REPORT

TO

KARIMBLA CONSTRUCTION SERVICES PTY LTD

ON

HYDROGEOLOGICAL ASSESSMENT

FOR

PROPOSED RESIDENTIAL DEVELOPMENT (STAGE 1)

AT

14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

2 March 2011

Ref: 23540Zrpt3

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
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1 INTRODUCTION

This report presents the results of our hydrogeological assessment of the site for Stage 1 of the proposed residential development at 14-18 Boondah Road, Warriewood. The assessment was commissioned by Karimbla Construction Services Pty Ltd (Order No 30328, dated 30 November 2010). The commission was in accordance with our proposal (ref P33279Zemail) dated 29 November 2010.

We understand that the proposed Stage 1 development will comprise seven, three to five storey unit buildings, over a common stepped basement level. The buildings and basement layout are indicated on attached Figures 1 and 2, respectively. Bulk excavations to depths between about 1m and 4.5m will be required to achieve the finished basement floor reduced levels (RLs) between 4.6m and 1.6m.

A road extending along the west and south of the proposed basement and then eastwards to Boondah Street, together with a Bio-Retention Basin (Basin A), to the south just across the above road are also proposed and will be constructed during the initial stages of the development.

Based on the provided civil drawings (Project No 10-23, Drg Nos C003^{A}, C010^{B} to CO15^{B}, CO40^{A} and CO42^{A}) prepared by AT&L, the underside of the Bio-Retention Basin will be at RL2.01m.

The purpose of the assessment was to address some of the hydrogeological issues associated with the Project Approval Conditions with respect to Stage 1 of the proposed residential development. In particular, Conditions B20, C19a to C19d and C19h to C19k have been addressed.

Jeffery and Katauskas Pty Ltd (J&K) previously completed a geotechnical investigation of the greater site area and the results were presented in our report (ref. 23540Zrpt) dated 8 December 2009. Relevant borehole logs and EFCP test results are included in attached Appendix A. We also completed a hydrogeological assessment which was presented in our report (ref 23540Z Let3) dated 13 September 2010. The present report incorporates the results of, and supersedes, the previous hydrogeological report. We further note that Environmental Investigation Services (EIS), the environmental division of J&K, have addressed the remaining hydrogeological, and also the acid sulphate soils, Conditions. This report must therefore be read in conjunction with the EIS report (ref E23540KBrpt).

2 STANDPIPE INSTALLATION AND TESTING

Standpipes were installed at five locations across the site in order to augment the previous hydrogeological information and for groundwater monitoring and testing purposes. The installation comprised the auger drilling of four boreholes (BH201 to BH204) just into the bedrock to depths between 1.3m and 4.5m. A standpipe was installed into each borehole as indicated for 'shallow' standpipes in attached Figure 5. In addition, three boreholes (BH201B, BH202B and BH205B) were auger drilled at least 3m into bedrock to depths between 4.5m and 6m. A standpipe was installed into each borehole as indicated for 'deep' standpipes in attached Figure 5, in an attempt to isolate the groundwater within the rock mass from the groundwater within the overlying soil profile.

Finally, BH205 was auger drilled 3m into bedrock to a depth of 6.5m and a full depth standpipe installed in an attempt to assess whether effective isolation of the rock mass had indeed been achieved in the adjacent BH205B standpipe. The standpipe installation was modified from that of the 'shallow' standpipe to take into account the additional depth into bedrock.

The borehole/standpipe locations, as indicated in Figure 1, were set out using taped measurements from existing surface features. The surface RLs at the borehole/standpipe locations were estimated by interpolation between spot heights shown on the provided unreferenced survey plan.

The subsurface soil and rock profile was assessed by logging the materials recovered on the auger during borehole drilling and must therefore be considered to be indicative only. Groundwater measurements were made during and shortly following completion of drilling individual boreholes. Two and three days following completion of drilling, the standpipes were developed as groundwater wells and additional groundwater level measurements were completed.

In order to assess the permeability of the subsurface soil and rock mass, each of the standpipes was pumped and the rate of groundwater recovery was measured. Using established seepage formulae, an approximate insitu permeability coefficient for the relevant horizon tested, was calculated.

Our geotechnical engineer was present full time on site during the fieldwork and set out the borehole locations, logged the subsurface profile, directed standpipe installation, and carried out the pump-out tests.

3 SITE DESCRIPTION

The Stage 1 site is located over the north-western portion of the greater site area, as indicated on Figure 1.

The greater site has an irregular plan shape, covers an area of about 81,000m^2, and is bounded by MacPherson Street along the north and Boondah Street along the east. From a high point in the local topography near the north-east corner of the site, the ground slopes down to the south and south-west at between 1° and 3°.

At the time of the investigation, the site was occupied by a number of fenced off paddocks. The vegetation cover was generally grass with dense trees and shrubs concentrated in an east-west direction over the central portion. Metal sheds and workshop buildings were located over the south-east, and a number of residences with associated outbuildings and driveways were scattered along the north.

A wetland area was located beyond the southern site boundary. Medium density residential developments were located beyond the western site boundary and across MacPherson Street to the north. The latter development included drainage diversions and small dams probably associated with flood control.

4 SUBSURFACE CONDITIONS

Based on the previous geotechnical investigation, the Stage 1 site (the site) was found to be underlain by a surficial topsoil/fill, over natural clayey soils then sandstone bedrock at relatively shallow depth. A relatively shallow groundwater level was also encountered.

Copies of the relevant borehole logs and Electrical Friction Cone Penetration (EFCP) results are included in Appendix A. The investigation locations are indicated on attached Figures 1 and 2.

In essence, the groundwater surface was assessed to have an overall slope down towards the south-west of about 1.5° to 2°. Over the north-east, the groundwater surface was located over the bedrock surface and/or within the upper weathered bedrock profile. Over the south-west, where the bedrock level is much deeper, the groundwater surface was located at increasing height above the bedrock. Extrapolation of the ground surface and groundwater surface levels beyond the site boundary indicates that the groundwater daylights some distance to the south-west which is consistent with the location of existing wetlands in that area.

A basement plan of the Stage 1 development is presented in Figure 2, with rock and groundwater surface level contours superimposed. A hydrogeological cross-sectional sketch through the site is presented in Figure 3.

5 HYDROGEOLOGICAL EVALUATION

It is evident that groundwater originating from the higher lying catchment to the north-east flows down to the south-west across the site and feeds the wetlands beyond. The wetlands are also fed by Fern Creek which flows from the west and discharges across the south-western corner of the site.

Reference to the Mona Vale orthophoto (U2767-4), 1:4000 series, indicates that Narrabeen Creek to the north and north-east is at a lower level than the groundwater level beneath the north-eastern portion of the site. The groundwater catchment is thus likely to be of limited extent, even though a dam and some drainage diversions have been constructed to the north between MacPherson Street and Narrabeen Creek.

The same orthophoto also indicates a minor ridgeline roughly along MacPherson Street, forming a watershed in the local topography.

As indicated in Figure 3, the proposed basement level will generally extend into bedrock and will also intersect the groundwater. The proposed basement could thus act as a cut-off resulting in a build-up of uphill groundwater levels and also lead to a change in downslope groundwater flows and flow paths.

In order to reduce the effect that the proposed basement will have on the groundwater, a bypass system with downslope infiltration will be provided so as to maintain the groundwater regime around the site and also the flow rates into the wetlands beyond the southern site boundary.

We have reviewed the data obtained from the borehole pump-out tests. Average permeability values of about $8x10^{-7}$m/sec and $2x10^{-7}$m/sec were indicated for the subsoils and underlying rock mass, respectively. However, examination of the results from BH205 and BH205B indicates that probably the rock mass was not effectively isolated from the overlying soils, and that the rock mass is relatively impermeable.

Using the above calculated permeabilities, seepage analyses were carried out using the 2D finite element computer program SEEP/W. A sensitivity analysis was also undertaken by varying the relative permeability of the rock mass.

Based on the above, the groundwater inflow rate along the upslope (north-eastern) side of the proposed basement of 4 litres/day/m or say, 720 litres/day has been estimated. A printout of the seepage analysis is presented in Figure 6. For the downslope infiltration we have carried out an analysis and estimate that the relationship between the area required for effective infiltration and the inflow rate is $A = q^2 x 10^{-4}$, where A is in m^2 and the inflow rate, q, is in l/day. The analysis assumed a permeability value of 10^{-7}m/sec for the soil profile and a water head of 0.4m.

6 RECOMMENDATIONS

As the proposed basement excavation will intersect the groundwater, temporary dewatering will be required during construction. Over the longer term, a bypass system with downslope infiltration will be adopted as indicated in Figure 4.

During construction, groundwater flows into the excavation must be collected in sumps and pumped to the proposed Bio-Retention Basin (Basin A) which will already have been constructed. From the basin, there will be controlled discharge to the nearby wetlands. The groundwater would need to be tested and, depending on groundwater quality, treatment may be required. In this regard, reference to the EIS report must be made. A geotechnical inspection should be carried out during excavation once the groundwater has been encountered and also once the bulk excavation is complete. The inspection is intended to confirm the groundwater conditions and to refine the recommendations which follow, if appropriate.

Also, continuous groundwater level monitoring within the existing standpipes must be carried out on a weekly basis during construction. This will allow the groundwater inflow rate to be finalised and the bypass design to be refined, if necessary. The existing standpipes must therefore be maintained so that ongoing future groundwater monitoring and testing can be carried out.

The purpose of the proposed bypass system is to collect all groundwater build-up along the upslope side of the basement, divert it around the basement, and then allow it to drain evenly by infiltration into the wetlands beyond.

Following completion of the basement structure, the bypass pipes can be installed onto a proposed bed with an even grade to the lines and levels indicated on attached Figure 4.

The batter behind the uphill basement wall along Macpherson Street should be backfilled using a free-draining material comprising a strong, durable, single size (say 20mm) washed aggregate, such as ‘blue metal’ gravel. The batter behind the remaining basement walls should be backfilled to bed level using the excavated spoil (clay and ripped sandstone) compacted in 200mm thick layers to a minimum density of 95% of Standard Maximum Dry Density (SMDD) and within +3% and −2% of Standard Optimum Moisture Content (SOMC).

The bypass pipes should comprise 'ag-lines' which are designed to accommodate the above estimated flow rates but with a factor of safety of 3 to take variations in subsurface conditions, simplifications/assumptions in the pump-out tests and seepage analyses and possible partial pipe siltation into account.

The batter above the pipes must be backfilled using a free-draining material as above, and be protected with a clay capping about 0.5m thick, compacted as above, to reduce the likelihood of stormwater surcharge. A suitably selected geofabric must be provided between the drainage material and the excavated face as well as the clay capping to act as a filter against subsoil erosion.

The two downslope drains should discharge into a filter bed to facilitate infiltration into the ground. The filter bed should comprise a 20mm clean gravel layer over a washed sand layer, wrapped in a geotextile fabric (such as Bidim A34), to act as a filter against subsoil erosion. Each filter bed should cover an area of 52m^2 which allows for a factor of safety of 2 (ie double the anticipated inflow). Due to the presence of a road and dam immediately downslope of the basement, the infiltration beds must be located beyond the dam. This will require the drains to extend beneath the proposed road. We suggest a layer of no fines concrete which will provide a flow rate equivalent to each of the drain pipes. The no fines concrete should be contained over its base and sides within a concrete lining to reduce seepage into the subgrade beneath the road reserve.

7 CONCLUSIONS

Provided the above recommendations are implemented, there should be little or no build-up of uphill groundwater levels. Further, the groundwater will not be lowered or raised below historical levels (other than possibly locally immediately adjacent to the basement) and groundwater flow (both volume and concentration) towards the wetlands will be maintained.

The relevant Project Approval Conditions will thus be satisfied.

8 GENERAL COMMENTS

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. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of Jeffery and Katauskas Pty Ltd. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

Should you require any further information regarding the above please do not hesitate to contact the undersigned.

A ZENON
Senior Associate
For and on behalf of
JEFFERY AND KATAUSKAS PTY LTD.

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No. **201**
1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 13-12-10
Method: SPIRAL AUGER JK300
Logged/Checked by: D.S./
R.L. Surface: ≈ 7.6m
Datum: AHD

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		SM	SILTY SAND: fine to medium grained, brown.	D			
								CL	SILTY CLAY: medium plasticity, orange brown.	MC>PL			
16-12-10						1		-	SANDSTONE: fine to medium grained, light grey.	XW	EL	-	VERY LOW 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 1.5m				50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 1.5m DEPTH, SLOTTED BETWEEN 0m AND 1.5m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 0.1 AND 0.5m, GATIC COVER CONCRETED AT SURFACE NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
						3							
						4							
						5							
						6							
						7							

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BOREHOLE LOG

Borehole No. **201B**
1/1

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 13-12-10
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 7.6m
Datum: AHD
Logged/Checked by: D.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
						0		SM	SILTY SAND: fine to medium grained, brown.	D			
								CL	SILTY CLAY: medium plasticity, orange brown.	MC>PL			
▼ 16-12-10						1		-	SANDSTONE: fine to medium grained, light grey.	-	-	-	VERY LOW 'TC' BIT RESISTANCE
						2							
						3							
▼ ON COMPLETION						4							
						5			END OF BOREHOLE AT 4.5m				50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 4.5m DEPTH, SLOTTED BETWEEN 1.5m AND 4.5m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL 1.2-1.7m AND 0.1-0.5m, GATIC COVER CONCRETED AT SURFACE NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
						6							
						7							

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Borehole No.
202
1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 13-12-10
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 5.4m
Datum: AHD
Logged/Checked by: D.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 sand, fine to medium grained, brown, with root fibres.	D			
								SC	CLAYEY SAND: fine to medium grained, brown.	D	-	-	
16-12-10						1		CL	SANDY CLAY: medium plasticity, orange brown..	MC>PL	-	-	
						2		-	SANDSTONE: fine to medium grained, light grey.	XW	EL	-	VERY LOW 'TC' BIT RESISTANCE
						3			END OF BOREHOLE AT 3.0m				50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 3.0m DEPTH, SLOTTED BETWEEN 0m AND 3m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 0.1 AND 0.5m, GATIC COVER CONCRETED AT SURFACE NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
						4							
						5							
						6							
						7							

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Borehole No. **202B**
1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 13-12-10
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 5.4m
Datum: AHD
Logged/Checked by: D.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
			0			FILL: Silty sand, fine to medium grained, brown, with root fibres.	D			GRASS COVER
					SC	CLAYEY SAND: fine to medium grained, brown.	D	-	-	
16-12-10			1		CL	SANDY CLAY: medium plasticity, orange brown.	MC>PL	-	-	
			2			as above, but orange brown and light grey.				
ON COMPLETION					-	SANDSTONE: fine to medium grained, light grey.	-	-	-	VERY LOW 'TC' BIT RESISTANCE 50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 6.0m DEPTH, SLOTTED BETWEEN 3m AND 6m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 1.5 AND 2.5m & 0.1 AND 0.5m, GATIC COVER CONCRETED AT SURFACE NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
			6			END OF BOREHOLE AT 6.0m				
			7							

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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No. **203**

1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION

Project: PROPOSED RESIDENTIAL DEVELOPMENT

Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z | **Method:** SPIRAL AUGER JK300 | **R.L. Surface:** ≈ 3.0m

Date: 13-12-10 | **Datum:** AHD

Logged/Checked by: D.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 ▼ 16-12-10			0		CL	SANDY CLAY: low plasticity, red brown, with fine to medium grained ironstone gravel and root fibres.	MC>PL			
						SANDY CLAY: low plasticity, light brown, with fine to medium grained ironstone gravel.	MC>PL			
			1			as above, but orange brown.				
			2							
					-	SANDSTONE: fine to medium grained, light grey.	XW	EL	-	VERY LOW 'TC' BIT RESISTANCE
			3							
						END OF BOREHOLE AT 4.5m				50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 3.5m DEPTH, SLOTTED BETWEEN 0.5m AND 3.5m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL 0.1-0.5m, GATIC COVER CONCRETED AT SURFACE NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
			4							
			5							
			6							
			7							

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

Borehole No.
204
1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 14-12-10
Method: SPIRAL AUGER JK300
Logged/Checked by: D.S./
R.L. Surface: ≈ 5.0m
Datum: AHD

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: Sand, fine to coarse grained, grey and brown, with root fibres.	D			GRASSS COVER
					CL	SANDY CLAY: medium plasticity, orange brown..	MC>PL	-	-	
16-12-10			1		-	SANDSTONE: fine to medium grained, light grey and orange brown.	XW	EL	-	VERY LOW 'TC' BIT RESISTANCE
						END OF BOREHOLE AT 1.3m				50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 1.3m DEPTH, SLOTTED BETWEEN 0m AND 1.3m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 0.1 AND 0.5m, GATIC COVER CONCRETED AT SURFACE NOTE BOREHOLE FROM AUGER CUTTINGS
			2							
			3							
			4							
			5							
			6							
			7							

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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
205
1/1

Client: KARIMBLA CONSTRUCTION

Project: PROPOSED RESIDENTIAL DEVELOPMENT

Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z

Date: 14-12-10

Method: SPIRAL AUGER
JK300

R.L. Surface: ≈ 3.1m

Datum: AHD

Logged/Checked by: D.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
			0		SM	SILTY SAND: fine to medium grained, brown, with fine to medium grained ironstone gravel and root fibres.	D			GRASSS COVER
16-12-10					CL	SANDY CLAY: medium plasticity, dark grey.	MC>PL	-	-	
			1			SANDY CLAY: medium plasticity, light brown.				
ON COMPLETION			2		SP	SAND: fine to medium grained, light grey.	W	-	-	
			3		-	SANDSTONE: fine to medium grained, light grey and red brown.	-	-	-	VERY LOW 'TC' BIT RESISTANCE
			4							50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 6.5m DEPTH, SLOTTED BETWEEN 3m AND 6.5m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 0.1 AND 0.5m, GATIC COVER CONCRETED AT SURFACE
			5							
			6							NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
						END OF BOREHOLE AT 6.5m				
			7							

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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

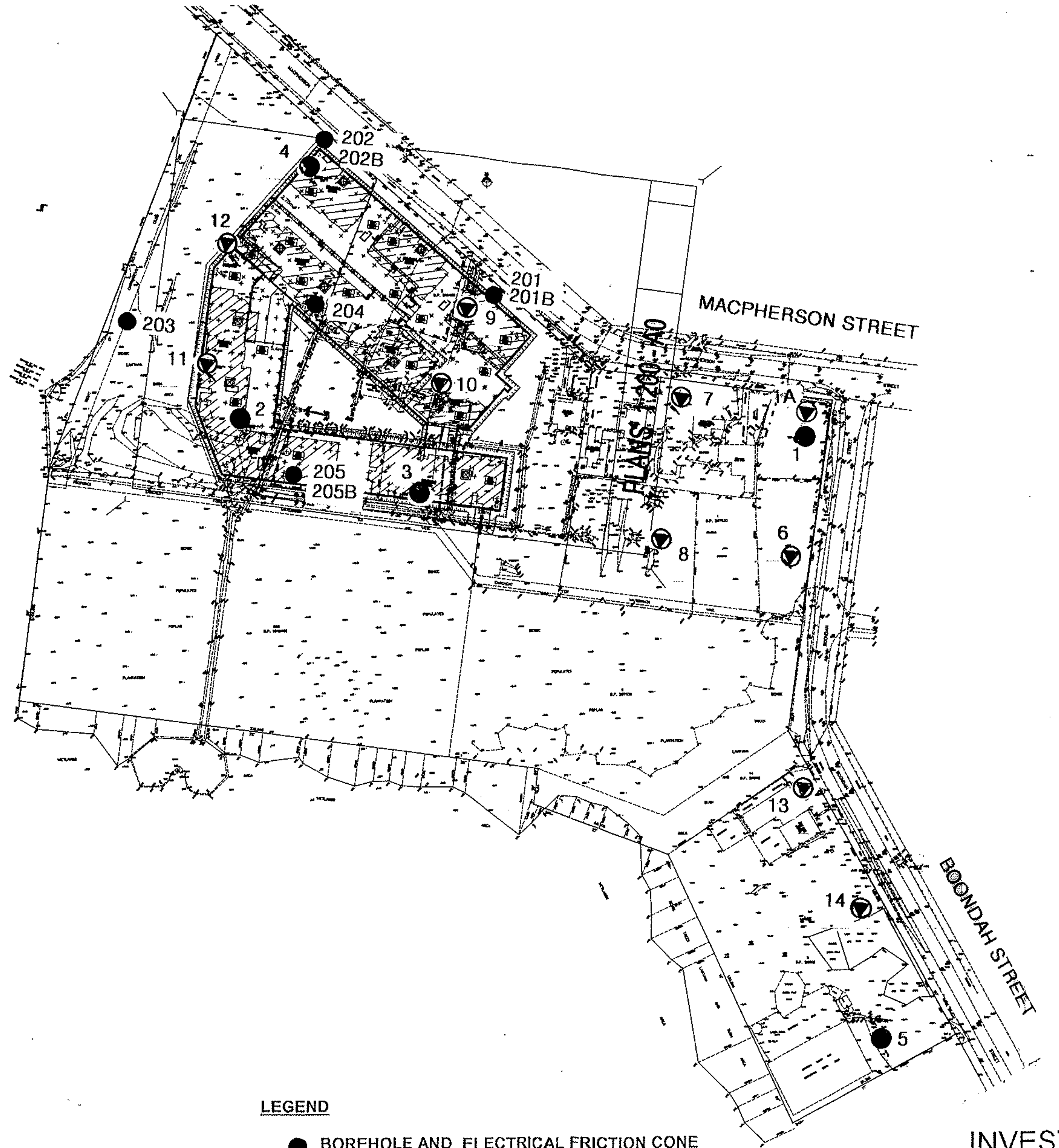
BOREHOLE LOG

Borehole No. **205B**
1/1

Client: KARIMBLA CONSTRUCTION
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 14-12-10
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 3.1m
Datum: AHD
Logged/Checked by: D.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
			0		SM	SILTY SAND: fine to medium grained, brown, with fine to medium grained ironstone gravel and root fibres.	D			GRASSS COVER
16-12-10					CL	SANDY CLAY: medium plasticity, dark grey.	MC>PL	-	-	
			1			as above, but light brown.				
			2		SP	SAND: fine to medium grained, light grey.	W	-	-	
			3		-	SANDSTONE: fine to medium grained, light grey and red brown.	-	-	-	VERY LOW 'TC' BIT RESISTANCE
ON COMPLETION			4							50mm DIA. CLASS 18 PVC STANDPIPE INSTALLED TO 6.0m DEPTH, SLOTTED BETWEEN 3m AND 6.0m, BACKFILLED WITH 2mm SAND, BENTONITE SEAL BETWEEN 2.5-3.5m AND 0.1-0.5m, GATIC COVER CONCRETED AT SURFACE
			5							
			6			END OF BOREHOLE AT 6.0m				NOTE: BOREHOLE LOG FROM AUGER CUTTINGS
			7							



LEGEND

● BOREHOLE AND ELECTRICAL FRICTION CONE PENETRATION TEST

▼ ELECTRICAL FRICTION CONE PENETRATION TEST

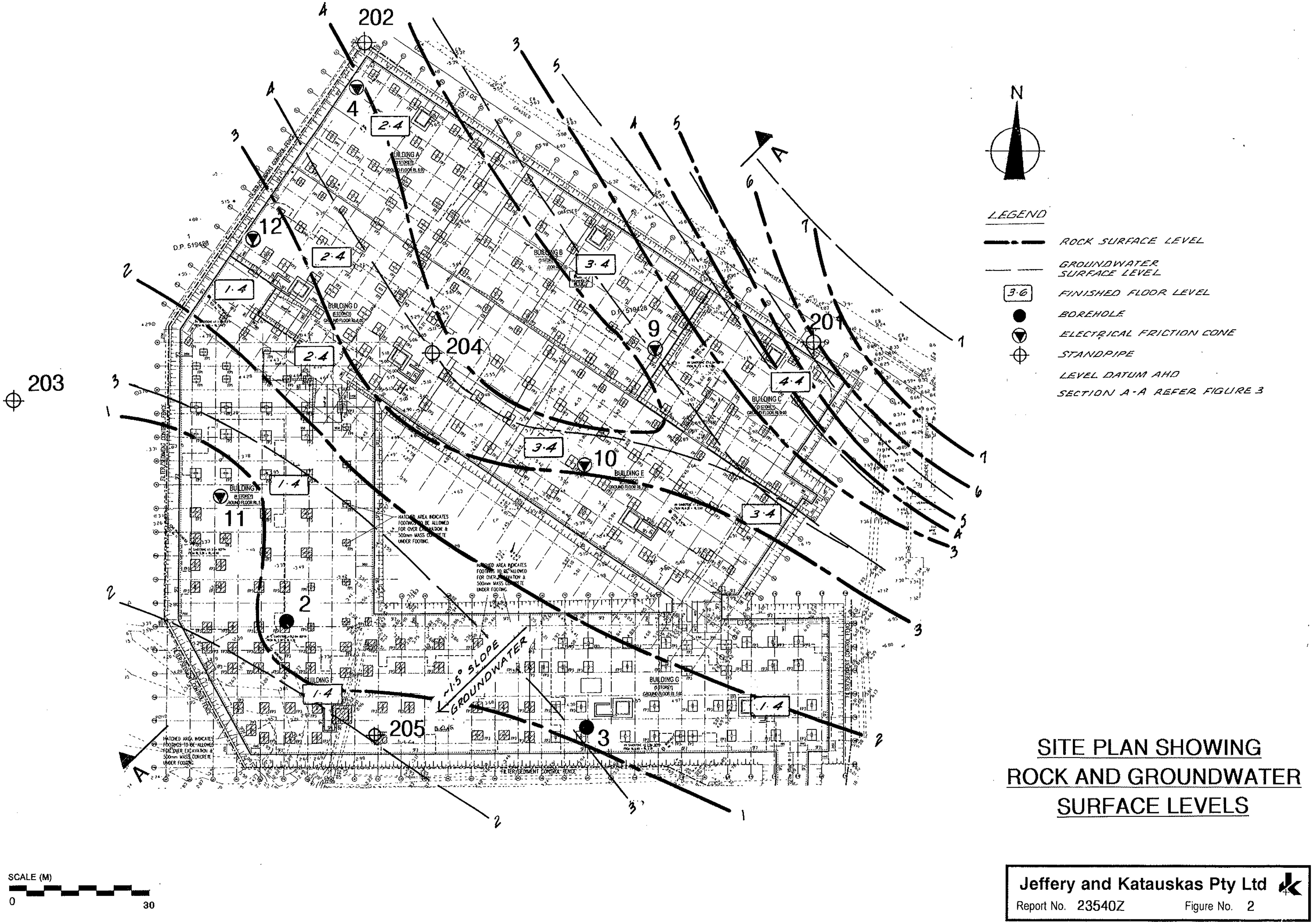
SCALE (m)

0 100

INVESTIGATION LOCATION PLAN

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

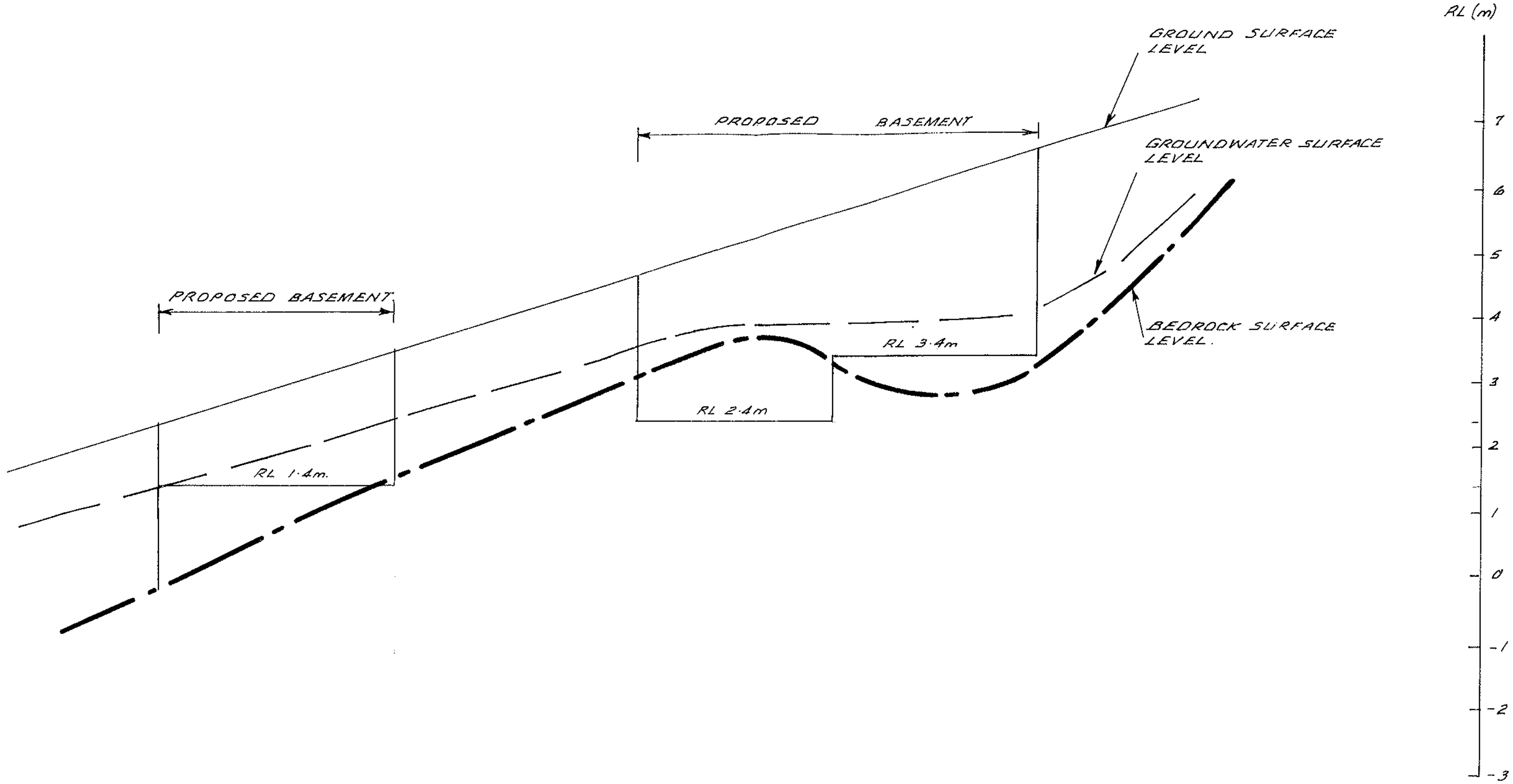
Report No. 23540Z **Figure No. 1**



SITE PLAN SHOWING ROCK AND GROUNDWATER SURFACE LEVELS

Jeffery and Katauskas Pty Ltd

Report No. 23540Z Figure No. 2

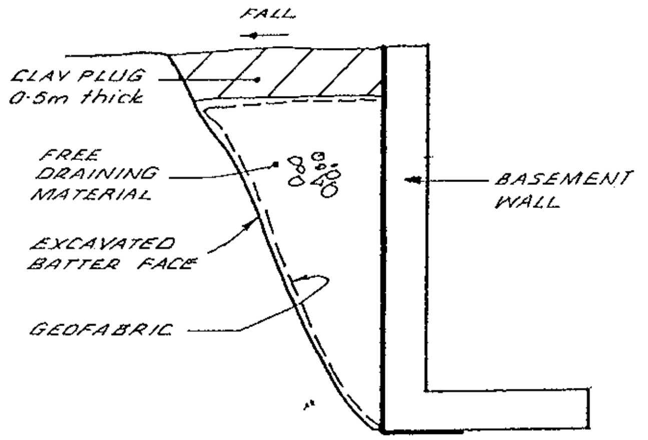


HYDROGEOLOGICAL CROSS SECTIONAL SKETCH A–A

HORIZONTAL SCALE (M)
0 30

VERTICAL SCALE (M)
0 3

Jeffery and Katauskas Pty Ltd
Report No. 23540Z Figure No. 3



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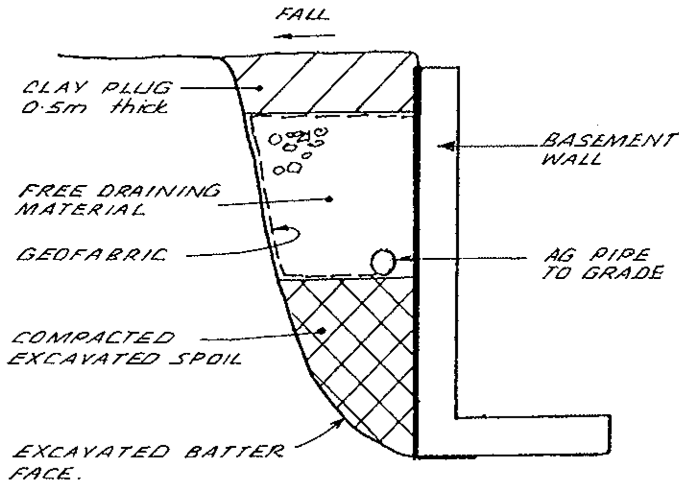

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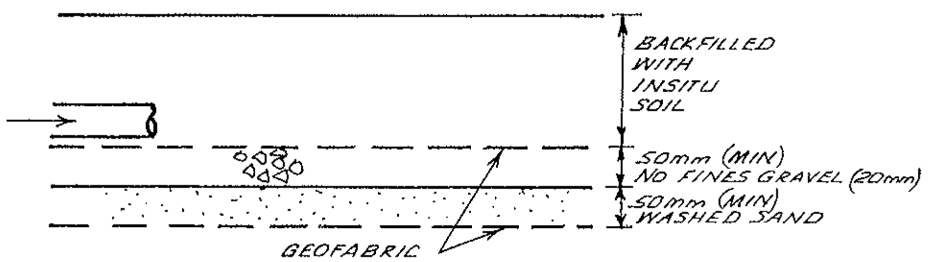

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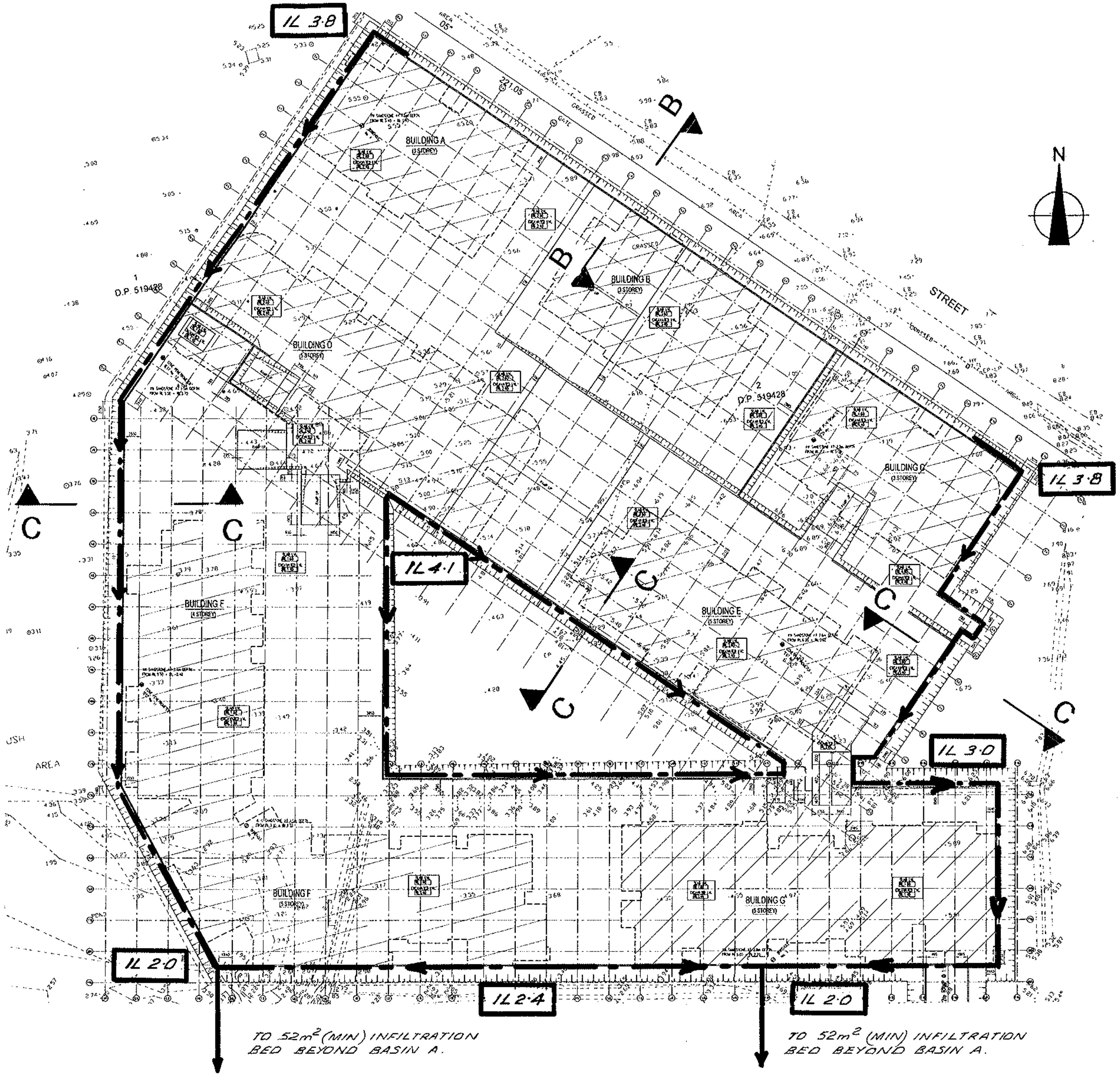

SCALE (M)
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PROPOSED BYPASS LAYOUT

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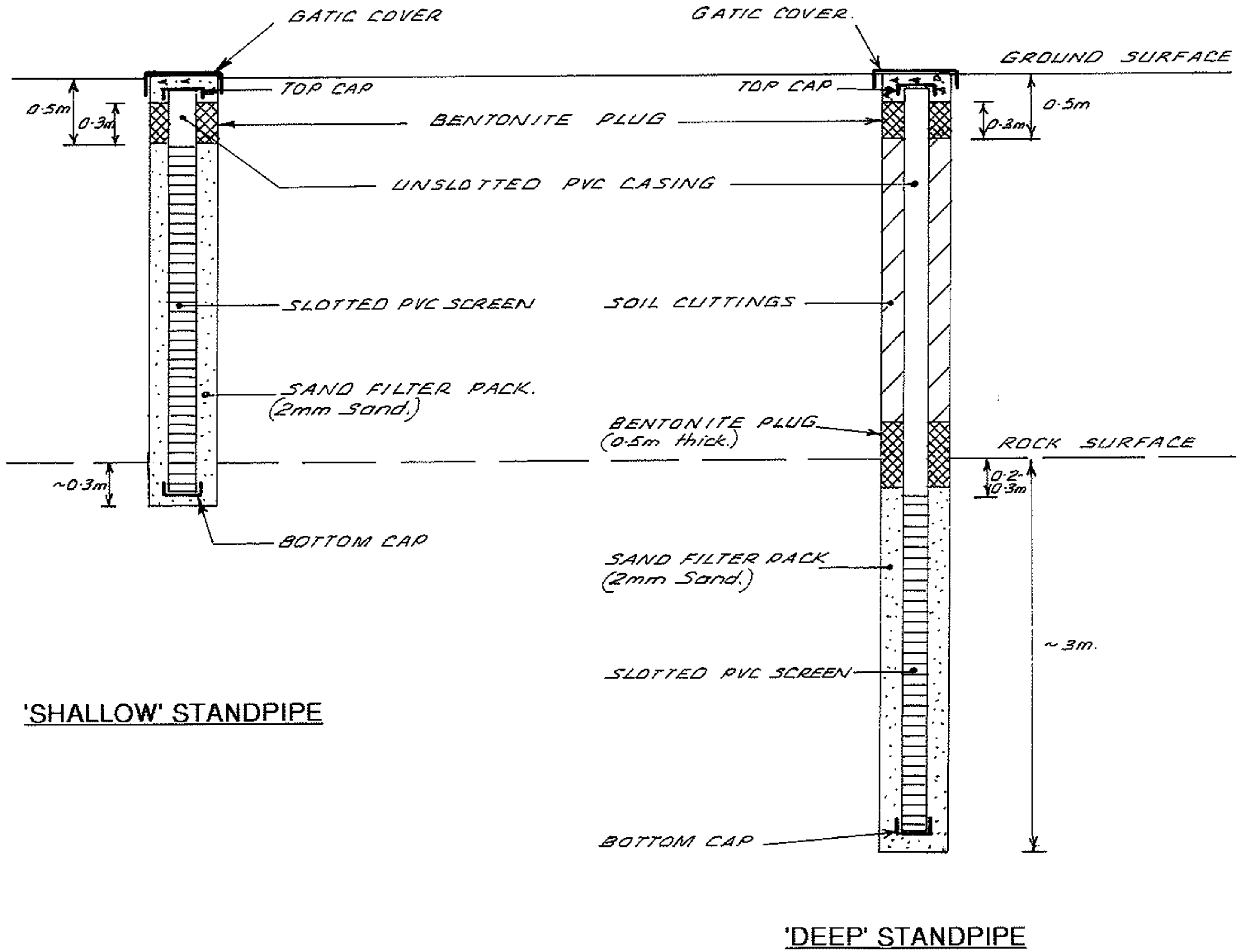
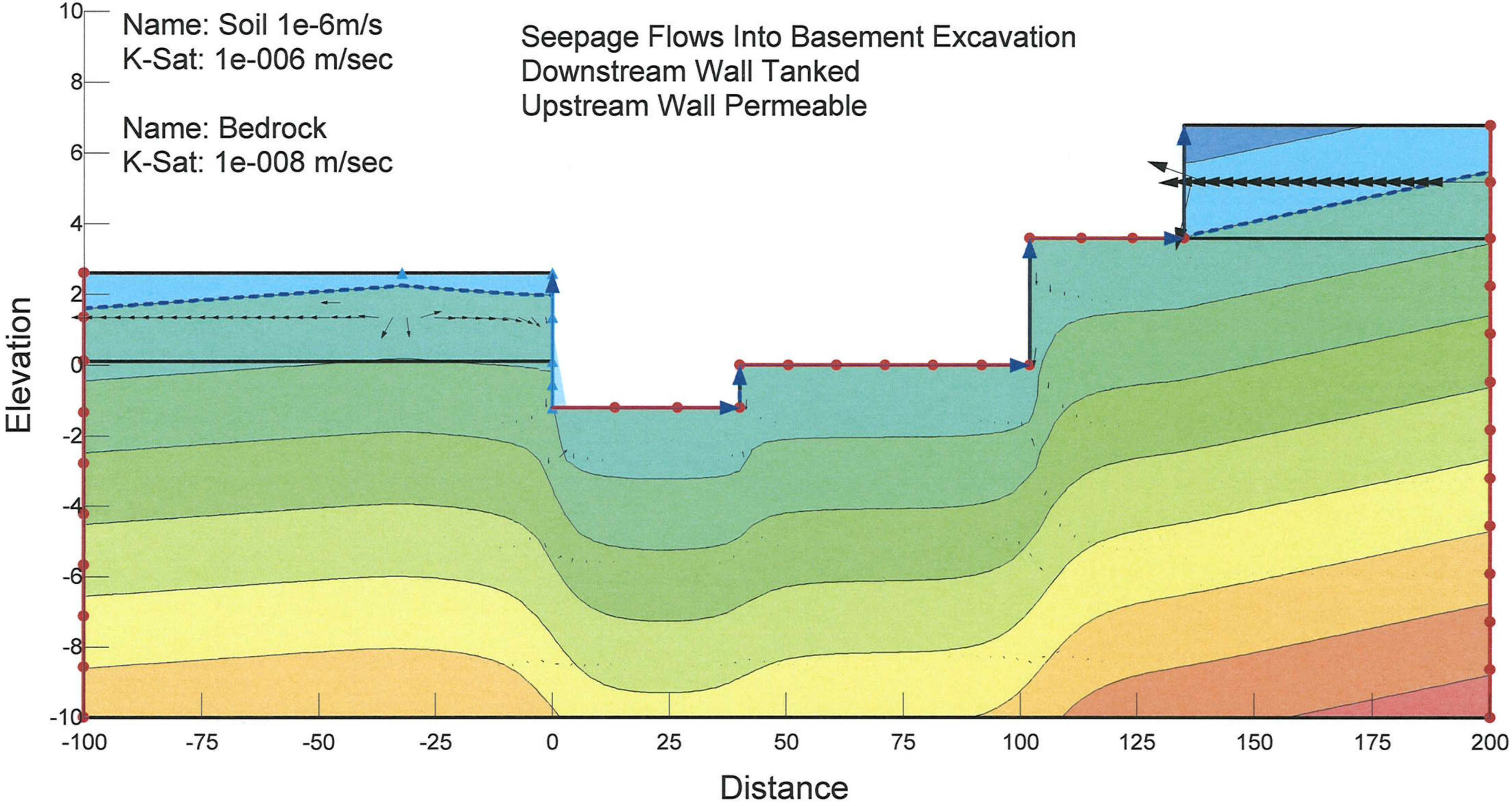
Report No. 23540Z   Figure No. 4



STANDPIPE DETAILS

Jeffery and Katauskas Pty Ltd	
Report No. 23540Z	Figure No. 5



Jeffery and Katauskas Pty Ltd			
Report No.	23540Z	Figure No.	6

APPENDIX A

Relevant Borehole Logs and EFCP Results

from previous Geotechnical Investigation

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Borehole No.
2
1/2

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 11-11-09
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 3.3m
Datum: AHD
Logged/Checked by: J.M.K./ [illegible]

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
		0		TOPSOIL: Silty sand, fine to medium grained, dark brown, with root fibres.				GRASS COVER
	N = 2 1,1,1		CL/SC	SANDY CLAY/CLAYEY SAND: low to medium plasticity fine to medium grained, orange brown mottled light grey, with silt fines.	M/ MC≈PL	F/VL	-	
	N = 11 7,6,5	1		as above, but with ironstone gravel.		VSt/ MD		
AFTER 15 MINS		2	-	SANDSTONE: fine to medium grained, light grey.	XW	EL	-	VERY LOW TO LOW 'TC' BIT RESISTANCE
		3, 4, 5		SANDSTONE: fine to medium grained, dark grey and dark brown.	DW	VL-L		LOW RESISTANCE
		6, 7						

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BOREHOLE LOG

Borehole No. **2**
2/2

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 11-11-09
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 3.3m
Datum: AHD
Logged/Checked by: J.M.K./

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
ON COMPLETION						8			SANDSTONE: fine to medium grained, light grey and orange brown.	DW	L		MODERATE RESISTANCE
						9			END OF BOREHOLE AT 9.0m				
						10							
						11							
						12							
						13							
						14							

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Borehole No. 3

1/1

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION SERVICES

Project: PROPOSED RESIDENTIAL DEVELOPMENT

Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z

Date: 11-11-09

Method: SPIRAL AUGER JK300

R.L. Surface: ≈ 5.0m

Datum: AHD

Logged/Checked by: J.M.K./

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/TOPSOIL: Silty sand, fine to medium grained, dark brown, with a trace of root fibres.	D			GRASS COVER
	DS	N = 2 1,1,1				FILL: Silty sand, fine to medium grained, orange brown, with fine to medium grained sandstone gravel.				APPEARS POORLY COMPACTED
	DS	N = 12 4,4,8			SC	SILTY CLAYEY SAND: fine to coarse grained, orange brown mottled light grey.	M	MD	-	
	DS		3		-	SANDSTONE: fine to coarse grained, light grey.	XW	EL		LOW 'TC' BIT RESISTANCE
	DS		4				DW	VL-L		
	DS		5					L		MODERATE RESISTANCE
			6			END OF BOREHOLE AT 6.0m				
			7							

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Borehole No.
4
1/2

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z
Date: 11-11-09
Method: SPIRAL AUGER JK300
R.L. Surface: ≈ 5.4m
Datum: AHD
Logged/Checked by: J.M.K./

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0		TOPSOIL: Silty sand, fine to medium grained, dark brown, with root fibres.	D			GRASS COVER
	N = 9 4,4,5	1	SC	SILTY CLAYEY SAND: fine to medium grained, orange brown.	D	L	-	
	N > 24 3,7, 17/100mm REFUSAL	2	-	SANDSTONE: fine to medium grained, light grey, dark brown, with iron indurated bands.	XW	EL	-	VERY LOW TO LOW 'TC' BIT RESISTANCE
AFTER 5 MINS		3						
		4						
		5						
		6		SANDSTONE: fine to medium grained, light grey and grey.	DW	VL-L		LOW RESISTANCE
		7						

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Borehole No. **4**

2/2

BOREHOLE LOG

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No. 23540Z **Method:** SPIRAL AUGER JK300 **R.L. Surface:** ≈ 5.4m
Date: 11-11-09 **Datum:** AHD
Logged/Checked by: J.M.K./ [signature]

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
ON COMPLETION						SANDSTONE: fine to medium grained, light grey.	XW	EL		
			8			SANDSTONE: fine to medium grained, grey brown.	DW	L		LOW TO MODERATE RESISTANCE
			9, 10, 11			SANDSTONE: fine to medium grained, light grey.	XW	EL		VERY LOW TO LOW RESISTANCE
			12, 13			SANDSTONE: fine grained.	DW-SW	M-H		MODERATE RESISTANCE
			14			END OF BOREHOLE AT 13.5m				

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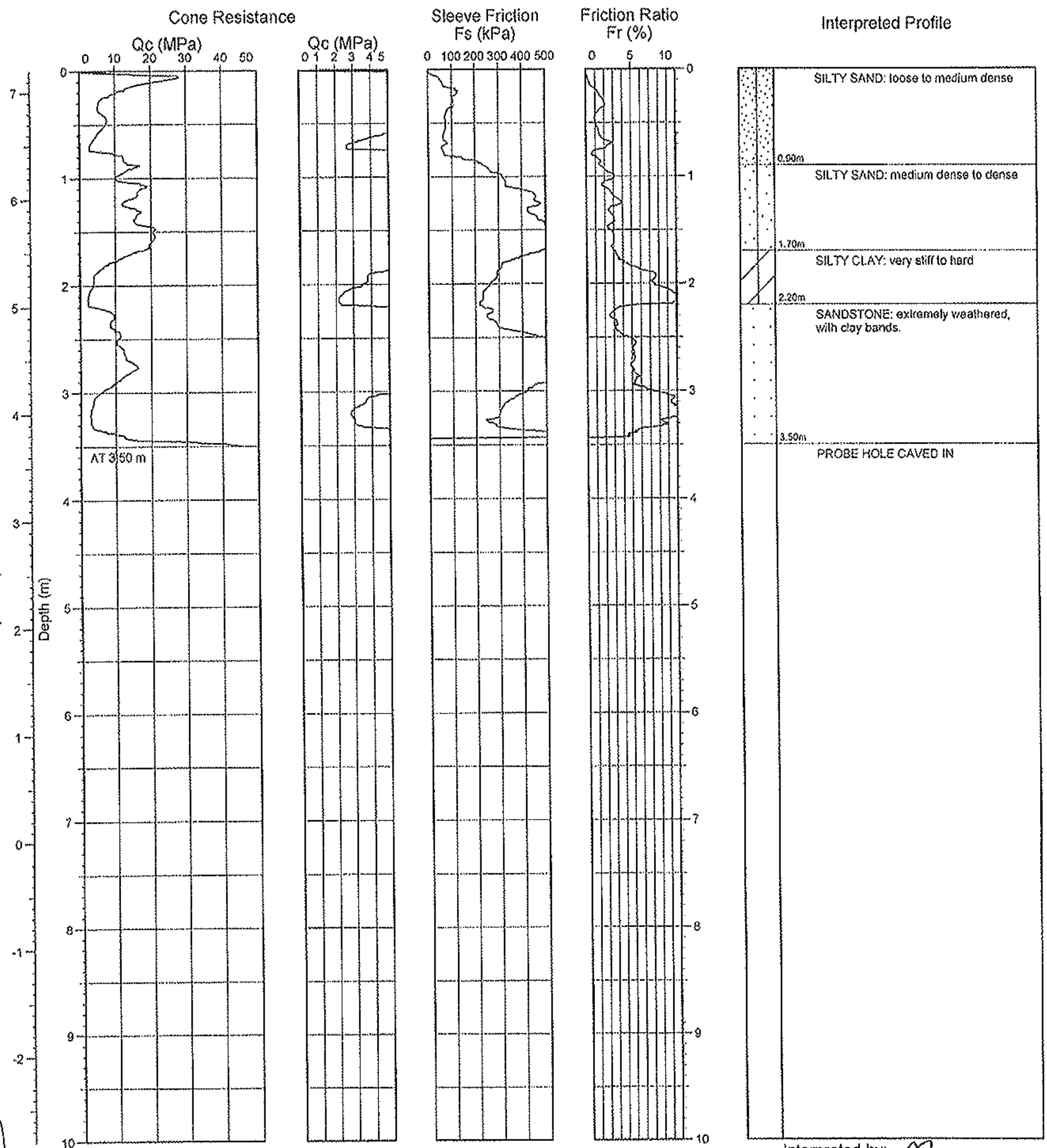
EFCP No. 9

1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client:	KARIMBLA CONSTRUCTION SERVICES
Project:	PROPOSED RESIDENTIAL DEVELOPMENT
Location:	14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No.: 23540Z	**R.L. Surface:** ~7.2 m	**Data File:** 23540Z_6.GEF
Date: 10/11/09	**Datum:** AHD	**Operator:** JMK



Interpreted by: Checked by: GR

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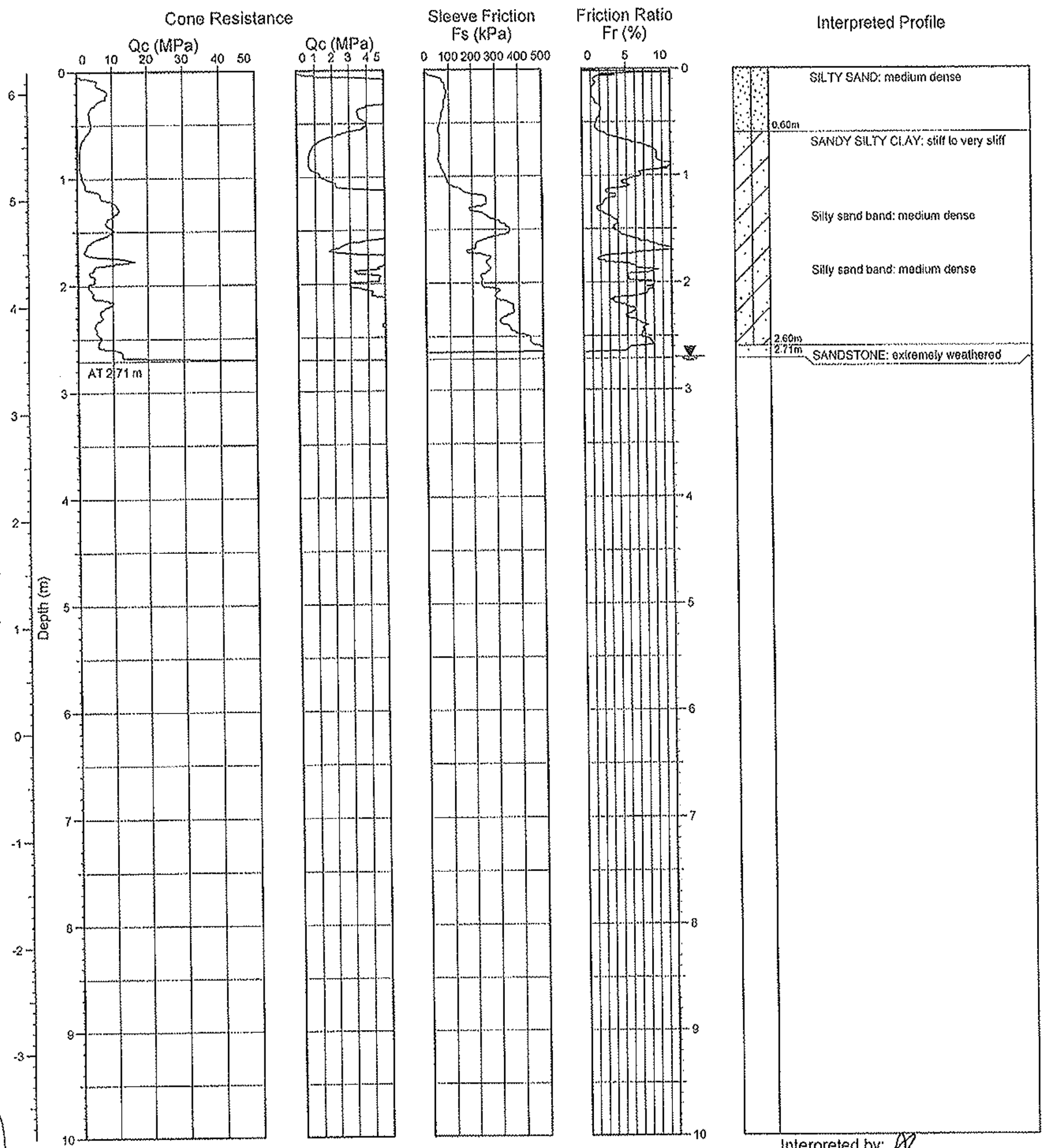
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
10
1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No.: 23540Z	**R.L. Surface:** ~6.2 m	**Data File:** 23540Z_5.GEF
Date: 10/11/09	**Datum:** AHD	**Operator:** JMK



Interpreted by: PL
Checked by: PL

Jeffery and Katauskas Pty Ltd

CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
11
1 / 1

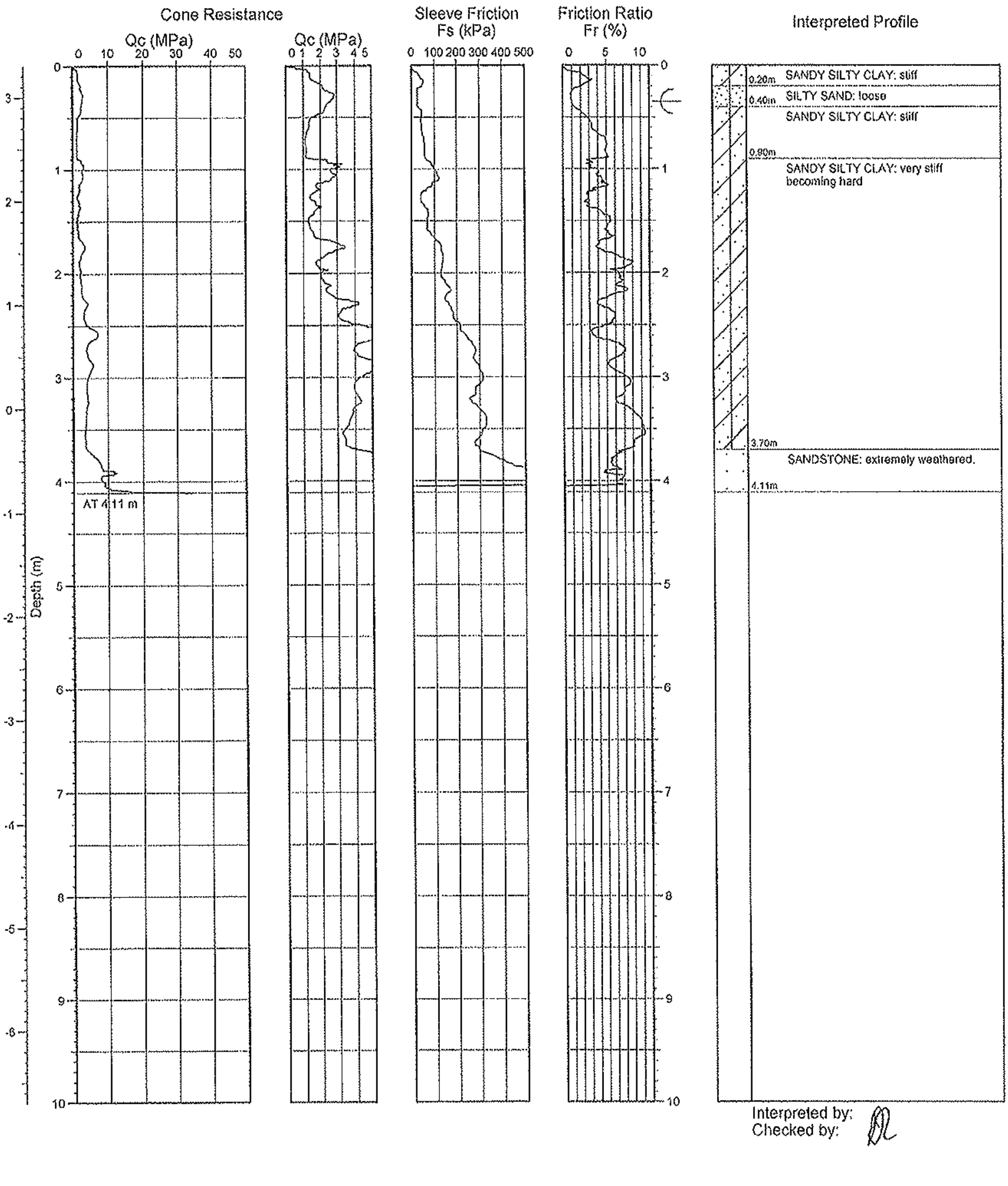
ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: KARIMBLA CONSTRUCTION SERVICES

Project: PROPOSED RESIDENTIAL DEVELOPMENT

Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No.: 23540Z	**R.L. Surface:** ~3.3 m	**Data File:** 23540Z_9.GEF
Date: 11/11/09	**Datum:** AHD	**Operator:** JMK



Interpreted by:
Checked by:

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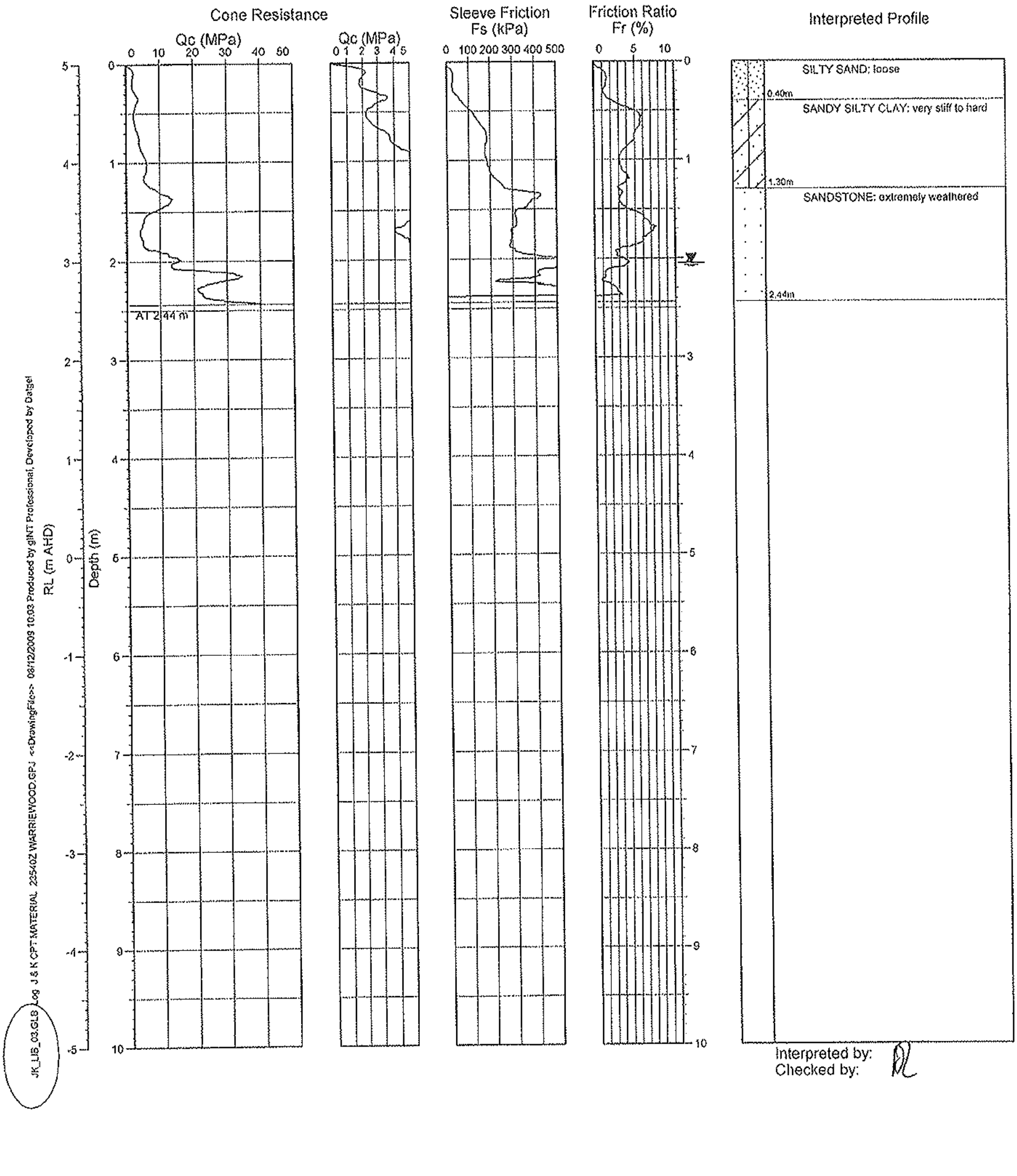
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
12
1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: KARIMBLA CONSTRUCTION SERVICES
Project: PROPOSED RESIDENTIAL DEVELOPMENT
Location: 14-18 BOONDAH AVENUE, WARRIEWOOD, NSW

Job No.: 23540Z	**R.L. Surface:** ~5 m	**Data File:** 23540Z_8.GEF
Date: 11/11/09	**Datum:** AHD	**Operator:** JMK



Interpreted by:
Checked by:

APPENDIX B

Report Explanation Notes

Jeffery and Katauskas Pty Ltd

CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
ABN 17 003 550 801

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 (eg sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 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.

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REVIEW OF DESIGN

Where major civil or structural developments are proposed or where only a limited investigation has been completed or 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.

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CONSULTING GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

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

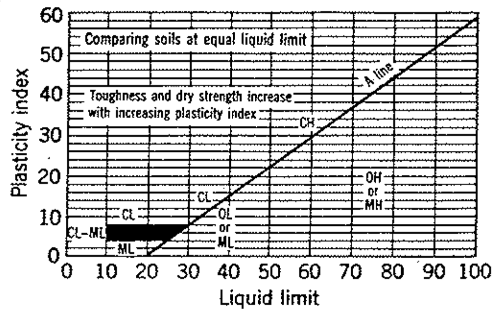
- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

UNIFIED SOIL CLASSIFICATION TABLE

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*)	$C_U = \frac{D_{60}}{D_{10}}$ 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
Fine-grained soils: More than half of material is *smaller* than 75 µm sieve size	Identification Procedures on Fraction Smaller than 380 µm Sieve Size		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)				
	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		

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.



Plasticity chart
for laboratory classification of fine grained soils

NOTE: 1) Soils possessing characteristics of two groups are designated by combinations of group symbols (e.g. 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.

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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.

Ref: Standard Sheets/Log Symbols
November 2007

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LOG SYMBOLS

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	