of the site changes.

EIS/J&K will not accept any responsibility whatsoever for situations where one or more of the above factors have changed since completion of the assessment. If the subject site is sold, ownership of the assessment report should be transferred by EIS to the new site owners who will be informed of the conditions and limitations under which the assessment was undertaken. No person should apply an assessment for any purpose other than that originally intended without first conferring with the consultant.

Changes in Subsurface Conditions
Subsurface conditions are influenced by natural geological and hydrogeological process and human activities. Groundwater conditions are likely to vary over time with changes in climatic conditions and human activities within the catchment (e.g. water extraction for irrigation or industrial uses, subsurface waste water disposal, construction related dewatering). Soil and groundwater contaminant concentrations may also vary over time through contaminant migration, natural attenuation of organic contaminants, ongoing contaminating activities and placement or removal of fill material. The conclusions of an assessment report may have been affected by the above factors if a significant period of time has elapsed prior to commencement of the proposed development.

This Report is Based on Professional Interpretations of Factual Data
Site assessments identify actual subsurface conditions at the actual sampling locations at the time of the investigation. Data obtained from the sampling and subsequent laboratory analyses, available site history information and published regional information is interpreted by geologists, engineers or environmental scientists and opinions are drawn about the overall subsurface conditions, the nature and extent of contamination, the likely impact on the proposed development and appropriate remediation measures.

Actual conditions may differ from those inferred, because no professional, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from predictions. Nothing can be done to prevent the unanticipated, but steps can be taken to help minimise the impact. For this reason, site owners should retain the services of their consultants throughout the development stage of the project, to identify variances, conduct additional tests which may be needed, and to recommend solutions to problems encountered on site.

Assessment Limitations
Although information provided by a site assessment can reduce exposure to the risk of the presence of contamination, no environmental site assessment can eliminate the risk. Even a rigorous professional assessment may not detect all contamination on a site. Contaminants may be present in areas that were not surveyed or sampled, or may migrate to areas which showed no signs of contamination when sampled. Contaminant analysis cannot possibly cover every type of contaminant which may occur; only the most likely contaminants are screened.

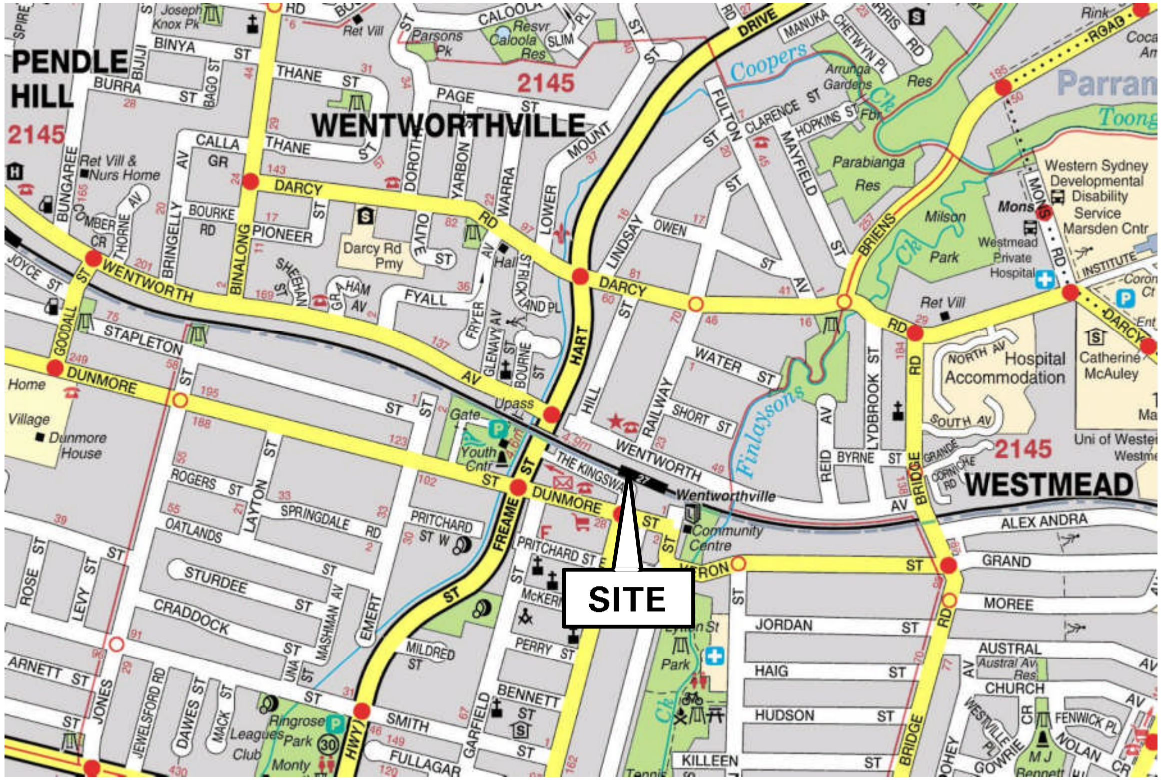
Misinterpretation of Site Assessments by Design Professionals
Costly problems can occur when other design professionals develop plans based on misinterpretation of an assessment report. To minimise problems associated with misinterpretations, the environmental consultant should be retained to work with appropriate professionals to explain relevant findings and to review the adequacy of plans and specifications relevant to contamination issues.

Logs Should not be Separated from the Assessment Report
Borehole and test pit logs are prepared by environmental scientists, engineers or geologists based upon interpretation of field conditions and laboratory evaluation of field samples. Logs are normally provided in our reports and these should not be re-drawn for inclusion in site remediation or other design drawings, as subtle but significant drafting errors or omissions may occur in the transfer process. Photographic reproduction can eliminate this problem, however contractors can still misinterpret the logs during bid preparation if separated from the text of the assessment. If this occurs, delays, disputes and unanticipated costs may result. In all cases it is necessary to refer to the rest of the report to obtain a proper understanding of the assessment. Please note that logs with the 'Environmental Log' header are not suitable for geotechnical purposes as they have not been peer reviewed by a Senior Geotechnical Engineer.

To reduce the likelihood of borehole and test pit log misinterpretation, the complete assessment should be available to persons or organisations involved in the project, such as contractors, for their use. Denial of such access and disclaiming responsibility for the accuracy of subsurface information does not insulate an owner from the attendant liability. It is critical that the site owner provides all available site information to persons and organisations such as contractors.

Read Responsibility Clauses Closely
Because an environmental site assessment is based extensively on judgement and opinion, it is necessarily less exact than other disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, model clauses have been developed for use in written transmittals. These are definitive clauses designed to indicate consultant responsibility. Their use helps all parties involved recognise individual responsibilities and formulate appropriate action. Some of these definitive clauses are likely to appear in the environmental site assessment, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to any questions.

REPORT FIGURES



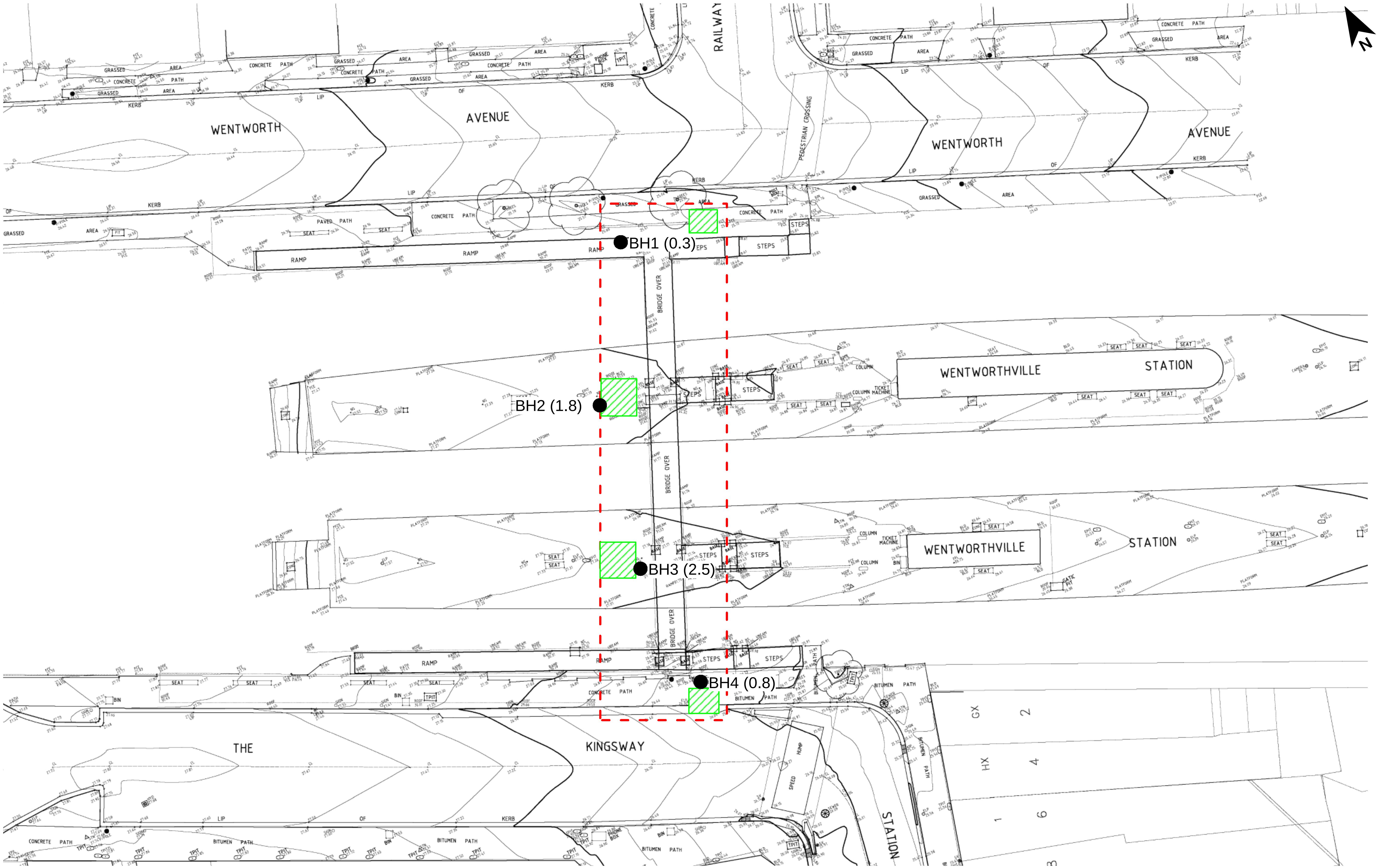
N

NOTES:
Figure 1 has been recreated from UBD on disc (version 5.0) and http://maps.six.nsw.gov.au/. Figure is not to scale.

UBD Map ref: 190 F16

Reference should be made to the report text for a full understanding of this plan.

EIS ENVIRONMENTAL INVESTIGATION SERVICES	Project Number: E26853KP	Title: SITE LOCATION PLAN
	Figure: 1	Address: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW



LEGEND:

Approximate site boundary

BH1 (0.3) JK borehole location, number and depth of fill (m)

Proposed lift location

NOTES:
Figure 2 has been recreated from a plan provided by Cardno that was used for the JK Geotechnics Figure 1.

The fill depths shown include the depth to the base of the fill from the surface level of the borehole (i.e. may include pavement thickness and voids etc).

The borehole locations presented on this plan have been established from site measurements only and should not be construed as survey points.

Reference should be made to the report text for a full understanding of this plan.

Approximate Scale (m): 0 – 20	EIS ENVIRONMENTAL INVESTIGATION SERVICES	Project Number: E26853KP	Title: JK BOREHOLE LOCATION PLAN
		Figure: 2	Address: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Appendix A: JK Borehole Logs and Explanatory Notes

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
1
1/1

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S
Date: 12-6-14
Method: SPIRAL AUGER DANDO TERRIER
R.L. Surface: ≈ 25.6m
Datum: AHD
Logged/Checked by: A.P.C./P.S.

Groundwater Record	Samples (ES / U50 / DB / DS)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			FILL: Silty clay, medium plasticity, brown, with fine to coarse grained sandstone and igneous gravel, roots and root fibres.	MC<PL			GRASS COVER
					CH	SILTY CLAY: high plasticity, brown mottled red brown, with fine to medium grained ironstone gravel.	MC<PL	H	>600 >600 >600	RESIDUAL
	DS	N = 22 7,9,13	1							
					-	SHALE: light grey and orange brown, with iron indurated M-H strength bands.	XW	EL		VERY LOW 'TC' BIT RESISTANCE
	DS	N = 87 27,42,45	2							
							XW-DW	EL-VL		VERY LOW TO LOW RESISTANCE
	DS		3			SHALE: dark grey and brown.	DW	VL-L		LOW RESISTANCE
								L		
	DS									
			4			END OF BOREHOLE AT 3.8m				'TC' BIT REFUSAL
			5							
			6							
			7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
2
1/2

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S
Date: 12-6-14
Method: HAND AUGER/ WASHBORE
R.L. Surface: ≈ 27.1m
Datum: AHD
Logged/Checked by: A.P.C./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION OF AUGERING					REFER TO DCP TEST RESULTS	0			ASPHALTIC CONCRETE: 50mm.t				
									FILL: Sandy gravel, fine to coarse grained shale and igneous, brown, fine to coarse grained sand.	D			APPEARS POORLY COMPACTED
ON COMPLETION OF CORING ▼						1			FILL: Silty clay, high plasticity, light grey mottled red brown, with fine to coarse grained ironstone, shale and igneous gravel.				HAND AUGER REFUSAL ON OBSTRUCTION COMMENCE WASHBORING
						2			REFER TO CORED BOREHOLE LOG				
						3							
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

CORED BOREHOLE LOG

Borehole No.
2
2/2

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S | **Core Size:** NMLC | **R.L. Surface:** ≈ 27.1m
Date: 12-6-14 | **Inclination:** VERTICAL | **Datum:** AHD
Drill Type: MELVELLE | **Bearing:** - | **Logged/Checked by:** A.P.C./P.S.

Water Loss/Level	Barrel Lift	Depth (m)	Graphic Log	CORE DESCRIPTION Rock Type, grain characteristics, colour, structure, minor components.	Weathering	Strength	POINT LOAD STRENGTH INDEX $I_s(50)$ EL VL L M H VH EH	DEFECT SPACING (mm) 500 300 100 50 30 10	DEFECT DETAILS DESCRIPTION Type, inclination, thickness, planarity, roughness, coating. Specific	General
		1								
				START CORING AT 1.82m						
FULL RET -URN		2		SILTY CLAY: high plasticity, light grey mottled brown, with L-M strength shale bands.	MC>PL	VSt			HP 230,250,250kPa	
				CORE LOSS 0.24m						
				SILTY CLAY: high plasticity, light grey mottled orange brown, with L-M strength shale bands.	MC>PL	VSt			HP 250,230,250kPa HP 250,250,280kPa	
				CORE LOSS 0.18m						
		3		SHALE: light grey mottled orange brown.	XW	EL				
					DW	L-M			- CS, 5°, 40mm.t - CS, 5°, 20mm.t - CS, 10°, 5mm.t - CS, 5°, 2mm.t - CS, 5°, 5mm.t - J, 35°, P, S - J, 50°, P, S - J, 20°, Un, R, IS - J, 20°, UN, R, IS - J, 20°, Un, R, IS - CS, 10°, 30mm.t	
		4		SHALE: dark grey.						
				END OF BOREHOLE AT 4.38m						
		5								
		6								
		7								
		8								

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
3
1/2

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S
Date: 13-6-14
Method: HAND AUGER WASHBORING
R.L. Surface: ≈ 27.2m
Datum: AHD
Logged/Checked by: A.P.C./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION OF AUGERING					REFER TO DCP TEST RESULTS	0			ASPHALTIC CONCRETE: 80mm.t				
									FILL: Silty clay, high plasticity, brown mottled orange brown, with fine to coarse grained igneous and sandstone gravel, concrete, brick and slag fragments.				APPEARS POORLY COMPACTED
						1			FILL: Sandy gravel, fine to coarse grained igneous, brown, fine to coarse grained sand, with brick, glass and concrete fragments.	MC>PL			HAND AUGER REFUSAL ON OBSTRUCTION COMMENCE WASHBORING
						2							
									REFER TO CORED BOREHOLE LOG				
						3							
						4							
						5							
						6							
						7							

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GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

CORED BOREHOLE LOG

Borehole No.
3

Client: CARDNO (NSW/ACT) PTY LTD

Project: PROPOSED ACCESS UPGRADE

Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S　**Core Size:** NMLC　**R.L. Surface:** N/A

Date: 13-6-14　**Inclination:** VERTICAL　**Datum:**

Drill Type: MELVELLE　**Bearing:** -　**Logged/Checked by:** A.P.C./P.S.

Water Loss/Level	Barrel Lift	Depth (m)	Graphic Log	CORE DESCRIPTION Rock Type, grain characteristics, colour, structure, minor components.	Weathering	Strength	POINT LOAD STRENGTH INDEX $I_S(50)$ EL VL L M H VH EH	DEFECT SPACING (mm) 500 300 100 50 30 10	DEFECT DETAILS – DESCRIPTION Type, inclination, thickness, planarity, roughness, coating. Specific	General
		2		START CORING AT 2.33m						
				CORE LOSS 0.19m						
FULL RET-URN		3		SHALE: grey and brown.	DW	L-M			- XWS, 5°, 50mm.t - J, SUBVERTICAL, Un, R - J, 70°, P, S, CLAY SMEAR - CS, 30°, 10mm.t - CS, 5°, 5mm.t - XWS, 5°, 10mm.t - J, SUBVERTICAL, Un, R, IS - CS, 10°, 40mm.t - CS, 5°, 30mm.t	
				END OF BOREHOLE AT 3.41m						
		4								
		5								
		6								
		7								
		8								
		9								

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GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
4

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S
Date: 13-6-14
Method: HAND AUGER WASHBORING
R.L. Surface: ≈ 26.7m
Datum: AHD
Logged/Checked by: A.P.C./P.S.

Groundwater Record	SAMPLES ES	U50	DB	DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION OF AUGERING					REFER TO DCP TEST RESULTS	0			FILL: Silty clay, high plasticity, brown, with roots and root fibres.	MC<PL			GARDEN BED
									FILL: Silty clay, high plasticity, brown mottled red brown, with fine to coarse grained sandstone and igneous gravel, glass, brick and plastic fragments.	MC>PL			APPEARS POORLY COMPACTED
						1		CH	SILTY CLAY: high plasticity, red brown, with fine to coarse grained ironstone gravel.	MC>PL	H		RESIDUAL
						2			REFER TO CORED BOREHOLE LOG				
						3							
						4							
						5							
						6							
						7							

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CORED BOREHOLE LOG

Borehole No.
4
2/2

Client: CARDNO (NSW/ACT) PTY LTD
Project: PROPOSED ACCESS UPGRADE
Location: WENTWORTHVILLE STATION, WENTWORTHVILLE, NSW

Job No. 26853S | **Core Size:** NMLC | **R.L. Surface:** ≈ 26.7m
Date: 13-6-14 | **Inclination:** VERTICAL | **Datum:**
Drill Type: MELVELLE | **Bearing:** - | **Logged/Checked by:** J.P./P.S.

Water Loss/Level	Barrel Lift	Depth (m)	Graphic Log	CORE DESCRIPTION: Rock Type, grain characteristics, colour, structure, minor components.	Weathering	Strength	POINT LOAD STRENGTH INDEX $I_S(50)$ (EL VL L M H VH EH)	DEFECT SPACING (mm) (500 300 100 50 30 10)	DEFECT DETAILS – DESCRIPTION: Type, inclination, thickness, planarity, roughness, coating. Specific / General
		1		START CORING AT 1.78m					
				CORE LOSS 0.12m					
▼ ON COMPLE-TION OF CORING FULL RET-URN		2 3		SHALE: grey and yellow brown, with ironstone indurated bands.	DW	M	• •		- FRAGMENTED ZONE, 150mm.t - CS, 0-5°, 5mm.t - FRAGMENTED ZONE, 80mm.t - J, 90°, P, S - J, 45°, Un, R - Cr, 20mm.t - J, 90°, Un, R - 2X J, 80 & 30°, P, S, IS - CS, 0-5°, 20mm.t - CS, 0-5°, 20mm.t - CS, 0-5°, 10mm.t - 5xCS, 0-5°, 5-20mm.t SPACED AT 20-40mm - J, 90°, P, S, IS
		4 5 6 7 8		END OF BOREHOLE AT 3.29m					

REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the SAA Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (e.g. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.075mm
Sand	0.075 to 2mm
Gravel	2 to 60mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose	less than 4
Loose	4 – 10
Medium dense	10 – 30
Dense	30 – 50
Very Dense	greater than 50

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength kPa
Very Soft	less than 25
Soft	25 – 50
Firm	50 – 100
Stiff	100 – 200
Very Stiff	200 – 400
Hard	Greater than 400
Friable	Strength not attainable – soil crumbles

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'Shale' is used to describe thinly bedded to laminated siltstone.

SAMPLING

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

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained 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.

Details of the type and method of sampling used are given on the attached logs.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu 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. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Premature refusal of the hand augers can occur on a variety of materials such as hard clay, gravel or ironstone, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock fragments. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually 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.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as CORE LOSS. The location of losses are determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the top end of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 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 with a tapered shoe, under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm 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:

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

  N = 13
  4, 6, 7

- 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

  N>30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

Occasionally, the drop hammer is used to drive 50mm diameter thin walled sample tubes (U50) in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

A modification to the SPT test is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as "N_c" on the borehole logs, together with the number of blows per 150mm penetration.

Static Cone Penetrometer Testing and Interpretation: Cone penetrometer testing (sometimes referred to as a Dutch Cone) described in this report has been carried out using an Electronic Friction Cone Penetrometer (EFCP). The test is described in Australian Standard 1289, Test F5.1.

In the tests, a 35mm diameter rod with a conical tip 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 frictional resistance on a separate 134mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by 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 as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

  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% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between EFCP and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of EFCP values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a rod into the ground with a sliding hammer and counting the blows for successive 100mm increments of penetration.

Two relatively similar tests are used:

- Cone penetrometer (commonly known as the Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS1289, Test F3.2). The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various Road Authorities.
- Perth sand penetrometer – a 16mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test F3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds. In any case, the boreholes or test pits represent only a very small sample of the total subsurface conditions.

The attached explanatory notes define the terms and symbols used in preparation of the logs.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than "straight line" variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems:

- Although groundwater may be present, in low permeability soils it 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 weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to 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 perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg bricks, steel etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably determine the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soil for Engineering Purposes'*. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg to a twenty storey building). If this happens, the company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects 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 this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.

If these occur, the company will be pleased to assist with investigation or advice to resolve any problems occurring.

SITE ANOMALIES

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

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

Attention is drawn to the document *'Guidelines for the Provision of Geotechnical Information in Tender Documents'*, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended 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. 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.

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. License to use the documents may be revoked without notice if the Client is in breach of any objection to make a payment to us.

REVIEW OF DESIGN

Where major civil or structural developments are proposed <u>or</u> where only a limited investigation has been completed <u>or</u> where the geotechnical conditions/ constraints are quite complex, it is prudent to have a joint design review which involves a senior geotechnical engineer.

SITE INSPECTION

The company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

i) a site visit to confirm that conditions exposed are no worse than those interpreted, to
ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types such as appropriate footing or pier founding depths, or
iii) full time engineering presence on site.

GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CH)
- SILT (ML, MH)
- SAND (SP, SW)
- GRAVEL (GP, GW)
- SANDY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SAND (SC)
- SILTY SAND (SM)
- GRAVELLY CLAY (CL, CH)
- CLAYEY GRAVEL (GC)
- SANDY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- BASALT, ANDESITE
- QUARTZITE

DEFECTS AND INCLUSIONS

- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

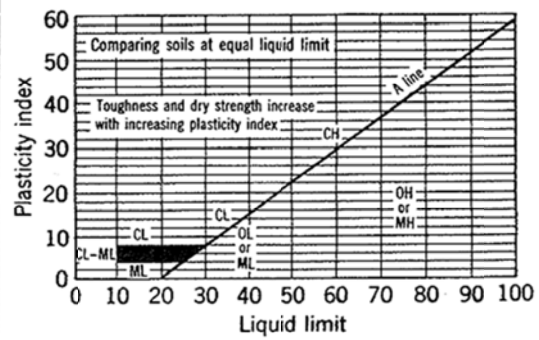
OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

Major Division	Subdivision	Fines	Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights)	Group Symbols [a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils: More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye)	Gravels: More than half of coarse fraction is larger than 4 mm sieve size	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols. $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or *PI* less than 4. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
	Sands: More than half of coarse fraction is smaller than 4 mm sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7

Identification Procedures on Fraction Smaller than 380 μm Sieve Size

Major Division	Subdivision	Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Fine-grained soils: More than half of material is *smaller* than 75 μm sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions. Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines).
2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

LOG SYMBOLS

LOG COLUMN	SYMBOL	DEFINITION
Groundwater Record	▼	Standing water level. Time delay following completion of drilling may be shown.
	—C—	Extent of borehole collapse shortly after drilling.
	▶—	Groundwater seepage into borehole or excavation noted during drilling or excavation.
Samples	ES	Soil sample taken over depth indicated, for environmental analysis.
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.
	DB	Bulk disturbed sample taken over depth indicated.
	DS	Small disturbed bag sample taken over depth indicated.
	ASB	Soil sample taken over depth indicated, for asbestos screening.
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.
	SAL	Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength.
	PID = 100	Photoionisation detector reading in ppm (Soil sample headspace test).
Moisture Condition (Cohesive Soils)	MC>PL	Moisture content estimated to be greater than plastic limit.
	MC≈PL	Moisture content estimated to be approximately equal to plastic limit.
	MC<PL	Moisture content estimated to be less than plastic limit.
(Cohesionless Soils)	D	DRY – Runs freely through fingers.
	M	MOIST – Does not run freely but no free water visible on soil surface.
	W	WET – Free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS	VERY SOFT – Unconfined compressive strength less than 25kPa
	S	SOFT – Unconfined compressive strength 25-50kPa
	F	FIRM – Unconfined compressive strength 50-100kPa
	St	STIFF – Unconfined compressive strength 100-200kPa
	VSt	VERY STIFF – Unconfined compressive strength 200-400kPa
	H	HARD – Unconfined compressive strength greater than 400kPa
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other tests.
Density Index/ Relative Density (Cohesionless Soils)		**Density Index (I_D) Range (%)** — **SPT 'N' Value Range (Blows/300mm)**
	VL	Very Loose <15 — 0-4
	L	Loose 15-35 — 4-10
	MD	Medium Dense 35-65 — 10-30
	D	Dense 65-85 — 30-50
	VD	Very Dense >85 — >50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other tests.
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Tungsten carbide wing bit.
	T_{60}	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.

LOG SYMBOLS continued

ROCK MATERIAL WEATHERING CLASSIFICATION

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Soil developed on extremely weathered 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 rock	XW	Rock is weathered to such an extent that it has "soil" properties, ie it either disintegrates or can be remoulded, in water.
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Journal of Rock Mechanics, Mining, Science and Geomechanics. Abstract Volume 22, No 2, 1985.

TERM	SYMBOL	Is (50) MPa	FIELD GUIDE
Extremely Low:	EL		Easily remoulded by hand to a material with soil properties.
-----------------------	--------------	0.03	
Very Low:	VL		May be crumbled in the hand. Sandstone is "sugary" and friable.
-----------------------	--------------	0.1	
Low:	L		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
-----------------------	--------------	0.3	
Medium Strength:	M		A piece of core 150mm long x 50mm dia. can be broken by hand with difficulty. Readily scored with knife.
-----------------------	--------------	1	
High:	H		A piece of core 150mm long x 50mm dia. core cannot be broken by hand, can be slightly scratched or scored with knife; rock rings under hammer.
-----------------------	---------------	3	
Very High:	VH		A piece of core 150mm long x 50mm dia. may be broken with hand-held pick after more than one blow. Cannot be scratched with pen knife; rock rings under hammer.
-----------------------	---------------	10	
Extremely High:	EH		A piece of core 150mm long x 50mm dia. is very difficult to break with hand-held hammer. Rings when struck with a hammer.

ABBREVIATIONS USED IN DEFECT DESCRIPTION

ABBREVIATION	DESCRIPTION	NOTES
Be	Bedding Plane Parting	Defect orientations measured relative to the normal to the long core axis (ie relative to horizontal for vertical holes)
CS	Clay Seam	
J	Joint	
P	Planar	
Un	Undulating	
S	Smooth	
R	Rough	
IS	Ironstained	
XWS	Extremely Weathered Seam	
Cr	Crushed Seam	
60t	Thickness of defect in millimetres	