REPORT

TO
SOUWEST DEVELOPMENT

ON
GEOTECHNICAL INVESTIGATION

FOR
PROPOSED RESIDENTIAL SUBDIVISION

AT
STATION STREET, MENANGLE, NSW

7 May 2014
Ref: 27284Zrpt

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

PO Box 976, North Ryde BC NSW 1670
Tel: 02 9888 5000 Fax: 02 9888 5001
www.jkgeotechnics.com.au

Jeffery & Katauskas Pty Ltd, trading as
JK Geotechnics ABN 17 003 550 801

Date: 7 May 2014
Report No: 27284Zrpt
Revision No: 0

Report prepared by:

A ZENON
Principal Geotechnical Engineer

For and on behalf of
JK GEOTECHNICS
PO Box 976
NORTH RYDE BC NSW 1670

This Report (which includes all attachments and annexures) has been prepared by JK Geotechnics (JK) for its Client, and is intended for the use only by that Client.

This Report has been prepared pursuant to a contract between JK and its Client and is therefore subject to:

a) JK's proposal in respect of the work covered by the Report;

b) the limitations defined in the Client's brief to JK;

c) the terms of contract between JK and the Client, including terms limiting the liability of JK.

If the Client, or any person, provides a copy of this Report to any third party, such third party must not rely on this Report, except with the express written consent of JK which, if given, will be deemed to be upon the same terms, conditions, restrictions and limitations as apply by virtue of (a), (b), and (c) above.

Any third party who seeks to rely on this Report without the express written consent of JK does so entirely at their own risk and to the fullest extent permitted by law, JK accepts no liability whatsoever, in respect of any loss or damage suffered by any such third party.

TABLE OF CONTENTS

1 INTRODUCTION

This report presents the results of a geotechnical investigation for the proposed residential subdivision at Station Street, Menangle, NSW. The investigation was commissioned by Ms Fiona Van Der Hoeven of Elton Consulting, on behalf of Souwest Development, by email dated 27 February 2014. The commission was in accordance with our proposal (Ref P38248Z Menangle) dated 5 February 2014. This report confirms and amplifies our preliminary geotechnical report dated 31 March 2014.

We understand from the land use allocation plan and from the geotechnical services brief prepared by Elton Consulting dated 31 January 2014, that the site will be subdivided into about 350 low density residential lots which will be serviced by internal roadways. A Neighbourhood Centre is also proposed.

The purpose of the investigation was to obtain geotechnical information on subsurface conditions as a basis for comments and recommendations on site constraints, general earthworks, footings (site classification), buried services trenches, and pavements, all for initial planning purposes.

2 INVESTIGATION PROCEDURE

The fieldwork for the investigation was carried out on 6 and 7 February 2014 and comprised the auger drilling of 15 boreholes (JK1 to JK15) to depths between 2m and 6m using our truck mounted JK350 drilling rig. The borehole locations, as indicated on attached Figure 1, were spread out relatively evenly across the original site area and agreed with the client, after which they were set out using a hand held GPS device. The surface reduced levels (RLs) at the borehole locations were estimated by interpolation between ground contours shown on the provided survey plan, and are thus approximate. The survey plan forms the basis of Figure 1.

The nature and composition of the subsurface soil and rock horizons were assessed by logging the materials recovered during drilling. The strength of the soil profile was assessed from the Standard Penetration Test (SPT) ‘N’ numbers, augmented by hand penetrometer readings on clayey samples recovered in the SPT split tube sampler. The strength of the bedrock was assessed by observation of drilling resistance when using a tungsten carbide (TC) bit, examination of the recovered rock chip samples, and subsequent correlation with laboratory moisture content testing. We note that rock strengths determined in this way are approximate and may vary by up to one order of strength magnitude. Groundwater observations were made during and on completion of drilling individual boreholes. Class 18 PVC standpipes were installed in four boreholes (JK1, JK8, JK9 & JK15) to depths ranging between 3.2m to 6m for the purpose of long term groundwater monitoring. Details of the standpipes are provided on the relevant borehole logs. For further details on the investigation procedure adopted, reference should be made to the attached Report Explanation Notes.

Our geotechnical engineer was present full time on site during the fieldwork and set out the borehole locations, nominated sampling and testing, directed standpipe installation, and logged the subsurface profile. The borehole logs are attached to this report together with a glossary of logging terms and symbols used.

Selected soil and rock chip samples were submitted to a NATA registered laboratory (Soil Test Services) for moisture content, Atterberg Limits, linear shrinkage and Emerson Class testing. The test results are summarised in the attached STS Tables A and B.

3 RESULTS OF INVESTIGATION

3.1 Site Description

The site is located within the slightly undulating topography of the region characterised by shallow gully features and low level rolling hills. The site itself has an irregular plan shape and is bounded by Menangle Road to the west and the Hume Highway to the east. Station Street extends along the western end of the southern site boundary, the Southern Highlands Rail Line extends north-south through the site, and Menangle Rail Station is located centrally within the site. The existing Menangle village is located immediately to the south-west.

At the time of the investigation, the site comprised predominately grass covered undulating paddocks which generally sloped down to the north and south-east at between about 3° and 5°. The high point in the local topography is located over the northern end of the existing Menangle Village. Two shallow and one deeper gully features within the site with side slopes between about 2° and 5° and 8° and 10°, respectively, extended roughly from south to north towards the meandering Nepean River, which is located some 900m to the north and to the east of the Menangle Rail Station. The gully feature located on the western side of the site fed into a siltation earth dam to the north. All of the gulley features and the dam were 'dry' at the time of the investigation. Small to medium size trees were concentrated around the banks of the deeper gulley feature located towards the east of the site.

Located centrally over the site and to the west of Menangle Station, were a number of large metal shed structures and metal silos, a dilapidated single storey concrete structure and low level stockpiles comprising timber and metal demolition materials. A relatively narrow overgrown concrete paved surface ran through the centre of this area and was generally in poor condition.

The rail corridor for the Southern Highlands Rail Line had been cut into the surrounding topography along the south and extended over a fill embankment along the north. The cutting at the southern end was up to about 4m deep at the Station Street bridge and had side slopes up to 40°. The embankment increased in height northwards from Menangle Station up to about 5m and had side slopes of about 30°.

One storey brick houses were located at the western end of Station Street and to the east of the Station Street bridge over the railway line.

To the west and south-west of the site, across Menangle Road and Station Street, respectively, were established residential areas, which included single storey timber panel cottages.

The grass covered paddocks continued to the north and south-east of the site

3.2 Subsurface Conditions

The 1:100,000 geological map of Wollongong indicates that the site is underlain by Hawkesbury Sandstone with the sandstone being capped by the Ashfield Shales over higher lying western portion of the site. The investigation has confirmed the above in general, and revealed a generalised subsurface profile comprising surficial fill/topsoil over residual silty clay with weathered shale and/or sandstone bedrock at relatively shallow depth. Groundwater was not encountered within the depths investigated. Reference should be made to the attached borehole logs for detailed subsurface conditions at specific locations. A summary of the subsurface conditions as encountered, is presented below:

Fill/Topsoil

Clayey and gravelly fill / topsoil was encountered at the surface of all boreholes and extended to a maximum depth of 0.5m, but was typically up to 0.2m deep. The fill/topsoil was assessed to be of low to medium plasticity with inclusions comprising ironstone gravel and root fibres.

Residual Silty Clay

Residual silty clay was encountered below the fill/topsoil in all boreholes. The silty clay varied between low and high plasticity and very stiff to hard strength.

W*eathered Shale and Sandstone Bedrock*

Weathered shale bedrock was encountered below the residual silty clay in boreholes JK1 to JK8, JK11, JK13 and JK15 (generally over the western portion of the site) at depths between 0.4m (JK15) and 2.1m (JK6). The shale on first contact was generally of extremely low to medium strength and rapidly improved to high strength with depth. Weathered sandstone bedrock was encountered below the residual silty clay in boreholes JK9, JK10, JK12 and JK14 (over the eastern portion of the site) at depths between 0.8m (JK10 and JK14) and 2.0m (JK12). The sandstone on first contact was generally of low to medium strength and rapidly improved to high strength with depth. The medium and higher strength shale and sandstone bedrock was encountered in all boreholes following relatively shallow or no penetration. Interbedded shale and sandstone was encountered below the shale at 3m depth in JK3. Shale was encountered below the sandstone at 1.8m depth and was in turn underlain by sandstone from 3m depth in JK9. Sandstone was encountered below the shale at 1.5m depth in JK11. Auger refusal was encountered in high strength shale and sandstone bedrock in boreholes JK1, JK8, JK9, JK10 and JK14 at depths between 2.0m (JK14) and 4.0m (JK8). The greatest depth to bedrock was concentrated within a strip extending east to west across the centre of the site.

Groundwater

Groundwater was not encountered and all boreholes were 'dry' during drilling, on completion of drilling, and a short period after completion of drilling individual boreholes.

The groundwater in the four boreholes which standpipes was measured on 18 March 2014, almost two weeks following the completion of drilling, with the following results:

Borehole	**Depth to Groundwater Surface (m)**
JK1	3.12
JK8	'dry'
JK9	2.31
JK15	4.64

3.3 Laboratory Test Results

The laboratory moisture content, Atterberg Limits and linear shrinkage test results confirmed our field assessed soil properties and indicated that the residual clays to have a moderate or slight shrink-swell reactivity.

The Emerson Class Number testing indicated the clay samples to have a moderate dispersion potential.

The moisture content test results on recovered rock chip samples correlated well with our field assessed rock strengths.

4 COMMENTS AND RECOMMENDATIONS

The comments and recommendations which follow should be considered as preliminary and general in nature and are intended to aid the planning and initial design process. More extensive geotechnical investigations will be required for detailed design and construction documentation.

4.1 General Statement

No significant geotechnical constraints were encountered, and the site is considered suitable for its intended purpose (ie. low density residential development with a neighbourhood/community centre).

We note that the site layout was revised subsequent to the fieldwork for the geotechnical investigation having been completed. Although the eastern portion of the site was not covered, significant variations are not expected, and the information presented in this report is considered adequate for planning purposes over the entire site area. The eastern portion of the site must, however, be included in the further geotechnical investigations recommended in Section 4.7 below.

4.2 Stability

The site grades are relatively flat (<5°) and bedrock underlies the site from relatively shallow depth (<2m). Potential stability or landslip are not expected to be an issue and therefore no special precautions need be taken in this respect.

4.3 Earthworks

Bulk earthworks should be carried out in accordance with AS3798. The relatively shallow depth to bedrock, together with the rock strength, must be given due consideration in the design of the depth and extent of bulk excavations which may be required. The residual silty clays are suitable for use as fill. In particular, all fill should be placed as engineered fill in layers no thicker than 250mm, which should be compacted to densities between 98% and 102% Standard Maximum Dry Density (SMDD) and within 2% of Standard Optimum Moisture Content (SOMC). The fill compaction should be Level 1 tested by a NATA registered laboratory.

Erosion control is essential as are shallow cut or fill earthworks batters as the clays have been found to be moderately dispersive. Permanent cut and fill earthworks batters should be no steeper than 1 Vertical (V) in 2.5 Horizontal (H), but preferably flatter where access for landscaping/maintenance is required.

4.4 Footings (Site Classification)

Based on current ground surface levels, the site classifies as ‘Class M’ with localised ‘Class S’ (BH8 and BH15), in accordance with AS2870-2011. The site classification may, however, change depending on the extent of bulk earthworks (ie. cut and fill) which will be carried out.

A supplementary geotechnical investigation will be required once the bulk earthworks are complete, to confirm the site classification for individual lots.

4.5 Buried Services

Trenches for the laying of services will probably encounter weathered shale or sandstone bedrock. Forty seven percent of the boreholes encountered bedrock within 1m depth and 73% of the boreholes encountered bedrock within 1.5m depth. The deepest bedrock was concentrated in an east-west trending strip extending through the middle of the site. We note that the refusal of the auger to further penetration was encountered between 2m and 4m depth in 33% of the boreholes drilled, and ‘hard rock’ excavation must be anticipated in the deeper trenches. Slow groundwater seepage into the deeper trenches (>2m) must also be anticipated.

4.6 Pavements

The design of pavements will depend on subgrade preparation, subgrade drainage, the nature and composition of any new fill imported to the site, as well as vehicle loadings and use.

Provided the subgrade is adequately prepared (ie. the width of the roadway is boxed out and the exposed subgrade at design level is successfully proof-rolled), flexible pavements may be tentatively designed for a soaked CBR value of 3%.

A supplementary geotechnical investigation along the proposed pavements will be required once the bulk earthworks are complete, to confirm the design CBR value.

4.7 Further Geotechnical Investigation

A further geotechnical investigation must be carried out once the bulk earthworks have been completed to confirm the site classification (AS2870) for individual lots and the CBR design value(s) for the proposed pavements.

The scope of the further geotechnical investigation can only be determined once the extent and depth of bulk earthworks have been established and the lot layouts finalised.

5 GENERAL COMMENTS

The comments and recommendations which follow should be considered as preliminary and general in nature and are intended to aid the planning and initial design process. More extensive geotechnical investigations will be required for detailed design and construction documentation.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

A waste classification will need to be assigned to any soil excavated from the site prior to offsite disposal. Subject to the appropriate testing, material can be classified as Virgin Excavated Natural Material (VENM), General Solid, Restricted Solid or Hazardous Waste. If the natural soil has been stockpiled, classification of this soil as Excavated Natural Material (ENM) can also be undertaken, if requested. However, the criteria for ENM are more stringent and the cost associated with attempting to meet these criteria may be significant. Analysis takes seven to

10 working days to complete, therefore, an adequate allowance should be included in the construction program unless testing is completed prior to construction. If contamination is encountered, then substantial further testing (and associated delays) should be expected. We strongly recommend that this issue is addressed prior to the commencement of excavation on site.

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 JK Geotechnics. 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.

115 Wicks Road
Macquarie Park, NSW 2113
PO Box 976
North Ryde, BC 1670
Telephone: 02 9888 5000
Facsimile: 02 9888 5001

SOIL TEST SERVICES
ABN 43 002 145 173

TABLE A
MOISTURE CONTENT, ATTERBERG LIMITS AND LINEAR SHRINKAGE TEST REPORT

Client: JK Geotechnics
Project: Proposed Sub-Division
Location: Off Station Street, Menangle, NSW

Ref No: 27284Z
Report: A
Report Date: 17/03/2014
Page 1 of 1

AS 1289	TEST METHOD	2.1.1	3.1.2	3.2.1	3.3.1	3.4.1
BOREHOLE NUMBER	DEPTH m	MOISTURE CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %	LINEAR SHRINKAGE %
JK1	0.50-0.95	10.4	45	20	25	11.0
JK1	1.20-1.50	5.5				
JK3	1.00-1.50	8.3				
JK4	0.50-0.95	18.3	56	26	30	14.5
JK5	2.50-3.00	5.2				
JK9	0.50-0.95	10.9	38	18	20	9.5
JK10	1.00-1.50	4.8				
JK14	1.00-1.50	9.6				

Notes:

- The test sample for liquid and plastic limit was air-dried & dry-sieved
- The linear shrinkage mould was 125mm
- Refer to appropriate notes for soil descriptions
- Date of receipt of sample: 10/03/2014

115 Wicks Road
Macquarie Park, NSW 2113
PO Box 976
North Ryde, Bc 1670
Telephone: 02 9888 5000
Facsimile: 02 9888 5001

SOIL TEST SERVICES
ABN 43 002 145 173

TABLE B
EMERSON CLASS NUMBER TEST REPORT

Client: JK Geotechnics
Project: Proposed Sub-Division
Location: Off Station Street, Menangle, NSW

Ref No: 27284Z
Report: B
Report Date: 17/03/2014
Page 1 of 1

BOREHOLE NUMBER	DEPTH (m)	Air dried soil crumbs in water	Remoulded soil samples in water	Calcite or Gypsum present/ absent	1: 5 Soil/Water Suspension	Emerson Class Number
JK5	0.50-0.95	Slaking (No Dispersion)	No Dispersion	Present	na	4
JK13	0.50-0.95	Slaking (No Dispersion)	No Dispersion	Present	na	4

NOTES:

- The lowest Emerson Class Number refers to the highest dispersion potential (Range: Class 1 to Class 8)
- Test Method: AS 1289 3.8.1-1997
- All contact water was distilled water, water temperature was 23°C
- Vigorous Shaking causes Dispersion/Flocculation
- Refer to appropriate notes for soil descriptions
- na refers to not applicable
- Date of receipt of samples: 10/03/2014

Authorised Signature / Date
(A. Tatikonda) Alur 17/3/14

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK1
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 79.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION & AFTER 20 HRS						0			FILL: Silty clay topsoil, low plasticity, dark brown, trace of root fibres.	MC<PL			GRASS COVER
								CH	SILTY CLAY: high plasticity, brown, trace of root fibres.	MC<PL	(H)		
					N = 28 7,12,16			CL	SILTY CLAY: medium plasticity, light grey, with fine to medium grained ironstone gravel.				TOO FRIABLE FOR HP TESTING
						1		-	SHALE: dark grey and red brown.	DW	M		MODERATE 'TC' BIT RESISTANCE
						2			as above, but with clay seams.				BANDED MODERATE RESISTANCE
▼ ON 18-3-14						3		-	INTERBEDDED SHALE AND SANDSTONE: fine grained, dark grey and red brown.		H		HIGH RESISTANCE
						4 5 6 7			END OF BOREHOLE AT 3.5m				'TC' BIT REFUSAL CLASS 18 PVC STANDPIPE INSTALLED TO 3.5m DEPTH. MACHINE SLOTTED BETWEEN 3.5m AND 0.5m, CASING 0.5m TO SURFACE, BACKFILLED WITH 2mm SAND FILTER SAND 3.5m TO 0.5m, BENTONITE SEAL 0.5m TO 0.2m, METAL MONUMENT CONCRETED AT SURFACE

BOREHOLE LOG

Borehole No.
JK2
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 81.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

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 topsoil, medium plasticity, brown, trace of root fibres.	MC<PL			GRASS COVER
								CH	SILTY CLAY: high plasticity, red brown, trace of fine to medium grained ironstone gravel.	MC<PL	H		
						1							
								CL	SILTY CLAY: medium plasticity, light grey and orange brown, with XW shale seams.				BANDED VERY LOW 'TC' BIT RESISTANCE
	■			■	N = 33 10,13,20							>600 >600 >600	
						2		-	SHALE: light grey and dark grey, with iron indurated seams and L strength seams.	XW	EL		VERY LOW RESISTANCE WITH LOW BANDS
				■									
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK3
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 81.5m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

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, trace of root fibres.	MC<PL			GRASS COVER
							▨	CH	SILTY CLAY: high plasticity, orange brown, trace of root fibres.	MC<PL	(H)		
	■			■	N = 32 8,12,20		▨		SILTY CLAY: high plasticity, light grey, with fine to medium grained ironstone gravel.		H	>600 >600 >600	
				■		1	▤	-	SHALE: brown and red brown.	DW	M		MODERATE RESISTANCE
						2	▤						
				■			▤						
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

COPYRIGHT

JK Geotechnics

GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK4
1/1

Client: SOUWEST DEVELOPMENT

Project: PROPOSED SUB-DIVISION

Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z

Date: 6-3-14

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 86.2m

Datum: ASSUMED

Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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 topsoil, medium plasticity, red brown, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL			GRASS COVER
								CH	SILTY CLAY: high plasticity, red brown and light grey, with fine to coarse grained ironstone gravel.	MC<PL	H		
	■			■	N = 20 9,10,10							>600 >600 >600	
						1							
				■	N = 29 8,16,13				as above, but light grey.			>600 >600 >600	
						2		-	SHALE: dark grey.	DW	M		LOW 'TC' BIT RESISTANCE
				■									
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK5
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 83.5m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL			VEGETATION COVER
				■	N = 20 7,10,10	1	▨	CL	SILTY CLAY: medium plasticity, brown, with fine to medium grained ironstone gravel.	MV<PL	(VSt)		TOO FRIABLE FOR HP TESTING
							▨	CH	SILTY CLAY: high plasticity, light grey.				
				■	N = 43 4,16,27		▤	-	SHALE: light grey, with iron indurated bands.	XW	EL		VERY LOW 'TC' BIT RESISTANCE
				■		2	▤		SHALE: dark grey and red brown.	DW	M-H		MODERATE RESISTANCE
						3			END OF BORHOLE AT 3.0m				
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
JK6
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER
JK350
Logged/Checked by: D.S./A.Z.
R.L. Surface: ≈ 80.0m
Datum: ASSUMED

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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 gravel, fine to coarse grained shale, dark grey, trace of clay fines and root fibres.	D			GRASS COVER
	■			■	N = 18 4,8,10	1		CH	SILTY CLAY: high plasticity, orange brown mottled light grey, with fine to medium grained ironstone gravel, trace of root fibres.	MC<PL	H	550 550 >600	
				■	N = 28 10,15,13	2		CL	SILTY CLAY: low plasticity, light grey and orange brown, with L strength shale seams.			>600 >600 >600	BANDED VERY LOW 'TC' BIT RESISTANCE
				■				-	SHALE: dark grey and red brown.	DW	L-M		LOW TO MODERATE RESISTANCE
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK7
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 80.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES				Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
	ES	U50	DB	DS									
DRY ON COMPLETION	■					0			FILL: Silty clay topsoil, medium plasticity, brown, trace of root fibres.	MC<PL			GRASS COVER
				■	N = 26 7,11,15			CL	SILTY CLAY: medium plasticity, light grey and orange brown, trace of root fibres.	MC<PL	H	>600 >600 >600	
				■		1		-	SHALE: brown and red brown.	DW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
				■		2			SHALE: dark grey, brown and red brown.		M-H		MODERATE TO HIGH RESISTANCE
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
JK8
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 6-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 84.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION, AFTER 22.5 HRS & ON 18-3-14	■					0			FILL: Silty clay, medium plasticity, dark brown, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL			GRASS COVER
	■							CL		MC<PL			
				■	N > 16 12,16/ 100mm REFUSAL			-	SILTY CLAY: medium plasticity, orange brown. SHALE: light grey and dark grey.	XW-DW	EL-VL		VERY LOW 'TC' BIT RESISTANCE
						1							
				■					SHALE: dark grey and brown.	SW	M		MODERATE RESISTANCE
						2							
				■		3							
				■					SHALE: dark grey.		H		HIGH RESISTANCE
						4			END OF BOREHOLE AT 4.0m				'TC' BIT REFUSAL CLASS 18 PVC STANDPIPE INSTALLED TO 4m DEPTH. MACHINE SLOTTED BETWEEN 1m AND 4m, CASING TO SURFACE, BACKFILLED WITH 2mm SAND FILTER SAND 4m TO 0.5m, BENTONITE SEAL 0.5m TO 0.2m, METAL MONUMENT CONCRETED AT SURFACE
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
JK9
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 72.5m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

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 topsoil, medium plasticity, dark brown, trace of root fibres.	MC<PL			GRASS COVER
	■			■	N = 16 7,8,8			CL	SILTY CLAY: medium plasticity, light grey and orange brown, with fine to medium grained sand.	MC<PL	H	450 400 400	
				■		1		-	SANDSTONE: fine grained, brown and light grey.	DW	M		MODERATE 'TC' BIT RESISTANCE
▼ ON 18-3-14				■		2			SHALE: dark grey, brown and red brown, with M strength sandstone seams.	SW	M-H		MODERATE TO HIGH RESISTANCE
				■		3			SANDSTONE: fine to medium grained, light grey and brown.		H		HIGH RESISTANCE
						4 5 6 7			END OF BOREHOLE AT 3.2m				'TC' BIT REFUSAL CLASS 18 PVC STANDPIPE INSTALLED TO 3.2m DEPTH. MACHINE SLOTTED BETWEEN 0.5m AND 3.2m, CASING TO 0.5m TO SURFACE, BACKFILLED WITH 2mm SAND FILTER SAND 0.5m TO 3.2m, BENTONITE SEAL 0.2m TO 0.5m, METAL MONUMENT CONCRETED AT SURFACE

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK10
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 74.5m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

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 topsoil, medium plasticity, brown, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL			GRASS COVER
	■			■	N > 20 11,20/ 150mm REFUSAL		▨	CL	SILTY CLAY: low plasticity, light grey and orange brown, trace of fine grained sand.	MC<PL	H	>600 >600 >600	
				■		1	⁘	-	SANDSTONE: fine grained, light grey and orange brown.	DW	M-H		MODERATE 'TC' BIT RESISTANCE
				■			⁘		SANDSTONE: fine grained, light grey.	SW	H		HIGH RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
JK11
1/1

Client: SOUWEST DEVELOPMENT

Project: PROPOSED SUB-DIVISION

Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z

Date: 7-3-14

Method: SPIRAL AUGER
JK350

R.L. Surface: ≈ 80.0m

Datum: ASSUMED

Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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, low plasticity, brown, with fine to medium grained ironstone gravel, trace of fine grained sand and root fibres.	MC<PL			GRASS COVER
	■			■	N > 22 8,22/ 100mm REFUSAL			CL	SILTY CLAY: medium plasticity, orange brown and light grey, with fine to medium grained ironstone gravel, trace of root fibres.	MC<PL	H	>600 >600 >600	
				■		1		-	SHALE: dark grey and brown.	DW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
				■		2			SANDSTONE: fine grained, light grey.	SW	H		HIGH RESISTANCE
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

BOREHOLE LOG

Borehole No.
JK12
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER JK350
R.L. Surface: ≈ 88.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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 topsoil, medium plasticity, brown, trace of root fibres.	MC<PL			GRASS COVER
								CH	SILTY CLAY: high plasticity, red brown and light grey, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL	H		
	■			■	N = 24 5,10,14							>600 >600 >600	
						1			SILTY CLAY: high plasticity, light grey, with fine to medium grained ironstone gravel, trace of fine grained sand.				
				■	N = 30 8,15,15							>600 >600 >600	
						2		-	SANDSTONE: fine grained, light grey.	DW-SW	M-H		MODERATE 'TC' BIT RESISTANCE WITH HIGH BANDS
				■									
						3			END OF BOREHOLE AT 3.0m				
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
JK13
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER
JK350
R.L. Surface: ≈ 84.0m
Datum: ASSUMED
Logged/Checked by: D.S./A.Z.

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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 sandy clay, low plasticity, brown, trace of fine to medium grained ironstone gravel and root fibres.	MC<PL			GRASS COVER
	■			■	N = 27 7,11,16	1		CH	SILTY CLAY: high plasticity, light grey and red brown, with fine to medium grained ironstone gravel.	MC<PL	H	>600 >600 >600	
				■ ■		2		-	SHALE: dark grey and red brown.	DW	M		LOW TO MODERATE 'TC' BIT RESISTANCE
						3 4 5 6 7			END OF BOREHOLE AT 3.0m				

BOREHOLE LOG

Borehole No.
JK14
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER JK350
Logged/Checked by: D.S./A.Z.
R.L. Surface: ≈ 87.0m
Datum: ASSUMED

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES 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 sandy clay, low plasticity, brown, fine to medium grained sand, trace of root fibres.	MC<PL			GRASS COVER
								CL	SILTY CLAY: medium plasticity, orange brown, with fine grained sand.	MC<PL	H		
	■			■	N > 20 8,20/ 150mm REFUSAL				as above, but mottled light grey.			>600 >600 >600	
				■		1		-	SANDSTONE: fine grained, light grey and red brown.	DW	M		
				■							H		HIGH 'TC' BIT RESISTANCE
						2			END OF BOREHOLE AT 2.0m				'TC' BIT REFUSAL
						3							
						4							
						5							
						6							
						7							

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

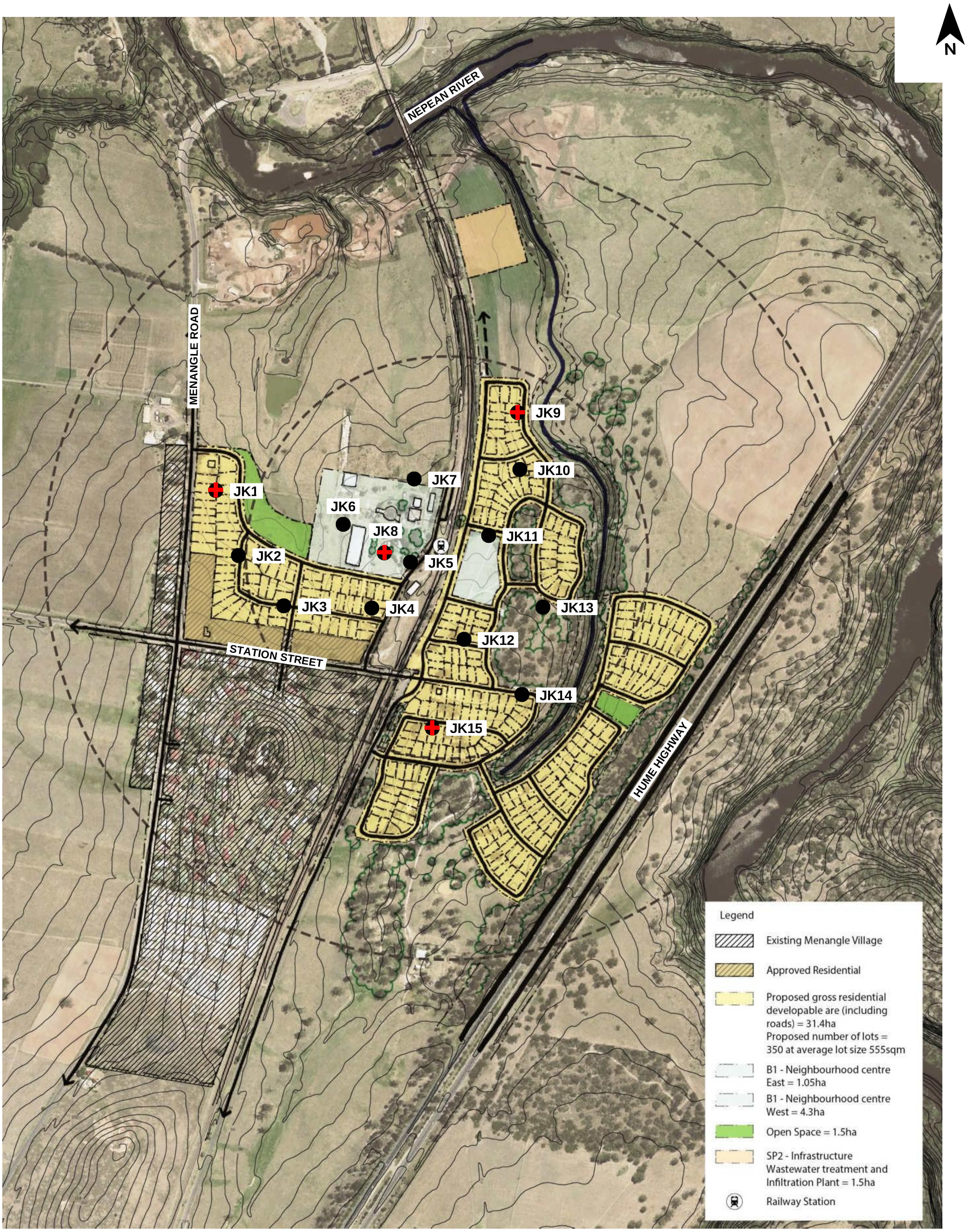
Borehole No.
JK15
1/1

Client: SOUWEST DEVELOPMENT
Project: PROPOSED SUB-DIVISION
Location: OFF STATION STREET, MENANGLE, NSW

Job No. 27284Z
Date: 7-3-14
Method: SPIRAL AUGER
JK350
Logged/Checked by: D.S./A.Z.
R.L. Surface: ≈ 87.0m
Datum: ASSUMED

Groundwater Record	SAMPLES ES	SAMPLES U50	SAMPLES DB	SAMPLES DS	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLET-ION						0			FILL: Silty clay, medium plasticity, brown, trace of root fibres.	MC<PL			GRASS COVER
								CL	SILTY CLAY: low plasticity, light grey, with fine to medium grained ironstone gravel, trace of root fibres.	MC<PL	(H)		
								-	SHALE: dark grey and red brown.	DW	L-M		LOW TO MODERATE 'TC' BIT RESISTANCE
						1					M		MODERATE RESISTANCE
						2							
						3							
						4							CLASS 18 PVC STANDPIPE INSTALLED TO 3. 5m DEPTH. MACHINE SLOTTED BETWEEN 6m AND 1m, CASING 1m TO SURFACE, BACKFILLED WITH 2mm SAND FILTER SAND 6.0m TO 0.5m, BENTONITE SEAL 0.5m TO 0.2m, METAL MONUMENT CONCRETED AT SURFACE
▼ ON 18-3-14													
						5							
						6			END OF BOREHOLE AT 6.0m				
						7							

COPYRIGHT



LEGEND:

● JK1 **Borehole location and number**

✚ **Groundwater monitoring well location**

NOTES:
Figure 2 has been recreated from the Site Concept Plan prepared by Elton Consulting

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.

Approx. Scale (m):
0 70 140 210 280 350

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

Title:
BOREHOLE LOCATION PLAN

Report Number:
27284Z

Figure Number:
1

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 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.

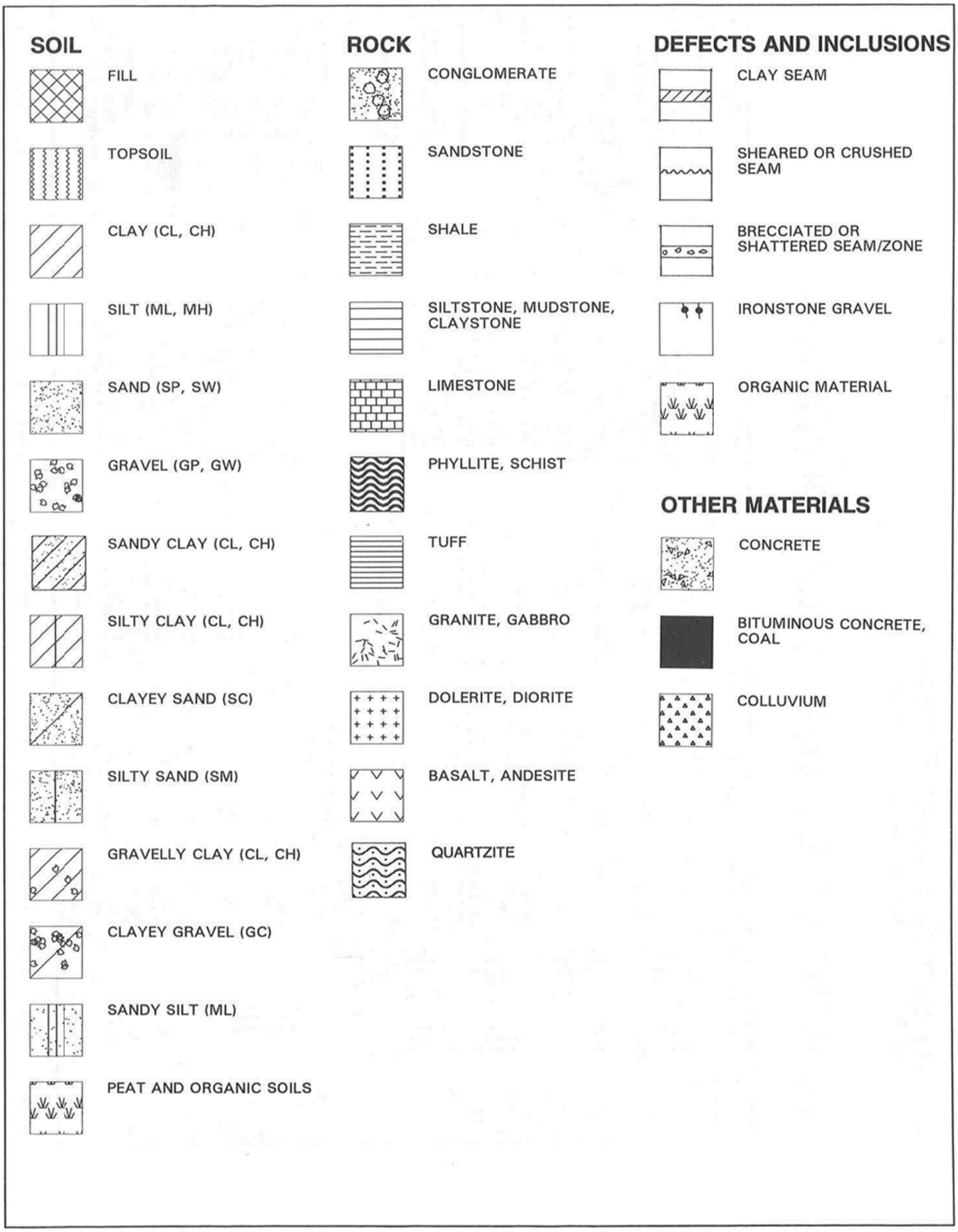
Requirements could range from:

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.

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

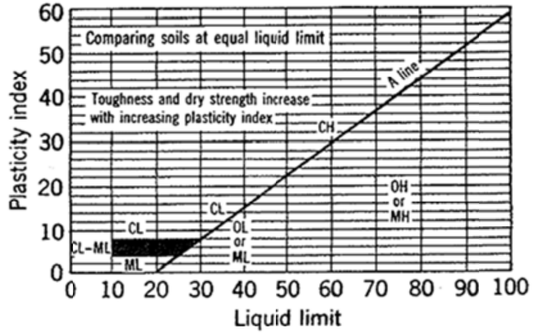
- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

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					Group Symbols a	Typical Names	Information Required for Describing Soils
		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)			
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	