Shoalhaven City Council C/- Watkinson Apperley Pty Ltd

martens consulting engineer

ENVIRONMENTAL

WASTEWATER

Hydrogeological Assessment:

Proposed Sub-division, Mundamia Release Area, Mundamia NSW.

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1 Overview

1.1 Introduction and Scope

This report documents the findings of a Hydrogeological Assessment (HA) undertaken at Mundamia Release Area, Mundamia, NSW.

The HA documents hydrogeological characteristics, assesses likely impacts associated with proposed site development and identifies mitigation measures to address potential adverse impacts on the site's groundwater system.

The principal potential impact covered by the assessment is habitat modification to the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle which may come about due to changes in groundwater regimes following site urban development.

This HA has put in place special protection and appropriate mitigation measures to address potential hydrogeological modification.

The site is on a ridge top position and the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle rely on shallow groundwater located at the base of the soil profile. This HA therefore considers the characteristics and assessment of this shallow aquifer and not the deeper rock aquifer.

1.2 Assessment Coverage

Site development assessed by this report is restricted to the development of:

Lot 3 DP568613:

Lot 384 DP755952;

Lot 1 DP1021332; and

Part Lot 458 DP1063107.

Figure 1 identifies the above allotments. Within Areas H and G (Figure 1) (Aboriginal Land Council land) the HA scope is limited to groundwater monitoring only.



2 Site Description

2.1 Location

The site is located approximately 4 km south west of Nowra and is within the Shoalhaven City Council Local Government Area.

2.2 Field Investigations

Field investigations for the HA were primarily undertaken 18 – 20 October, 2010. Geotechnical data derived by Martens and Associates on 9 September, 2008 was used to supplement the former investigations. Investigations included the following:

- Walkover inspection of the site to assess existing site conditions, local topography, geology, soil conditions and vegetation;
- Completion of 8 boreholes with a truck mounted hydraulic auger on 18 – 20 October, 2010 with Groundwater Monitoring Bore (GMB) installation into 5 of the 8 boreholes;
- Completion of 13 boreholes with a 4WD mounted hydraulic auger on 9 September, 2008;
- Falling head tests to estimate hydraulic conductivity (k) at each GMB;
- Collection of 6 soil samples for Wilting Point and Field Capacity analysis by laboratory; and
- o Installation of data loggers in accordance with the schedule provided in Table 1.



Table 1: Groundwater and rain gauge monitoring schedule.

Element	Monitoring Frequency (minutes)	Monitoring Period	Observations	Monitoring Method
GMB1, GMB2, GMB3, GMB4	10	19.10.2010 to 20.01.2011	GL, GT	Data logger
GMB5	10	19.10.2010 to 20.01.2011	BP, GL, GT, EC	Data logger
Rain Gauge	15	19.10.2010 to 20.01.2011	R	Rain gauge data logger

Key: BP = barometric pressure, GL = groundwater level, GT = groundwater temperature, EC = groundwater Electrical Conductivity, R = rain depth (mm).

2.3 Topography and Drainage

While site slopes vary from approximately 1 - 50% they are typically low at 3 - 6%. Indicative sub-catchments are shown in Figure 2.

2.4 Soil Profile

2.4.1 Overview

Borehole observations indicate that the site's soil profile typically comprises shallow (0 - 0.8 m deep) silty sand, silty gravel and gravels over extremely weathered sandstone. A deeper profile up to 2.8 m deep is also observed on the site and comprises silty sand over clayey sand and clays. The deeper profile is also underlain by extremely weathered sandstone. Borehole logs are provided in Attachment B with borehole locations provided in Figure 3.

2.4.2 Available Water Holding Capacity

6 soil samples were analysed by laboratory in order to better understand soil moisture conditions. Results are summarised in Table 2.

Table 2: Summary of available soil available water holding capacity results.

Sample ID. 1	Field Capacity ²	Wilting Point ³	Soil Texture
2761/4/0.4	9.9	5.4	Silty gravel
2761/8/0.3	16.8	12.1	Clayey sand
2761/6/0.5	23.2	11.6	Clay fill
2761/2/1.0	15.1	8.0	Silty sand
2761/3/0.35	19.7	8.9	Organic silty sand
2761/5/0.1	19.1	9.9	Organic silty sand

Notes: $1 \cdot \#/\#/\# = \text{project ID/borehole ID/sample depth.}$ 2. 0.3 bar %. 3. 15 bar %.



2.5 Groundwater

2.5.1 Overview

Based on field and monitoring observations the shallow site groundwater system is generally characterised as follows:

- o Unconfined.
- Moderate hydraulic conductivity (K).
- Base comprises extremely to moderately weathered sandstone with a low K value.
- Flow in areas of shallow soil is ephemeral (non-permanent) with the soil profile frequently becoming unsaturated.
- o Flow in areas of deeper soil is less ephemeral.
- Flow vectors are expected to generally mimic the topography of the sandstone rock layer (which is expected to be similar to ground level topography but at a lower level).
- o Groundwater availability is controlled by recharge, which is controlled by antecedent rainfall and evapotranspiration (ET).
- o Groundwater discharges to the surface as seepage in areas where the sandstone rock layer forms the ground level. This occurs at the top of steep slopes on adjacent land.

2.5.2 Hydraulic Conductivity (K)

Site K testing to date is summarised in Table 3. Results indicate that site soils are of moderate permeability. Refer to Figure 3 for the location of GMBs.



Table 3: Summary of aquifer K testing results.

GMB	Test Medium	Estimated K (m/d)
1	Sand	5.46
1	Sandstone rock	0.01
2	Variable	0.42
3	Silty Sand	0.09
4	Silty sand and silty gravel	1.86
5	Silty sand	0.53
Geometric mean		0.36
Median	Variable	0.48
Mean		1.40

Notes: ¹ Results based on Martens and Associates testing completed on 19-20.10.2010. ² Test type = falling head. All data analysed using the Hvorslev (1981) method.

2.5.3 Manual Groundwater Level Measurements

Manual groundwater level measurements taken during this investigation are summarised in Table 4 together with GMB details.

Table 4: Manual groundwater level measurements.

GMB ID	GMB1	GMB2	GMB3	GMB4	GMB5
Surveyed GL (mAHD)	67.27	69.62	60.50	63.50	55.24
Invert (mAHD)	66.64	66.81	59.86	62.50	54.47
Depth into Ground (m)	0.64	2.81	0.64	1.00	0.77
MGA Easting	277612.00	277887.90	278361.30	278027.40	278501.90
MGA Northing	6137025.30	6137094.00	6137231.90	6137511.90	6137574.30
Top of pipe level (mAHD)	67.99	70.31	61.19	64.15	55.91
Pipe Height above GL (m)	0.72	0.69	0.69	0.65	0.67
Total Well Length (m)	1.36	3.50	1.33	1.65	1.44
		Manual Dip Measure	ments (mAHD/mBGL)		
20/10/2010	66.88/0.39	67.25/2.37	dry	dry	dry
22/11/2010	66.80/0.47	67.69/1.93	60.01/0.49	dry	dry
20/01/2011	66.69/0.58	67.76/1.86	dry	dry	dry

2.5.4 Continuous Groundwater Level and Rain Measurements

A residual groundwater level plot for all GMBs with rainfall is provided in Figure 4. Individual groundwater level and rain plots are provided for



GMBs 1-5 in Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9 respectively. Groundwater level response plots for GMB1, GMB3 and GMB5 are provided in Figure 10, Figure 11 and Figure 12 respectively. Groundwater level response plots for GMB2 and GMB4 are not provided due to a poor regression.

Analysis of continuous groundwater level and rain data indicates the following:

- o GMB1 and GMB3 are saturated above the soil/rock interface for approximately 50% of the monitoring period.
- o GMB2 is saturated above the soil/rock interface for the whole of the monitoring period.
- GMB4 remained dry above the soil/rock interface throughout the whole of the monitoring period. This is expected given that the silty gravel layer above the rock is considered to be highly permeable.
- o GMB5 is saturated above the soil/rock interface for approximately 35% of the monitoring period.
- o Based on the groundwater level response plot at GMB5 (Figure 12), which had the highest linear regression value, groundwater level response occurs once daily rain exceeds approximately 3 mm. Analysis of long-term climate data for Nowra indicates that on average a rain day of greater than 3 mm will occur 63 days per year.
- GMBs generally respond in a similar manner to stresses with the exception of GMB4. GMB4 was installed into soil considered to be more permeable than other GMBs.
- The mechanism responsible for groundwater level trends is principally influenced by recharge (a function of rainfall infiltration and ET). Soil type also influences groundwater level trends as less permeable soils retain groundwater for a longer period of time. Available Water Holding Capacity results (Table 2) support this conclusion.

2.5.5 Groundwater Electrical Conductivity (EC)

Groundwater EC was continuously monitored by a data logger at GMB 5. The maximum observed EC value of 510 µS/cm indicates groundwater is fresh.



2.5.6 Vegetation

The Spring Tiny Greenhood Orchid has been mapped (Figure 3) outside of the site whilst the Nowra Heath Myrtle has been mapped (Figure 3) both within and outside of the site. Advice from the project flora and fauna consultants is that both of these species may be adversely affected by potential changes to the surface water and groundwater regimes which may come about due to the proposed-development.

The habitat of the Spring Tiny Greenhood Orchid is associated with the moss gardens within some areas of Kunzea Shrubland. As no moss garden mapping is available, Kunzea Shrubland is taken as a mapping surrogate for potential Spring Tiny Greenhood Orchid (outside of mapped instances) habitat. This assessment therefore conservatively presumes that the Spring Tiny Greenhood Orchid could exist in areas of mapped Kunzea Shrubland.

Discharge of groundwater to the surface as seepage flow occurs in areas of sandstone outcropping and is the mechanism which provides groundwater to Spring Tiny Greenhood Orchid and Nowra Heath Myrtle. These species are considered to not be wholly reliant on groundwater as flow from surface water is also considered to sustain these species.

Seven areas of Kunzea Shrubland are mapped near the site (Areas A – G in Figure 3).

Of the seven areas depicted in Figure 3, Areas A, B, C and G have catchments that do not encroach onto areas of proposed site development. Areas D, E and F have catchments that do encroach upon areas of proposed site development and therefore are considered prone to potential impacts associated with site urban development.

Nowra Heath Myrtle is mapped downslope of areas proposed to be developed and therefore is considered prone to potential impacts associated with site urban development.

2.5.7 Conceptual Hydrogeological Model

The conceptual model is based on information detailed in Section 2 and is summarised as a schematic in Figure 13.

Inflow to the shallow groundwater system consists of infiltrated rainfall; outflows include ET and discharge as spring-flow (seepage).



3 Groundwater Impact Assessment

3.1 Potential Impacts

3.1.1 Altered Flow Regime

The proposed-development has the potential to alter groundwater flow to potential orchid habitat in Kunzea Shrubland Areas D, E and F (Figure 3) and to areas of Nowra Heath Myrtle whose hydrogeological catchment encroaches upon areas of proposed site development.

Urban development may alter flow regime as follows:

- o Impervious areas shall increase resulting in reduced groundwater recharge.
- Reduced site vegetation shall result in reduced evapotranspiration.
- Reduced overall recharge shall reduce the total soil moisture content and therefore reduce the frequency of groundwater 'flow' events and the number of days per year when seepage to vegetated lands shall occur.

3.1.2 Changes to Flow Quality

Changes to groundwater quality may potentially impact the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle areas identified above due to reductions in water quality. We note that this potential impact is considered less likely and can be managed more readily than impacts associated with altered flow regime.

3.2 CLASS-U3M-1D (Unsaturated Moisture Movement Model)

3.2.1 Overview

The CLASS soil moisture model developed by eWater Cooperative Research Centre is used to assess site groundwater recharge flow to the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle. The model utilises site rainfall and evaporation data together with soil profile properties to assess the net recharge to groundwater.

In consultation with eWater Cooperative Research Centre it was confirmed the CLASS model was appropriate for this application as follows:

 Groundwater flow is ephemeral and therefore not suited to modelling with conventional groundwater models such as MODFLOW.



- The conceptual hydrogeological model is suited to CLASS as the soil/rock interface layer has a low slope and soil stratigraphy is not overly complex.
- Long-term climate data is considered important for the model simulation and CLASS is run using a long-term daily climate file.
- Catchment and soil science experts of the eWater Cooperative Research Centre indicated that the model was suitable for the intended application.

3.2.2 Inputs

Input parameters used in the model are summarised in Table 5 with 'screen dumps' of model inputs shown in Figure 14.

Table 5: CLASS input parameters.

Element	Input
Soil Layers	1
Soil Layer Depth (mBGL)	0 to 0.5
Soil Parameters	Loamy Sand (CLASS default soil catalogue parameters)
Soil K (m/d)	0.5
Ksub (m/d) ¹	0.5
Climate file	Daily 50 yr rain and evaporation file derived from NOWRA RAN BOM station

Notes: ¹ A Ksub value of 0.5 m/d was assigned so that flux out of the soil layer could be considered as seepage.

3.2.3 Results

Total seepage flux determined by the CLASS modelling system indicate an average of 473 mm/yr of water passes beyond root zones for undeveloped site conditions.

A 'first principles' analysis was used to verify CLASS results. Assuming mean annual rainfall of 1,256 mm; mean annual actual ET of 650 mm and a run-off coefficient of 0.15, seepage flux is estimated at 418 mm. This calculation validates the CLASS model results.

A sensitivity analysis was completed assuming vegetation was forest (compared to grass in primary analysis). This sensitivity analysis determined an average annual recharge of 436 mm/yr which



indicates that the CLASS model is relatively insensitive to vegetation type.

Seepage output results from the CLASS model are provided in Figure 15.

3.2.4 Impact Assessment

3.2.4.1 Overview

Advice from Allen, Price and Associates (project planner for Twynam Property Group) suggests that impervious area will be approximately 40% of total Malbec site area. Advice from Watkinson Apperley (Council's project planner) indicates that a similar impervious/pervious area balance is likely to result from the development proposed on Council lands.

This assessment is completed on the basis of recharge per ha of development to allow application to each site and future staging as required.

Average pre-development recharge is calculated to be 4.73 ML/ha/yr. Development resulting in an impervious area of 40% will decrease the average recharge to 2.84 ML/ha/yr (0.6 x 4.73 = 2.84). Consequently, 1.89 ML/ha/yr of supplementary recharge will be required to achieve a neutral impact.

As the final development design shall impact final impervious areas Table 6 has been prepared to provide recharge requirements for a range of final impervious area percentages.

All areas of the site require application of supplementary seepage (Figure 3).



Table 6: Supplementary recharge requirements.

Existing Annual Average Recharge (ML/ha/yr)	Impervious Area (%)	Required Supplementary Recharge to Achieve Neutral Impact (ML/ha/yr)
	30	1.42
	35	1.66
	40	1.89
4.73	45	2.13
	50	2.37
	55	2.60
	60	2.84

3.2.4.2 Conclusion

Analysis confirms that proposed urban development shall result in reduced groundwater recharge. This shall result in reduced seepage to downslope vegetation which is likely to have an adverse impact on vegetation health. Therefore, mitigation measures are required to ensure the protection of downslope vegetation in particular the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle.

Due to the hydrogeological catchments of the site and location of potential Spring Tiny Greenhood Orchid habitat and Nowra Heath Myrtle, mitigation works are required across all areas of the site as shown in Figure 3.

Importantly, with mitigation works outlined in Section 4 of this report, the post-development flow to the potential Spring Tiny Greenhood Orchid habitat and Nowra Heath Myrtle shall be equivalent to the predevelopment flow thus ensuring no adverse hydrogeological effects on this valuable ecological resource.



4 Mitigation Strategy

4.1 Mitigation Objective

The objective of the mitigation strategy is to develop site design recommendations to ensure that the development does not significantly alter the volume of groundwater available to the Spring Tiny Greenhood Orchid and Nowra Heath Myrtle.

4.2 Mitigation Strategy

4.2.1 Overview

Existing site recharge conditions result in maximum duration seepage flow after rainfall recharge occurs throughout the catchment. To best mimic this process it is recommended that supplementary recharge be applied throughout the catchment and not concentrated at the end of the stormwater system low in the hydrogeological catchment of the potential Spring Tiny Greenhood Orchid habitat and Nowra Heath Myrtle. To achieve this, recharge systems should be applied at regular lateral and longitudinal spacing.

4.2.2 Supplementary Recharge System (SRS)

A stormwater recharge infiltration system is proposed to be designed to augment natural recharge. The system is to supply supplementary recharge at rates detailed in Table 6. Final required supplementary recharge volume will depend on the development's impervious area percentage.

Structures suited to facilitating supplementary recharge include:

- Road side swales
- o Bio-retention swales
- o Bio-retention basins
- o Rain gardens

4.3 Location and Design of SRS

4.3.1 Location

Recharge structures are to be sized to replace lost recharge and located to ensure recharge is distributed throughout the catchment. The distribution of the SRS at a range of distances from the potential



Spring Tiny Greenhood Orchid habitat and Nowra Heath Myrtle shall assist in ensuring temporal seepage patterns remain unaltered.

SRS are required across the entire site (Figure 3).

4.3.2 Typical Design of SRS

SRS sizing is based on the following assumptions:

- 189 mm/ha/yr of supplementary recharge is required to replace lost recharge.
- o The SRS is designed to recharge water for events of 3 mm/d rainfall or greater based on observed groundwater response to this size of rainfall event. Review of climate information indicates rainfall of 3mm or more occurs on average 63 days per year based on local climate record analysis.
- Site soils are generally silty sands and clayey sands and therefore the minimum expected K value is 240 mm/d (i.e 10 mm/hr).
- o To achieve 189 mm/ha/yr of recharge over 63 days with a daily recharge rate of 240 mm/d a recharge basin area of 125 m²/ha is required (1890000/(63 x 240). This area rate does not take into account SRS side batters and therefore a nominal footprint of 250 m²/ha is considered appropriate.
- SRS are to store 240 mm of water from any given rainfall event to ensure adequate daily infiltration. This may be provided as standing water depth 240 mm deep or aggregate filled storage beds of approximately 720 mm depth or a combination of the two.
- It is noted that the distributed recharge areas shall need to be hydraulically connected to the potential Spring Tiny Greenhood Orchid habitat and Nowra Heath Myrtle areas. Groundwater flow obstructions such as roads along contours with pavements to/or near rock shall need to ensure that water can flow unobstructed to the site boundaries. This is to be addressed at detailed design stage but is expected to be feasible by adopting some or all the following:
 - Under road culverts at specific locations;
 - Permeable aggregate drains upslope, beneath and downslope of roads;
 - Permeable road sub-base.



4.3.3 Monitoring and Performance Criteria of SRS

The SRS should be inspected regularly for debris build up and sediment accumulation.

If SRS infiltration becomes reduced then the SRS base may require stripping of fines to ensure ongoing effective infiltration from the system.

4.4 Water Quality Measures

4.4.1 Groundwater

Review of typical pollutant generation rates for agricultural and residential land uses indicate Event Mean Concentrations (EMCs) for the proposed residential land use are typically lower than for agricultural land use (predominant current land use). Therefore, as pollutant concentrations shall be reduced the quality of water seeping through to the aquifer should be the same or better.

4.4.2 Surface Water

Stormwater quality will need to be addressed. This is outside the scope of this investigation.



5 Conclusion

This Hydrogeological Assessment confirmed that the site has a shallow ephemeral (non-permanent) groundwater system within the soil mantle over shallow sandstone rock. This groundwater discharges as seepage at areas of rock outcropping and maintains water supply to potential Spring Tiny Greenhood Orchid habitat within Kunzea Shrubland and Nowra Heath Myrtle vegetation.

Groundwater flow directions at the site are considered to approximate natural ground level vectors. Sensitive vegetation's hydrogeological catchments cover the entire proposed site development.

Mitigation measures have been outlined to ensure the protection of the vegetation associations, these include a system of stormwater infiltration areas to supplement groundwater recharge.

The recommended stormwater infiltration areas are to be located throughout the development area. Recharge systems are required at a rate of 125 m^2 /ha (nominal footprint of 250 m^2 /ha with side batters) and are to include 240 mm of runoff storage.

Design of road and other structures/infrastructure with the potential to intercept, disrupt or redirect groundwater flows is to be undertaken with due consideration to maintain the existing downslope groundwater regime.

Assessment findings indicate that site development is able to proceed with a neutral impact provided the recommendations in this report are adhered to.



6 Limitations Statement

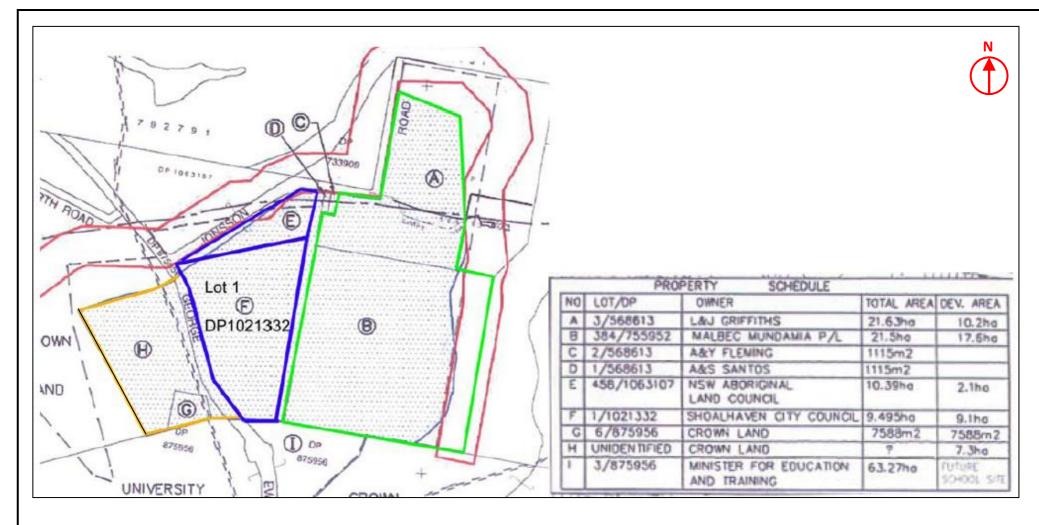
Groundwater conditions during proposed works may be found to be different from those detailed in this report due to investigation limitations and/or climate conditions. Should, during site works, soil or water conditions be found to be significantly different to those detailed in this report, works shall cease immediately and the new conditions should be assessed by Martens & Associates to determine implications before recommencement.

Martens & Associates Pty Ltd has undertaken this assessment for the purposes of the current development proposal. No reliance on this report should be made for any other investigation or proposal. Martens & Associates accepts no responsibility, and provides no guarantee regarding the characteristics of areas of the site not specifically studied in this investigation.



7 Attachment A – Figures

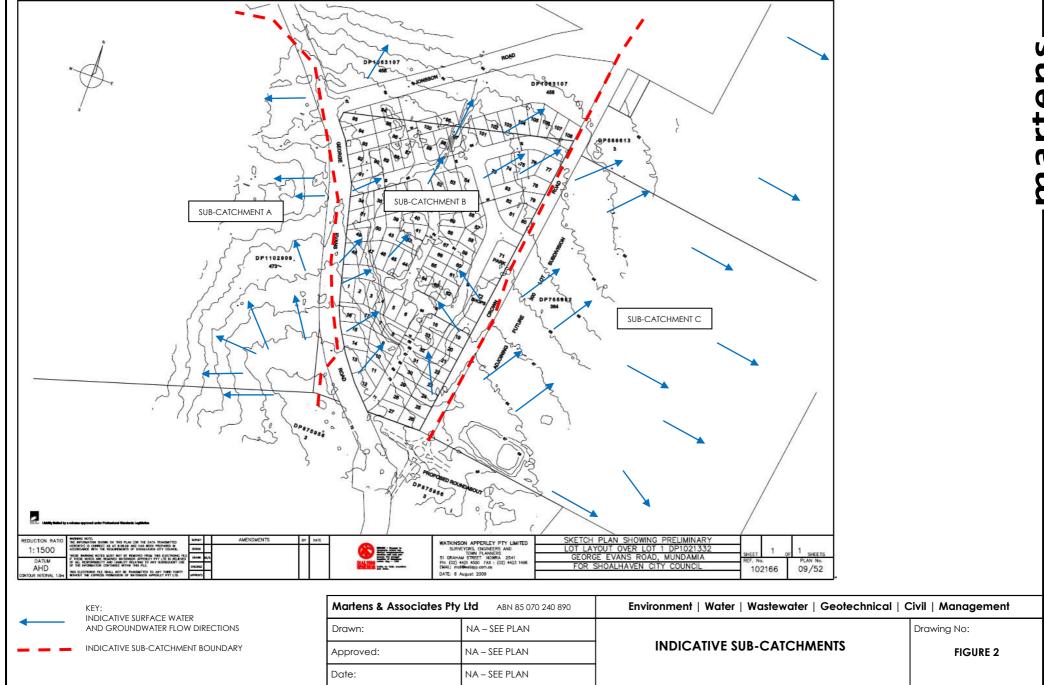




 Areas covered by Groundwater Assessment = A, B, E, F, G and H.

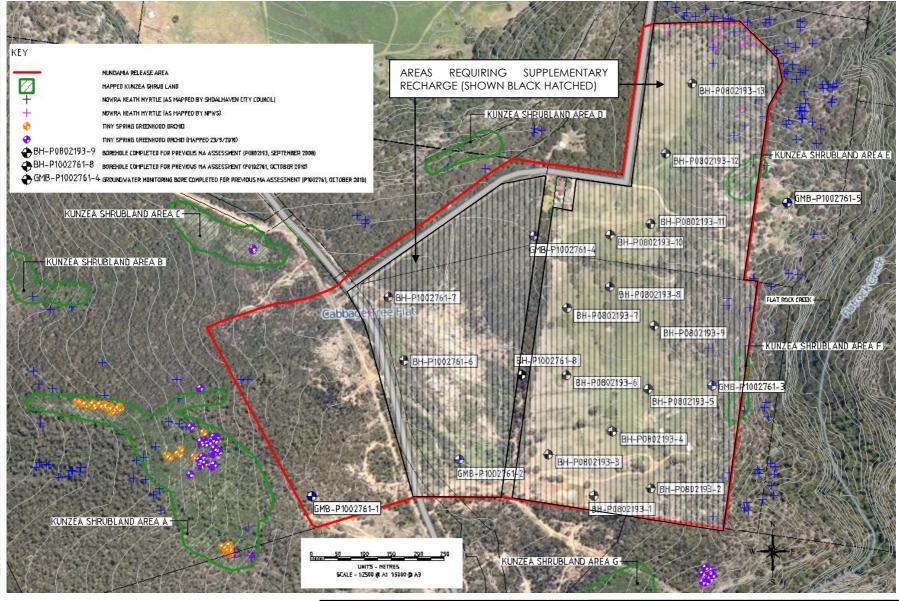
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management				
Drawn:	WATKINSON APPERLEY		Drawing No:			
Approved:	AN	AREAS COVERED BY GROUNDWATER ASSESSMENT	FIGURE 1			
ate: 30.06.2010		ASSESSMENT				
Scale:	APPROX 1: 16,550		Job No: P1002761			

Job No: P1002761



NA – SEE PLAN

Scale:



- Borehole locations indicative only.
- ^{2.} GMB locations surveyed.

Martens & Associates Pty	Environment Water	
Drawn:	BR	
Approved:	AN	BOREHOLE AND
Date:	15.02.2011	
Scale:	APPROX 1: 7,080	

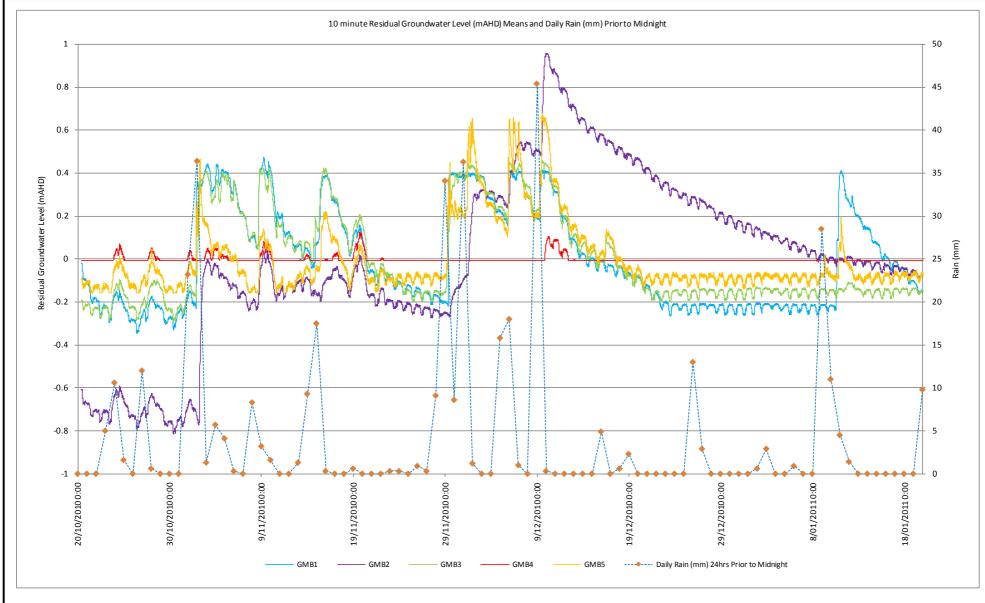
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DLE AND GMB LOCATIONS

Wastewater | Geotechnical | Civil | Management

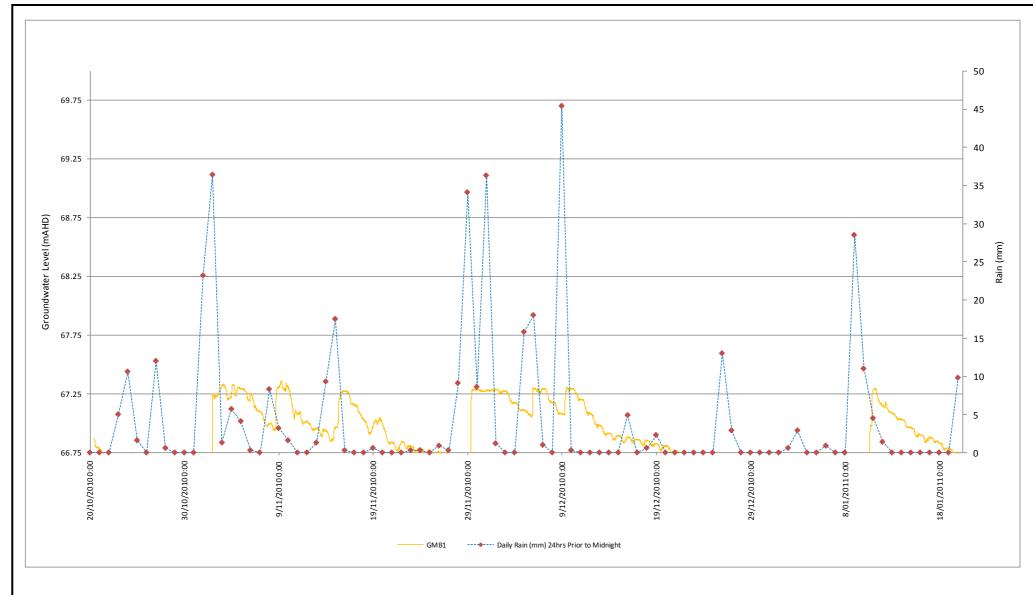
FIGURE 3

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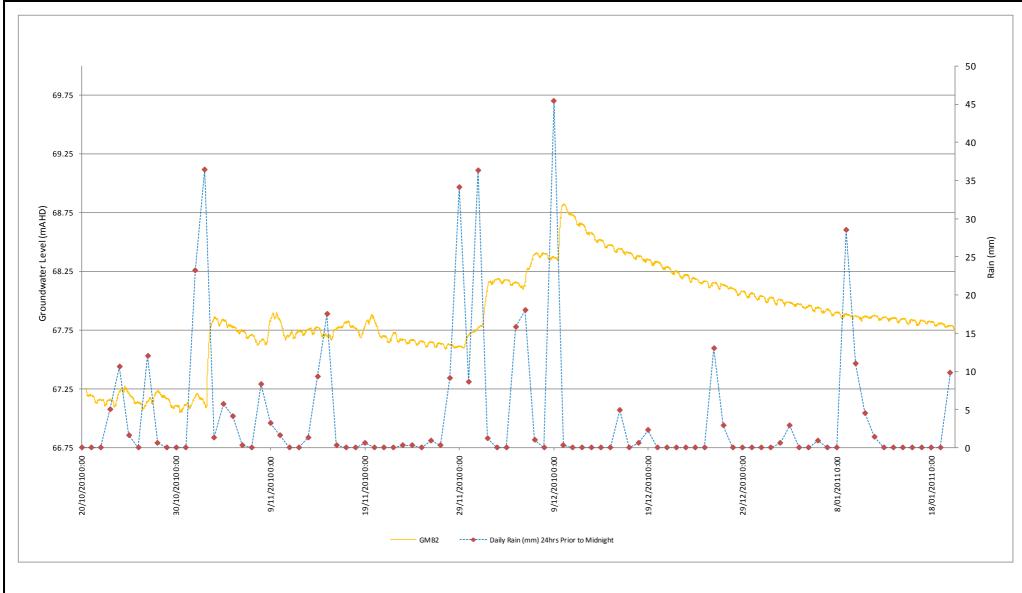


Residual mean = observed level – mean GMB level over monitoring period. This was done to normalise data.

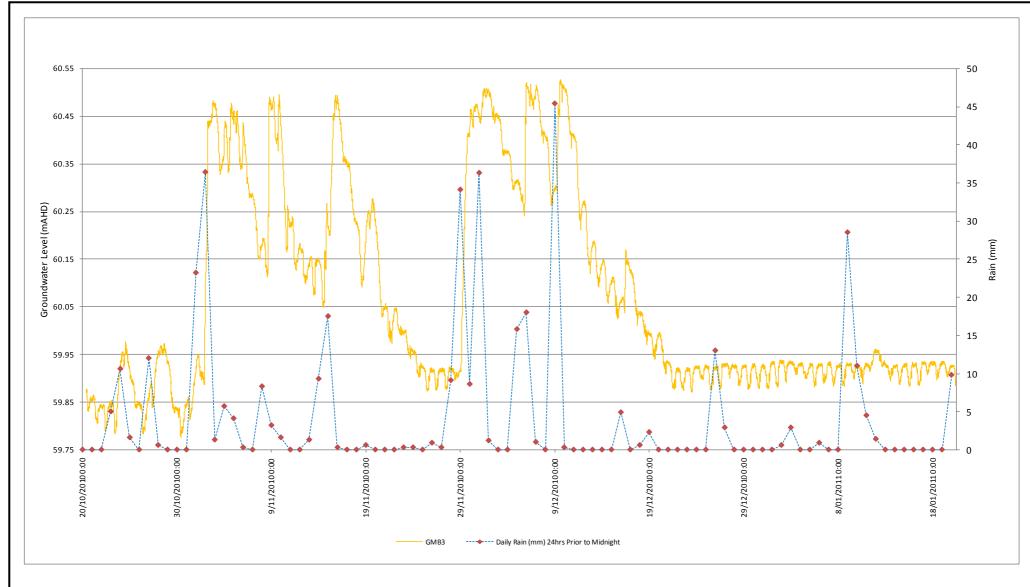
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	Approved:	AN	RESIDUAL MEAN GROUNDWATER LEVELS AND SITE RAIN	FIGURE 4	
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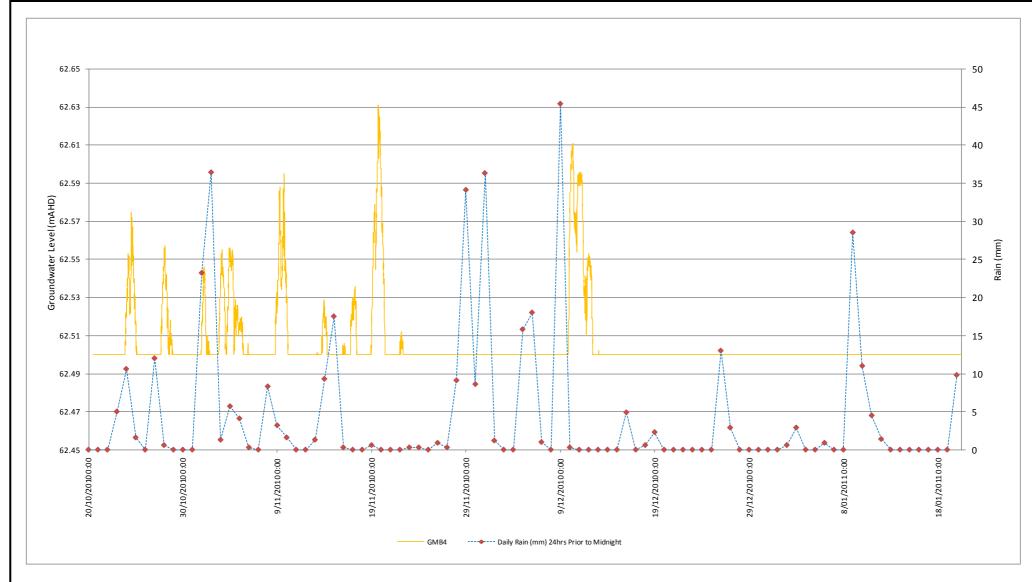
Martens & Associates Pty	Ltd ABN 85 070 240 890	Environment Water Wastewater Geotechnical Civil Management			
rawn: BR			Drawing No:		
Approved:	AN	GMB1 CONTINUOUS GROUNDWATER LEVEL AND RAIN	FIGURE 5		
Date:	15.02.2011	ROIN			
Scale:	NA		Job No: P1002761		



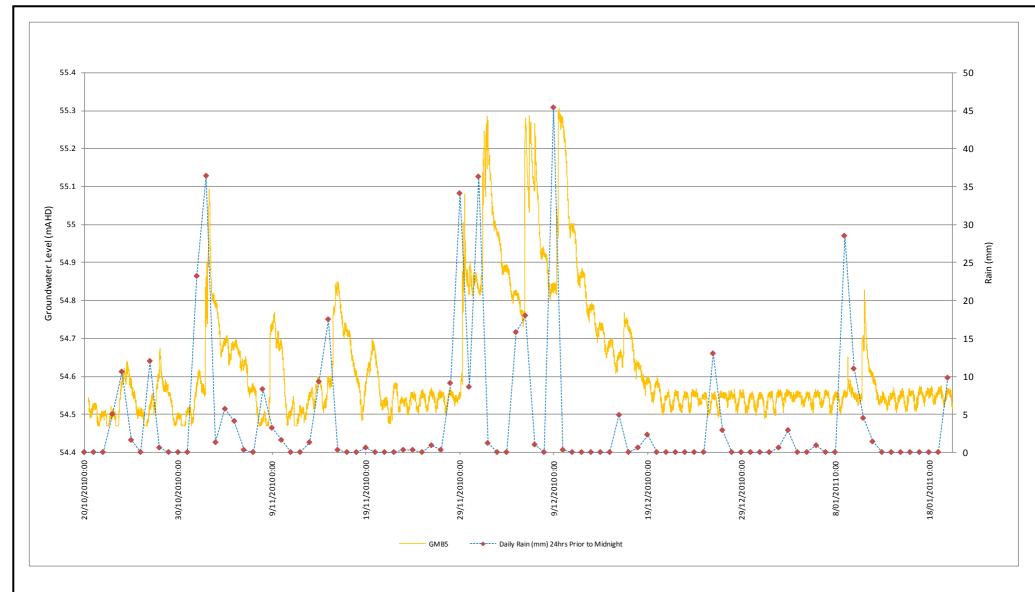
	Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
	Drawn:	BR	GMB2 CONTINUOUS GROUNDWATER LEVEL AND RAIN	Drawing No:
	Approved:	AN		FIGURE 6
	Date:	15.02.2011	KOIN	
	Scale:	NA		Job No: P1002761



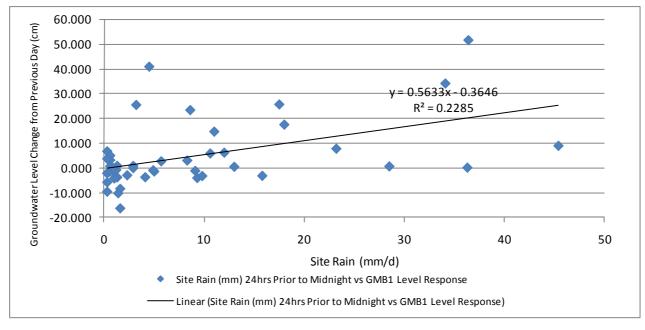
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
Drawn:	BR	GMB3 CONTINUOUS GROUNDWATER LEVEL AND RAIN	Drawing No:
Approved:	AN		FIGURE 7
Date:	15.02.2011	KAIN	
Scale:	NA		Job No: P1002761



Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
Drawn:	BR	GMB4 CONTINUOUS GROUNDWATER LEVEL AND RAIN	Drawing No:
Approved:	AN		FIGURE 8
Date:	15.02.2011	KAIN	
Scale:	NA		Job No: P1002761

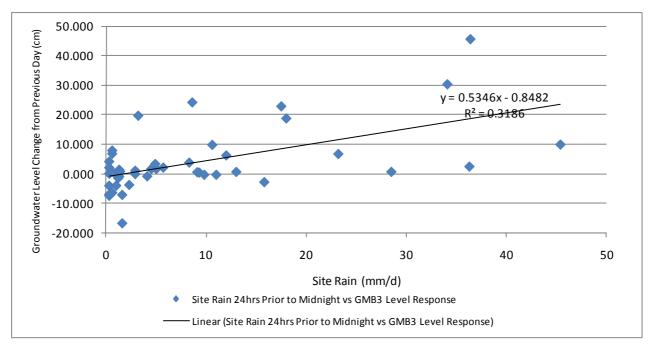


Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
Drawn:	BR	GMB5 CONTINUOUS GROUNDWATER LEVEL AND RAIN	Drawing No:
Approved:	AN		FIGURE 9
Date:	15.02.2011	KAIN	
Scale:	NA		Job No: P1002761



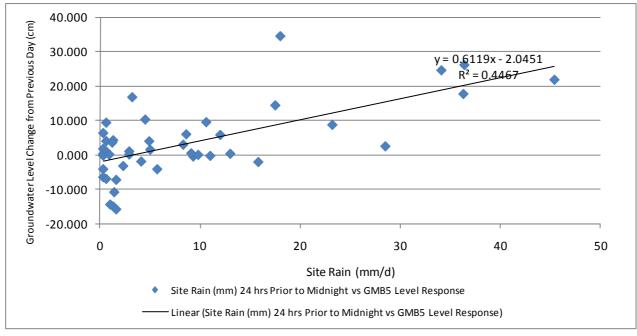
1. Line formula indicates that a groundwater response occurs once daily rainfall exceeds 0.65 mm.

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management		
Drawn:	BR		Drawing No:	
Approved:	AN	GMB1 GROUNDWATER LEVEL RESPONSE VS DAILY RAINFALL	FIGURE 10	
Date:	15.02.2011	DAILI KAINI ALL		
Scale:	NA		Job No: P1002761	



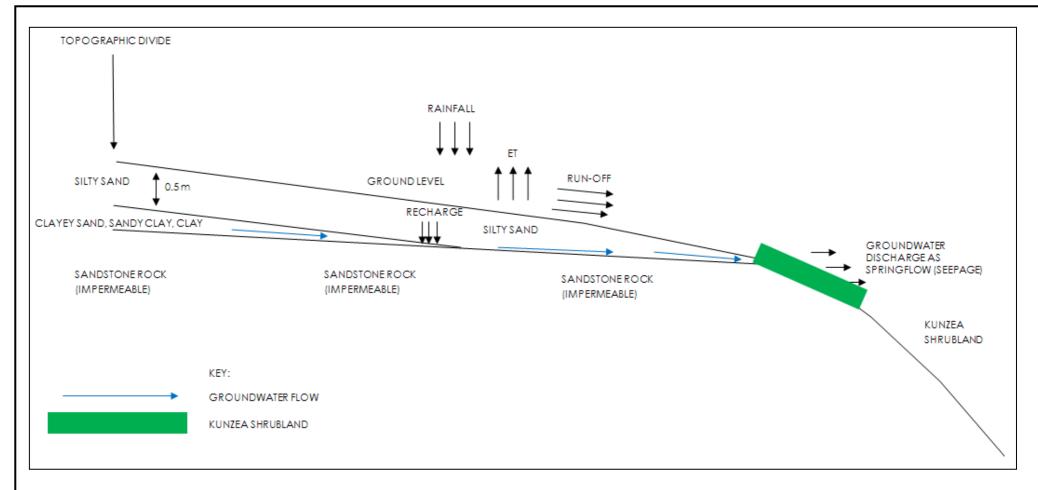
1. Line formula indicates that a groundwater response occurs once daily rainfall exceeds 1.59 mm.

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management		
Drawn:	BR		Drawing No:	
Approved:	AN	GMB3 GROUNDWATER LEVEL RESPONSE VS DAILY RAINFALL	FIGURE 11	
Date:	15.02.2011	DAILI KAINI ALL		
Scale:	NA		Job No: P1002761	

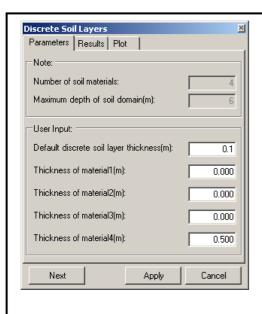


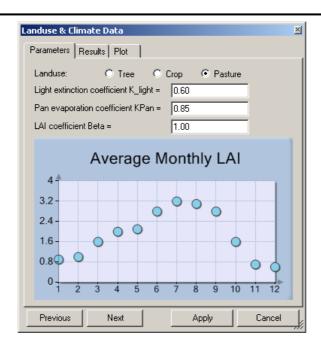
1. Line formula indicates that a groundwater response occurs once daily rainfall exceeds 3.34 mm.

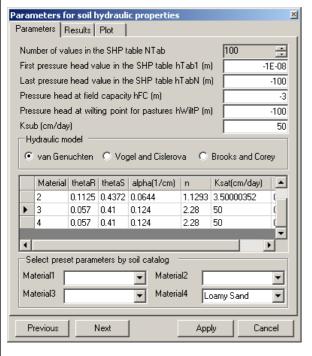
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management		
Drawn:	BR		Drawing No:	
Approved:	AN	GMB5 GROUNDWATER LEVEL RESPONSE VS DAILY RAINFALL	FIGURE 12	
Date:	15.02.2011	DAILI KAINI ALL		
Scale:	NA		Job No: P1002761	

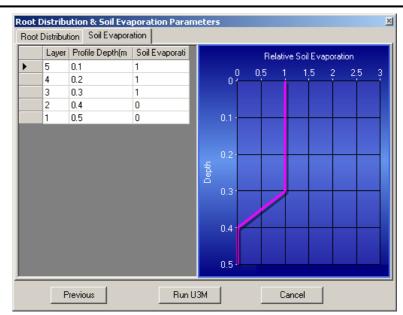


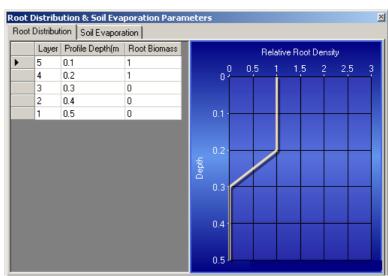
Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management		
Drawn:	BR		Drawing No:	
Approved:	AN	CONCEPTUAL HYDROGEOLOGICAL MODEL	FIGURE 13	
Date:	15.02.2011			
Scale:	NA		Job No: P1002761	



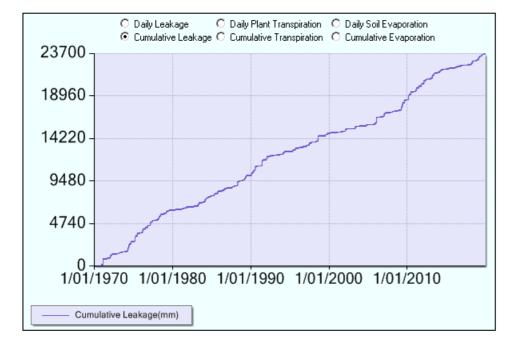


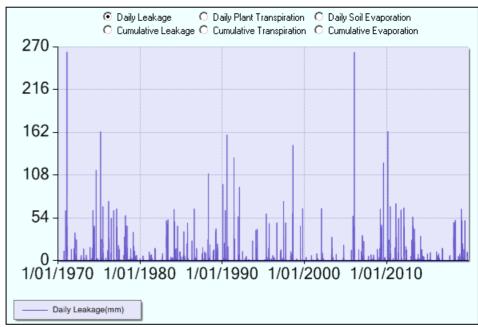






Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
Drawn:	BR		Drawing No:
Approved:	AN	CLASS MODEL INPUTS	FIGURE 14
Date:	18.02.2011		
Scale:	NA		Job No: P1002761





Martens 8	Martens & Associates Pty Ltd ABN 85 070 240 890		Environment Water Wastewater Geotechnical Civil Management	
Drawn:		BR		Drawing No:
Approved:	:	AN	CLASS MODEL OUTPUT PLOTS	FIGURE 15
Date:		18.02.2011		
Scale:		NA		Job No: P1002761

8 Attachment B – Borehole logs



CL	IEN ⁻	Т	S	hoalhav	en (City	Counci			COMMENCED	18.10.10		COMPLET	ED	18.10.10			REF	E	3H1
	OJE	СТ					Investig			LOGGED	BR		CHECKED	,	AN			Sheet 1		
SIT			Α	borigina			Council	(Mu	ındamia)	GEOLOGY	Sandstone		VEGETAT	-	Grass			PROJECT N	IO . P10	02761
-	IPME		IMEN	ISIONS	Auge		0.66m depth			EASTING NORTHING	-		RL SURFA ASPECT	_	67.27m AF West	ID		SLOPE	4%	
-				ION DA		IIII X	0.00m deptin		M	ATERIAL D	ATA		AGFECT		77631	S	AMPLIN	IG & TES		
Т						ш	(2)	Z					>	×		T		WATER		ETAILS
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	L M PENETRATION	H RESISTANC	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, particle characteristics, org	PTION OF STE mottling, colour, p lanics, secondary ontamination, odo	asticity, rocks and minor con	, oxidation, nponents,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)		0.72m agl		Well Cover
Α	Nil	N	М	0.05			x x x	SM	SILTY SAND - Brov			ediately			A					Bentonite Seal.
A	Nil	N	М	0.28			-	SW	SAND - Light brow with depth, co		ight grey t					0.1	27617170			UPVC Pipe. 0.18m bgl 0.2m bgl
А	Nil	N	М	0.66			F 7	SW	SLIGHTLY WE	ATHERED S	ANDSTO	NE.						0.635m bgl		UPVC Screen.
				0.66					Borehole terminated	at 0.66m on sandstone.	slightly we	eathered							<u>-~~~</u>	- , -
				1.0																1.0
				_																- -
				-																-
																				- -
				2.0																2.0
				_																- - -
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				_																- - -
				3.0																3.0
																				- - -
				_																- -
				_																-
				4.0																4.0
				_																-
		45.	,	4.5					Molecular	TDAT/ON TO	101075									4. <u>5</u>
N B E H S P A	H Ba Ex A Ha Ha T Pu	atural existing ckhoe cavate and au and sp sh tub ger	expos exca buck or ger ade e	ure SH vation SC et RE Nil	JPPOF H Sho C Sho B Roo I No:	ring tcrete k Bol	ts 🅎 Wat	e obse neasu er leve er outf	erved D Dry L Loured M Moist M M el W Wet H H Wp Plastic limit R Re flow WI Liquid limit	ow VS oderate S gh F efusal St VSt H	SISTENCY Very Soft Soft Firm Stiff Very Stiff Hard Friable	DENSITY VL Very Loose L Loose MD Medium D D Dense VD Very Dens	se A A B E Dense U U D E se M M	Auger s Bulk sar Jndistu Disturb Moistur	i & TESTII ample mple rbed sample ed sample e content ample (x mi	le i n) i	pp Pocket p S Standard VS Vane sh DCP Dynan penetro FD Field de WS Water s	nic cone ometer nsity	SYM	ASSIFICATION MBOLS AND L DESCRIPTION USCS Agricultural
	C Co		Core	r		F	XCAVATI	ON I	OG TO BE READ IN CONJU	JNCTION WIT	H ACCOMP	ANYING REP	ORT NOTE	ES AN	ID ABRR	EVIAT	IONS			
\vdash			7							MARTENS &				1				orin		

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PR	OJE	СТ	$\overline{}$				l Investiç			LOGGED	BR	CHECKED	A	١N			Sheet 1		
SIT	Έ		S	hoalhav			Council	(Mu	ındamia)	GEOLOGY	Sandstone	VEGETATIO	ON C	Grass			PROJECT	NO . P	1002761
	IPME			1010110	Auge		0.0			EASTING NORTHING	-	RL SURFAC	_	9.62m AHD)		01.005	5-10	2007
EXC				ISIONS		mm X	2.8m depth		M 2	ATERIAL DA	- \ΤΔ	ASPECT	ľ	iorth East	SA	MPIIN	SLOPE		17/0
						·		z	INIT	TI EINIAE DA	NIA .		×		T				DETAILS
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	U PENETRATIO	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR mottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)		0.69m agl		Well Cover
А	Nil	N	D	0.3			× × × × × × × × × × × × × × × × × × ×	OL	ORGANIC SILT	- Dark brown	, possibly fill?			A	0.1	2761/2/0	.1		Bentonite Seal.
А	Nil	N	D	0.5				CL	SILTY CLAY gravels (10-2					A	0.35	2761/2/0	.35		_
Α	Nil	N	D	1.0				SM		ark brown, ve 0-15mm, 30% e root?), poss	6), wood			A	1.0	2761/2/1.			UPVC Pipe
A	Nil	N	М	2.4			× × × × × × × × × × × × × × × × × × ×	OH	coarse grain	ent, very moi	st, possibly fill? sigh sand content, t, possibly			A	2.5	2761/2/2	5		000000000000000000000000000000000000000
A Nil N M C CL coarse grained, very moist, possibly extremely weathered sandstone.														Well end plug.					
N B E H S P	Na Ex H Ba Ex A Ha Ha T Pu Au	atural oxisting ackhoe acavate and au and sp sh tub ager	expos e buck or ger ade e	ure SI vation S(et RI Ni	UPPO H Sh C Sh B Ro il No	oring otcrete ck Bo	lts <u>▼</u> Wat ort Wat	e obse measu er leve er outf	rved D Dry L Lo red M Moist M Mi I W Wet H Hi Wp Plastic limit R Re low WI Liquid limit	ow VS oderate S gh F efusal St VSt H	SISTENCY	ose A Au	iger san ilk san ndistur sturbe pisture	& TESTING ample nple bed sample d sample content mple (x mm	pr S V: D	Standard S Vane sh CP Dynam penetro D Field der	nic cone ometer nsity	S	YMBOLS AND OIL DESCRIPTION Y USCS
			7								ASSOCIATES PTY LTD		Т						

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PR	OJE	СТ					l Investiç			LOGGED	BR		CHECKE)	AN				Sheet 1	of	1	
SIT			M	undami	_		884, DP7	5595	52)	GEOLOGY	Sandstone		VEGETAT		Moss/g				PROJECT	NO.	P1002761	
-	IPME		NINAT N	SIONS	Aug		0.6m depth			EASTING NORTHING	-		RL SURFA	ACE	60.50m	AHD			SLOPE	100	100/	
EXC				ION DA		ımm x	U.Sm depth		M.A	TERIAL D	<u> -</u> ΔΤΔ		ASPECT		East		SA		G & TE		prox 10%	-
\vdash						Ξш	(D	z	III.	TI EITIAE B	AIA			 	<						DETAIL	LS
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	L DENETDATIO	# RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, org	PTION OF STI mottling, colour, p anics, secondary ontamination, odd	lasticity, rocks and minor cor	s, oxidation, mponents,	CONSISTENCY	A TIONAL	DENSILY INDEX	TYPE	DEPTH (M)		0.69m agl			Well Cover
А	Nil	N	М	- - 0.3			* * * * * * * * * * * * * * * * * * *	SM	ORGANIC SIL	-TY SAND -	Dark brow	'n.				Α	0.05	2761/3/0	05		//	Bentonite Seal 0.2m bgl - UPVC Pipe.
А	Nil	N	М	0.55			× × × × × × × × × × × × × × × × × × ×	SM	ORGANIC SILTY S	SAND - Ligh asing with de		oisture				A	0.35	2761/3/0	35			0.34mbgl _Gravels JPVC Screen
Α	Nil	N	М	0.6			7 8	EW	EXTREMELY WEAT	_		/						0.64m b	gl — —		- 0 w	ell end plug.
									gravels (2-5mm, 5 Borehole termina weath	,, <u>,</u>	on modera							0.64mt	g — —			1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
E N X B E H S	Na Ex H Ba Ex A Ha Ha	atural o	exposi excar bucki or ger ade	ure SI vation S0 et RI	C Sh B Ro	ORT noring notcret ock Bo o supp	lts	e obse measu er leve er outf	rved D Dry L Lored M Moist M M M M M M M M M M M M M M M M M M M	w VS oderate S gh F	VSISTENCY Very Soft Soft Firm Stiff Very Stiff Hard Friable	DENSITY VL Very Loose L Loose MD Medium D D Dense VD Very Dens	se A . B Dense U D D	Auger Bulk sa Undist Disturl Moistu	G & TES sample ample turbed sa bed sam ure conte sample (ample ple ent	pp S VS DO	Pocket pr Standard S Vane sho CP Dynam penetro D Field der S Water sa	ic cone meter sity		Y US	S AND SCRIPTION
Α		ger		r			✓ vval		···					_								
							EXCAVATION	ON LO	OG TO BE READ IN CONJU	JNCTION WIT	H ACCOMF	ANYING REP	ORT NOT	ES A	ND AB	BRE	/IATIC	ONS				
										MARTENS &	ASSOCIAT	ES PTY LTD		- 1		_		- !	ovin	[

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PR	OJE	СТ	H	ydroge	ologica	l Investiç	gatio	n	LOGGED	BR	CHECKED		AN			Sheet 1 o	
SIT	Έ		SI	noalhav	en City	Counci	l (Μι	ındamia)	GEOLOGY	Sandstone	VEGETATIO	ON	Shrubland			PROJECT NO.	P1002761
-	IPME				Hand Aug				EASTING	-	RL SURFAC	_	63.50m AHD				
EXC				SIONS		0.98m depth		M	NORTHING	- NTA	ASPECT		North-North V			SLOPE G & TESTI	0-2%
\vdash	LA	CAI	A	ONDA			z	IVI	ATERIAL DA	AIA .	Ι, Ι			\ <u>\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\</u>	VIVIE LIIV		ELL DETAILS
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, org	PTION OF STR mottling, colour, planics, secondary a ontamination, odor	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	0.7	70m(TBC??)agl	Well Cover Concrete
НА	Nil	N	D	0.1		× × ×	SM	SILTY S	AND - Dark b	prown.			А	0.05	2761/4/0	05	
НА	Nil	N	D	0.3		× × × × × × × × × × × × ×	SM	SILTY SAND	- Light brown	n to yellow.			А	0.2	2761/4/0.	2	Bentonite Seal
НА	Nil	N	D	0.8			GM	SILTY GRAVEL - Lig gravels	ht brown to y (10-40mm, 8				А	0.4	2761/4/0.		UPVC Pipe. O -0.45m bgl Gravels. UPVC Screen.
НА	Nil	N	D	0.98		7 7	EW	EXTREMELY WI	EATHERED (/hite to grey.	SANDSTONE -					0.95m b	101	Well end plug.
N	Na	itural (expos	2.0 - - - 3.0 - - - - - - - - - - - - - - - - - - -	JPPORT - Shoring	WATER	e obse	MOISTURE PENE	TRATION CON	SISTENCY DENSITY Very Soft VL Very Lor	ose A Au	uger s	S & TESTING	pp		enetrometer	2.0 2.0 3.0 3.0 4.0 CLASSIFICATION SYMBOLS AND
X B E H S P	Ex H Ba Ex A Ha Ha T Pus	disting ckhoe cavate nd au and sp sh tub ger	excar buck or ger ade e	vation SC et RI Ni	H Shoring C Shotcret B Rock Bo II No supp	N Non e X Not lts	e obse measu er leve er outfl	red M Moist M M W Wet H Hi Wp Plastic limit R Re ow WI Liquid limit	oderate S gh F efusal St VSt H		Dense A Au Dense U Ui D Di se M Me	uger s ulk sa ndistu isturb oistur	sample	pr S V: D	Standard S Vane sho CP Dynam penetro D Field der	penetration test ear iic cone meter sity	
PT Push tube A Auger CC Concrete Corer EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS WS Water sample																	
H			7				J. 4 L(O TO BE IVEND IN CONTR		ASSOCIATES PTY LTD	JIM NOTE	2 ///	ים אוטטו י כ.				

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PR	OJE	СТ	Н	ydroge	olog	gical	Investi	jatio	n	LOGGED	BR		CHECKED		AN			Sheet 1		
SI	ΓЕ		М	undami	a (L	ot 3	, DP568	613)		GEOLOGY	Sandstone		VEGETAT	ION	Grass			PROJECT	NO . P1	002761
EQI	JIPMEI	NT			Auge	er				EASTING	-		RL SURFA	CE	55.24m Al	HD				
EXC				SIONS		mm X	0.6m depth			NORTHING	-		ASPECT		North			SLOPE	5%	
_	EX	CA	/AT	ON DA			-		M.A	TERIAL D	ATA						SAMPLI	NG & TES		
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga		lasticity, rocks and minor co		CONSISTENCY	DENSITY INDEX	T N N N N N N N N N N N N N N N N N N N	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	(M)	0.67m agl -	WELL	Well Cover
Α	Nil	N	D	- 0.2			× × × × × × × × ×	SM	ORGANIC SIL	TY SAND -	Dark brow	'n.			A	A 0	.1 2761/5/	0.1	•	Bentonite Seal. UPVC Pipe. 0.2m bgl
Α	Nil	N	М	- - - 0.7			* * * * * * * * * * * * * * * * * * *	SM		mm, 10%), s ncreasing wi	slightly mo th depth.	ist,			A		25 2761/5/			
Α_	Nil	N	M	0.75	****	-	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	EW	EXTREMELY WEAT gravels (2-4)						P	A 0.	75 2761/5/ 0.77m		~ -	Well end plug.
E N	QQUIPPI		/ ME*	1.0	JPPO H Sh	RT	WATER N Non		Borehole termina weath	ated at 0.75r ered sandst	n on extre	DENSITY			3 & TESTI	NG	no Pocket	popetrameter		1. 4. ASSIFICATION MBOLS AND
E	E: BH Ba	xisting ckhoe	excave bucke	ration SC et RE	Sh Ro	otcrete ck Bo	e X Noti lts ∇7 Wat		red M Moist M Me I W Wet H Hig	oderate S gh F	Soft Firm	VL Very Loo L Loose MD Medium D	B E Dense U l	Bulk sa Jndistu	urbed samp	ole	S Standar VS Vane s		est S0	OIL DESCRIPTION
E F	Ex IA Ha	cavate and au	or ger			suppo			Wp Plastic limit R Re		Stiff	D Dense VD Very Dens	D D	Disturb Aoistur	ed sample e content ample (x m		DCP Dyna	mic cone rometer	Y	-
	T Pu	sh tub iger					→ Wat	er inflo	w	F	Friable		UX I	UNC S	ampie (XIII		WS Water		Ľ	
	C Co		Core	r		_	=XC\\\\\T'	אווי כ	OG TO BE READ IN CONJU	INCTION WIT	н ассоли		ORT NOT	-Q A N	ID VDDD) E\/I^	TIONS			
\vdash			7				-vousail	JIN LC	O TO BE IVEND IN CONJU	MARTENS &			OKT NOTE	_				ovin		

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PR	OJE	СТ	$\overline{}$				Investi			LOGGED	BR	CHECKED		AN			Sheet 1 of 1
SIT	Έ		S	noalhav			Counci	(Mı	undamia)	GEOLOGY	Sandstone	VEGETATI	ON	Grass			PROJECT NO. P1002761
_	IPME				Auge					EASTING	-	RL SURFA	_	-			I
EXC				SIONS		mm X	1.65m depth		M /	NORTHING	- \ΤΔ	ASPECT		North West			SLOPE 2% IG & TESTING
\vdash		CA		ON DA			(2)	z	1417	AT ENIAL DA	NIA .		×	;	T	AWIFLIN	IG & TESTING
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	DENETRATIO	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, org	PTION OF STR mottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	A	RESULTS AND DDITIONAL OBSERVATIONS
А	Nil	N	М	- - 0.3			 	CL	CLAY (POSSI gravels (BLY FILL) - L (4-30mm, 5%	ight brown,), soft.			А	0.1	2761/5/0.	Sandstone fill observed within 10m of borehole, (bricks and large pieces of concrete 1m x 1m x 2m high, fill).
А	Nil	N	М					- CL	CLAY (POSS gravels (IBLY FILL) - [(2-4mm, 10%				А	0.5	2761/5/0.	5
А	Nil	N	М	1.0				CL	sand content, mois	sture increasi	ng at 1.2m, soft,			A	1.0	2761/5/1.	0 1.
А	Nil	N	М	_				CL									
gravels (2-3mm, 5%).															2 <u>.</u> 3 <u>.</u>		
N X B E H S P	Na E: H Ba Ex A Ha Ha T Pu Au	atural oxisting ckhoe cavate and au and sp sh tub iger	expos e buck or ger ade e	ure Sh vation SC et RE Ni	B Ro		lts ل Wat	e obse measu er leve	erved D Dry L Loured M Moist M M. el W Wet H Hi. Wp Plastic limit R Refollow WI Liquid limit	ow VS oderate S gh F efusal St VSt H	SISTENCY DENSITY		uger s ulk sa ndistu isturb oistur	& TESTIN sample mple urbed sample ed sample re content ample (x mr	e V n) F	P Pocket per Standard S Vane she ICP Dynam penetro D Field den VS Water sa	nic cone Y USCS Ometer nsity N Agricultural
	U Co	ncrete	Core	<u> </u>			EXCAVATI	ON L	OG TO BE READ IN CONJU	JNCTION WITH	I ACCOMPANYING R	EPORT NOTE	S AN	ND ABBRI	EVIATI	ONS	
П			_							MARTENS &	ASSOCIATES PTY LT	D	Т		_		

CL	.IEN	T	S	hoalha	ven	City	Counci	l		COMMENCED	19.10.10		COMPLETI	ED 1	9.10.10			REF	BH7	
-	OJE	СТ					Investiç			LOGGED	BR		CHECKED	А	.N			Sheet 1		
SI			S	hoalha			Council	(Mur	ndamia)	GEOLOGY	Sandstone		VEGETATI	_	IA			PROJECT NO	D. P1002761	
-	JIPME		DIMEN	ISIONS	Auge		.05m depth			EASTING NORTHING	-		RL SURFA		Vant			SLOPE	1-2%	
EXC				ION DA		mm x u	.usm deptn		M.A	TERIAL D	<u>'</u> ΔΤΔ		ASPECT	V	Vest	SA		G & TEST		
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	PENETRATION	RESISTANCE	GRAPHIC LOG	CLASSIFICATION	DESCRI Soil type, texture, structure, r	PTION OF STF	RATA asticity, rocks, o	oxidation, ponents,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)		RESU	LTS AND OBSERVATION	ıs
A ME	ANS Nil	N Z Z	D			IΙΨ	GRAPI	MIND CLASSI	GRAVELS (5-50mm, coar EXTREMELY W	ntamination, odo , 95%) - Rem se to fine sar EATHERED	nainder mad nd. SANDSTO	le up by	CONSI	DENSI	F	DEP.		Soil cover na about 25-3	tural on large area o Om Ø as existent of al tree growth.	of _
P E E E F	N N; C E BH Ba E E; HA Ha B Ha PT Pu	atural xisting ckhoo ccava and au and sp sh tub	expos g exca e buck tor uger pade	ure S vation S et F	RB Ro	RT oring otcrete ck Bolts suppor	₩ Wat	e observ measure er level er outflo	ved D Dry L Lo ed M Moist M M W Wet H Hi Wp Plastic limit R Re w WI Liquid limit	ow VS oderate S gh F efusal St VSt H	Very Soft Soft I	DENSITY //L Very Loose _ Loose MD Medium D D Dense //D Very Dense	se A A B B ense U U D D e M M	luger sa Julk sam Jndistur Disturbe Toisture	& TESTING ample pple bed sample d sample content mple (x mm	pr S V: D	o Pocket pr Standard S Vane sho CP Dynam penetro D Field der /S Water sa	ic cone meter sity	CLASSIFICAT SYMBOLS AN t SOIL DESCRI Y USCS N Agricultu	ND IPTION
(C Co	iger ncrete	e Core	r																
L						E.	XCAVATIO	ON LO	G TO BE READ IN CONJU				ORT NOTE	S AN	D ABBRE	VIATI	ONS			
1										MARTENS &	ASSOCIATE	S PTY LTD		- 1	_	'	!	ovina		

CL	IEN	Γ	S	hoalhav	en (City	Council			COMMENCED	19.10.10	COMPLETED	19	.10.10			REF	BH8
PR	OJE	СТ	Н	ydroge	olog	ical	Investig	jatio	n	LOGGED	BR	CHECKED	ΑN	I			Sheet 1 of	1
SIT			S	hoalhav		_	Council	(Mı	ındamia)	GEOLOGY	Sandstone	VEGETATIO	N NA	Casurina	a pine	needles	PROJECT NO.	P1002761
_	IPME				Auge					EASTING	-	RL SURFACE	_					
EXC				ISIONS		nm X	2.5m depth		M 2	NORTHING	- \ΤΔ	ASPECT	No	rth West	84		SLOPE 1	I-2%
\vdash		CA		ION DA		ш	(0	z	IVIZ	AT ENIAL DA	NIA .		×		\ <u>\</u>	VIVIE LIIV	IG & TESTIN	
МЕТНОD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATIO	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR mottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	A	RESULT: DDITIONAL OE	
А	Nil	Z	D	- - - - - - - 0.9				SC	CLAYEY SAND - Yel ironstone gra	low to orange avels (10-15r				A	0.3	2761/5/0.	3	
А	Nil	N	D	1.0				SC	CLAYEY SAND - Re ironstone gra	eddish brown avels (10-15r				A	1.0	2761/5/1.	0	<u>1.</u>
Α	Nil	N	D	-				CL	CLAY - Reddish b	rown, gravels	(5-10mm, 5%).			A	1.5	2761/5/1.	5	
A	Nil	N	D	1.9				EW	Grading to mode with depth (mode	rately weathe erately weathe	red sandstone ered sandstone							2 <u>.</u>
EXTREMELY WEATHERED SANDSTONE – Grading to moderately weathered sandstone with depth (moderately weathered sandstone after about 2.2m).															3 <u>.</u>			
N B E H S P A	Na Ex H Ba Ex A Ha Ha T Pu	atural oxisting ckhoe cavate and au and sp sh tub iger	expos g exca e buck or iger pade ie	ure SI vation S0 et RI Ni	JPPOF H Sho C Sho B Roo II No	oring otcrete ck Boli suppo	s <u>▼</u> Wate rt <u></u> Wate → Wate	e obse measu er leve er outf er inflo	rved D Dry L Lo red M Moist M M Wet H Hig Wp Plastic limit R Re low WI Liquid limit	ow VS oderate S gh F sfusal St VSt H F	SISTENCY	ose A Aug B Bull Dense U Und D Dis se M Moi Ux Tub	jer sam c samp disturbed turbed sture c e sam	ole ed sample sample content ple (x mm)	PF S V: D FI W	Standard S Vane she CP Dynam penetro D Field der S Water sa	nic cone ometer nsity	CLASSIFICATION SYMBOLS AND YMBOLS AND YUSCS N Agricultural
\vdash			_			E	:AUAVATI(JN L(OG TO BE READ IN CONJU		ASSOCIATES PTY LTD	-OKI NOTES	AND	ADBKE/	v IA I I	UNO -	_	_

CL	IEN	Г	M	ALBEC	PRO	PEF	RTIES P	TY L	.TD	COMMENCED	9/9/08	cc	OMPLETED	9/9/08	3			REF	BH1	
PR	OJE	СТ	PF	RELIMIN	IARY	GE	OTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CH	HECKED	ASN				Sheet 1	of 1	
SIT	Έ		JC	NSSON	RO	AD,	MUNDA	AIMA	L	GEOLOGY	SANDSTONE	VE	EGETATION	GRAS	SS			PROJECT NO	2193	
EQL	IPME	NT			4WD N	NOUN	NTED PUS	H TUBI	Ε	EASTING	NA	RL	L SURFACE	NA				•		
EXC	AVAT	ION E	IMEN	ISIONS	Ø 50m	nm x 1	400mm dep	th		NORTHING	NA	AS	SPECT	NE				SLOPE	< 2°	
	ΕX	CA	/AT	ION DA	TA				M.A	TERIAL DA	ATA					SA	MPLIN	G & TEST	ING	
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH(M)	⊩ PENETRATION	RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, org	PTION OF STR nottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxid and minor compon	lation, ents,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	ΑC	RESUL' DDITIONAL O	TS AND BSERVATIONS	
PT	Nil	N	М	0.1			× × ×	SM	ORGANIC SILTY SAN	ND - Brown, n	noist, soft, roo	tlets.			PT	0.05	2193/1	1/0.05		
PT	Nil	N	М	_ _ _ _ 0.5				sc	CLAYEY SAND - Lig with clay conte	ht brown/ yel	low, moist, loo				PT	0.4	2193/1	//0.4		-
PT	Nil	Z	М	- - 1.0 - - - 1.4				EW	EXTREMELY W Grey, clay wit gravels (ora		(ironstone)	=			PT PT	0.8	2193/ 2193/1		1	1.0
	OLIJEŽI.	AENT	ME		PPORT		WATER		extremely	erminated at deveathered sail		ISITY	SAMPLIN	G & TE	STING				3	
N X B E H S P A C	E: H Ba Ex A Ha Ha T Pu	ckhoe cavate nd au and sp sh tub iger	exca buck or ger ade e	vation SC et RB	Shorii Shoto Rock No su	rete Bolts		neasure r level r outflo	ed M Moist M Mo W Wet H Hig Wp Plastic limit R Ref w WI Liquid limit	derate S : h F I usal St S VSt \ H I	Stiff D	Very Loose Loose Medium Dense Dense Very Dense	A Auger B Bulk s U Undis D Distur M Moistu Ux Tube	ample turbed sam bed sam ire conte	ample pple ent	S VS DC FD	Pocket per Standard p Vane shea P Dynamic penetron Field dens Water san	penetration test ar c cone neter ity	SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural	1
						E)	XCAVATIO	ON LO	G TO BE READ IN CONJU	JNCTION WITH	I ACCOMPANY	'ING REPOR	T NOTES	AND A	BBRE\	/IATI	ONS			
			~							MARTENS &	ASSOCIATES E	PTVITD					_		_	_

CL	EN	Γ	M	ALBEC	PR	OPE	RTIES F	YTY	LTD	COMMENCED	9/9/08	COMPLET	ED 9/9/0	08			REF	BH2
PR	OJE	СТ	PF	RELIMIN	IAR	Y G	EOTEC	HNIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1	
SIT	Е		JC	ONSSON	I RO	DAD	, MUND	AMI	4	GEOLOGY	SANDSTONE	VEGETAT	ON GRA	ASS			PROJECT NO	. 2193
	IPMEI	NT					INTED PUS			EASTING	NA	RL SURFA	CE NA					
EXC	AVAT	ION D	IMEN	ISIONS	Ø 50	mm x	700mm dept	th		NORTHING	NA	ASPECT	NE				SLOPE	< 2 °
	EX	CAV	/AT	ION DA	TA				MA	TERIAL DA	TA				SA	MPLIN	G & TEST	ING
МЕТНОD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	AD	RESUL [*] DITIONAL O	TS AND BSERVATIONS
PT	Nil	N	М	0.1			× × ×	SM	ORGANIC SILTY SAN	ID - Brown, n	noist, soft, rootlets.			PT	0.05	2193/2	1/0.05	
PT	Nil	N	М	_ 0.3				sc	CLAYEY SAND - Lig		low, moist, loose			PT	0.2	2193/2	//0.2	-
PT	Nil	N	М					EW	EXTREMELY WEA with slightl	THERED SA y weathered				PT	0.5	2193/2	2/0.5	-
PT	Nil	N	М	0.7			- , a	EW	EXTREMELYW	EATHERED	SANDSTONE							-
																		-
				1.0					Borehole terr moderately we									1 <u>.0</u>
				_														-
				_														-
																		-
																		-
				_														-
				2.0														2 <u>.0</u>
																		-
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				3.0														- 3.0
				5.0														-
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																		-
																		-
																		-
				4.0														4.0
																		-
																		-
		15:		_					MOIOTURE	DATION	ISTENCY DENSITY		UNO 6 F	07111				-
N	Na	itural e	expos	ure SH	PPOF Sho	ring				se A Au			pp	Pocket pen	etrometer	CLASSIFICATION SYMBOLS AND		
N Natural exposure SH Shoring N None observed D Dry L Low VS Very Soft VL Very Loose A Auger sample X Existing excavation SC Shotcrete X Not measured M Moist M Moderate S Soft L Loose B Bulk sample BH Backhoe bucket RB Rock Bolts W Wet H High F Firm MD Medium Dense U Undisturbed samp E Excavator Nil No support Wp Plastic limit R Refusal St Stiff D Dense D Disturbed sample														VS	Vane shea		SOIL DESCRIPTION	
BH Backhoe bucket RB Rock Bolts Water level W Wet H High F Firm MD Medium Dense U Undisturbed sample VS Vane she E Excavator Nil No support Wp Plastic limit R Refusal St Stiff D Dense D Disturbed sample DCP Dynami H Hand auger VS Very Stiff VD Very Dense M Moisture content penetrol S Hand spade Ux Tube sample (x mm) FD Field dens													penetrom	neter	Y USCS			
HA Hand auger ✓ Water outflow WI Liquid limit VSt Very Stiff VD Very Dense M Moisture content penetrometer ✓												N Agricultural						
			Corer															
_						E	EXCAVATION	ON LO	OG TO BE READ IN CONJU		ACCOMPANYING REF	PORT NOTE	S AND /	ABBRE'	VIATIO	ONS		

CL	IEN ⁻	Г	М	ALBEC	PR	OPE	RTIES F	YTY	LTD	COMMENCED	9/9/08	COMPLET	r ED 9	9/9/08			REF	BH3
PR	OJE	СТ	PF	RELIMIN	NAF	RY G	EOTEC	HNIC	AL ASSESSMENT	LOGGED	JSF	CHECKE	ο Δ	ASN			Sheet 1 c	
SIT	Έ		JC	ONSSON			, MUND			GEOLOGY	SANDSTONE	VEGETA	ION	RASS			PROJECT NO	2193
EQU	IPMEI	NT			4W	D MOI	JNTED PUS	H TUE	BE	EASTING	NA	RL SURF	ACE N	NΑ				
EXC	AVAT	ION E	IMEN	ISIONS	Ø 5	c mm0	1350mm dep	oth		NORTHING	NA	ASPECT	N	١E			SLOPE	< 2°
	EX	CA	/AT	ION DA					M.A	TERIAL DA	ATA					SAMPL	NG & TEST	ING
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	7	M PENEIRATION H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX		TYPE	DEPTH (M)	RESULI ADDITIONAL O	TS AND BSERVATIONS
PT	Nil	N	М	0.15			* * * * * * *	SM	ORGANIC SILTY SAM	ND - Brown, r	noist, soft, rootlets.				PT	0.1 21	93/3/0.1	-
PT	Nil	N	М	-				sc	CLAYEY SAND - Lig clay content	ght brown/ ye increasing w					PT PT		3/3/0.4	- - - -
PT	Nil	N	М	0.8 - 1.0				CL	SANDY CLAY - Ligh	t brown, with moist, soft.	sandstone gravels				PT	1.0 219	3/3/1.0	- 1 <u>.0</u>
PT	Nil	N	М	1.1				EW		ith sandstone	gravels							-
	OLIJEN.	MENT.	/ ME		JPPC	RT	WATER		Borehole ter extremely w	rminated at 1. reathered sar	35m on	SAM	PLING 8	TEST .	ING			2.1 3.1 4.1
N X B E H S P A	Na Ex H Ba Ex A Ha Ha T Pu:	atural e kisting ckhoe cavate and au and sp sh tub iger	expos exca buck or ger ade e	ure SH vation SC et RB	Sh Sh Ro	oring otcrete ock Bol suppo	N None x Not r ts <u>₩</u> Wate	neasur er level er outfl	ved D Dry L Lov ed M Moist M Mo W Wet H Higi Wp Plastic limit R Ref ow WI Liquid limit	v VS V derate S h F I usal St S VSt V	/ery Soft VL Very L Soft L Loose	oose A A B B B III Dense U U D D Dense M M	uger sar ulk samp Indisturb isturbed oisture oube sam	mple ble ed sam sample content	ple	S Standar VS Vane si DCP Dyna	nic cone cometer ensity	SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural
C	C Con	crete (Corer				FXCAVATI	אומכ	OG TO BE READ IN CONJU	INCTION WITH	I ACCOMPANIVING P	FPORT NOT	FS AN	D ARR	RF\/	IATIONS		
\vdash		_	_				LACAVAII	JIN L	OO TO DE KEND IN CONJU		ASSOCIATES PTY LT		LO AN	י אסמ		- 6/10117	_	

CL	IEN	Г	M	ALBEC	PR	OPE	RTIES P	TY	LTD	COMMENCED	9/9/08	COMPLETE	9/9/0	18			REF	BH4	
PR	OJE	СТ	PF	RELIMIN	IAR	ΥG	EOTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1		
SIT			JC	ONSSON			, MUNDA			GEOLOGY	SANDSTONE	VEGETATIO	_	SS			PROJECT NO	2193	
_	IPME				_		INTED PUS		E	EASTING	NA	RL SURFAC	_						
EXC				ISIONS		Omm x	1300mm dep	oth		NORTHING	NA	ASPECT	NE				SLOPE	< 2°	
	EX	CA	/AT	ION DA					MA	TERIAL DA	ATA	, ,			SA	MPLIN	G & TEST	ING	
METHOD	SUPPORT	WATER	MOISTURE	DEPTH(M)	NOIT A GTENED	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a intamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH(M)	AD	RESUL ⁻ DITIONAL O	TS AND BSERVATIONS	
PT	Nil	N	М	0.15			* * * * * * *	SM	ORGANIC SILTY SAN	ND - Brown, n	noist, soft, rootlets.			PT	0.1	2193/	4/0.1		-
PT	Nil	N	М					sc	CLAYEY SAND - Lig clay content	ght brown/ yel increasing w				PT	0.4	2193/4	/0.4		-
PT	Nil	Ф. Ф.	w	1.0				CL	SANDY CLA sandstone	Y - Grey, wet gravels at 0.				PT	0.9	2193/-	Ground water	at 0.6m.	- - - - 1.0
									Borehole termina	ated at 1.3m o	on sandy clay.								
							WATER N None	observ							pp I	Pocket per	netrometer	CLASSIFICATIO SYMBOLS AND	3. <u>c</u>
N Natural exposure SH Shoring N None observed D Dry L Low VS Very Soft VL Very Loose A Auger sample X Existing excavation SC Shotcrete X Not measured M Moist M Moderate S Soft L Loose B Bulk sample BH Backhoe bucket RB Rock Bolts Water level W Wet H High F Firm MD Medium Dense U Undisturbed sar E Excavator Nil No support Wp Plastic limit R Refusal St Stiff D Dense D Disturbed samp VSt Very Stiff VD Very Dense M Moisture content S Hand spade PT Push tube													sample mple ent	S VS DCF FD	Pocket per Standard p Vane shea P Dynamic penetrom Field densi Water sam	enetration test ir cone neter ity	SYMBOLS AND SOIL DESCRIPT Y USCS N Agricultural		
C	C Con	iger crete (Corer																
\vdash			- ~			E	EXCAVATION	ON LC	OG TO BE READ IN CONJU		ACCOMPANYING REF	PORT NOTES	AND A	\BBRE\	/IATIC	ONS			

CL	IEN	Г	М	ALBEC	PR	OPE	RTIES F	ΥT	LTD	COMMENCED	9/9/08	COMPLETE	9/9/0)8			REF	BH5	
PR	OJE	СТ	PF	RELIMIN	IAR	ΥG	EOTEC	HNIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1 c		
SIT	Έ		JC	NSSON			, MUND			GEOLOGY	SANDSTONE	VEGETATIO	N GRA	SS			PROJECT NO	2193	
	IPME				_		JNTED PUS		BE	EASTING	NA	RL SURFAC							_
EXC				ISIONS		0mm x	1400mm dep	oth		NORTHING	NA .	ASPECT	NE				SLOPE	<2°	_
	EX	CA	/AT	ION DA				-	MA	TERIAL DA	ATA	1 1			SA	MPLIN	G & TEST	ING	
METHOD	SUPPORT	WATER	MOISTURE	DEPTH(M)	NOIT A GT FIND OF	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH(M)	ΑC	RESULT ODITIONAL O	TS AND BSERVATIONS	
PT	Nil	N	М	0.15			* * * * * * * *	SM	ORGANIC SILTY SAM	ND - Brown, n	noist, soft, rootlets.			PT	0.1	2193/	5/0.1		-
PT	Nil	0.3 <u>V</u> Y	М	 				sc	CLAYEY SAND - Ora with minor	inge, moist(w sandstone g	et at 0.3m), loose ravels.			PT	0.4	2193/5	Ground wate	er at 0.3m.	-
PT	Nil	Υ	w	- - 0.8				HW	HIGHLY WEA	THERED SA	NDSTONE								-
PT	Nil	Y	w	- 1.0 - - - 1.4				sc	CLAYEY SAND - sandstor	Grey,wet, loo ne gravels at	ose, with minor 1.2m.			PT	1.2	2193/	5/1.2		1.0
E	QUIPI	иемт	//ME	- 2.0	PPO		WATER		Borehole terminate MOISTURE PENET		n clayey sand.	SAMPLI	NG & TE	STING					3.0.
N X B E H S P A	E: H Ba Ex A Ha Ha T Pu	atural e kisting ckhoe cavate nd au ind sp sh tub iger	exca buck or ger ade	vation SC et RB	Ro	oring otcrete ck Bolt suppo	s 🎹 Wate	neasur er level er outfl	ed M Moist M Mo W Wet H High Wp Plastic limit R Ref ow WI Liquid limit	derate S S n F F usal St S VSt \ H F	/ery Soft VL Very Loos Soft L Loose Firm MD Medium D stiff D Dense Very Stiff VD Very Dens lard riable	B Bulk Jense U Undi D Distr	sample sturbed s urbed sar ture cont	sample mple ent	S VS DC	Standard p Vane shea Dynamic penetron Field dens Water san	cone neter ity	SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural	1
		ger crete (Corer							_		_							_
_						E	EXCAVATION	ON LO	OG TO BE READ IN CONJU		ACCOMPANYING REF	PORT NOTES	AND A	BBRE	VIATIO	ONS			_

CL	IEN	Γ	M	ALBEC	PR	OPE	RTIES F	TY	LTD	COMMENCED	9/9/08	СОМР	LETED	9/9/08	3			REF	BH6	
PR	OJE	СТ	PF	RELIMIN	IAR	Y G	EOTECH	HNIC	AL ASSESSMENT	LOGGED	JSF	CHEC	KED	ASN				Sheet 1		
SIT	Έ		JC	NSSON	I RO	OAD	, MUND	AMI/	4	GEOLOGY	SANDSTONE	VEGE.	TATION	GRA	ss			PROJECT N	O. 2193	
EQU	IPME	NT					JNTED PUS			EASTING	NA	RL SU	RFACE	NA						
EXC	AVAT	ION E	IMEN	ISIONS	Ø 50	0mm x	1200mm dep	oth		NORTHING	NA	ASPE	СТ	NE				SLOPE	< 2 °	
	ΕX	CAV	/AT	ION DA	TΑ				MA	TERIAL DA	ATA					SA	MPLIN	G & TEST	ΓING	
МЕТНОБ	SUPPORT	WATER	MOISTURE	DEPTH (M)	UCIT AGTENED	RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY		DENSITY INDEX	TYPE	DEPTH(M)		DITIONAL (TS AND OBSERVATIONS	
PT	Nil	N	М	0.1			^ × ^ × ^	SM	ORGANIC SILTY SAN	ID - Brown, n	noist, soft, rootlets.				PT	0.05	2193/6	/0.05		
PT	Nil	N	М				* * * * * * * * * * * * * * * * * * *	CS	CLAYEY / SILTY SA	ND - Light bı	rown, soft, moist.				PT	0.5	2193/6	6/0.5		- - - -
PT	Nil	N	М					CL	SANDY CLAY sandstone	′ - Grey, wet, gravels at 0.9	soft, some) - 1.1m.									1 <u>.0</u>
									Borehole termina	ted at 1.2m o	on sandy clay.									
N	Na	atural e	expos	ure SH	PPOI Sho	oring	WATER N None		ved D Dry L Lov	/ VS \		Loose A	AMPLINI Auger	sample		pp	Pocket pen	etrometer	CLASSIFICATIC SYMBOLS AND	
X B E H S P A	E: H Ba Ex A Ha Ha T Pu	kisting ckhoe cavate ind au ind sp sh tub iger	exca buck or ger ade e	vation SC et RB Nil	Sho	oring otcrete ck Bolt suppo	X Notr s <u>₩</u> Wate	neasur er level er outfl	ed M Moist M Mo W Wet H Higi Wp Plastic limit R Ref ow WI Liquid limit	derate S S n F F usal St S VSt \ H F	Very Soft VL Very Soft L Loose Firm MD Mediu bitff D Dense Very Stiff VD Very I lard riable	e B um Dense U e D Dense M	Bulk sa	ample urbed sam ed sam re conte	ample pple ent	S VS DCF FD	Pocket pen Standard p Vane shea Dynamic penetrom Field densi Water sam	enetration test r cone leter ty	SYMBOLS AND SOIL DESCRIPT Y USCS N Agricultura	TION
\vdash			_			E	EXCAVATION	ON LO	OG TO BE READ IN CONJU		ACCOMPANYING I		OTES A	AND A	BBRE\	/IATIC	ONS			

CLIE	EN٦	Γ	M	ALBEC	PR	OPE	RTIES P	TY	LTD	COMMENCED	9/9/08	c	OMPLETED	9/9/0	8			REF	BH7	
PRC	JE	СТ	PF	RELIMIN	IAR	Y G	EOTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CI	HECKED	ASN				Sheet 1	of 1	
SITE	Ξ		JC	NSSON	IRO	DAD	, MUNDA	MI/	1	GEOLOGY	SANDSTONE	VE	EGETATIO	gRA	SS			PROJECT NO). 2193	
EQUIF	MEN	ΙT			4WE	O MOL	JNTED PUSI	H TUB	E	EASTING	NA	RI	L SURFACE	. NA						
EXCA	VAT	ON D	IMEN	ISIONS	Ø 50	Omm x	1200mm dep	th		NORTHING	NA	AS	SPECT	NE				SLOPE	< 2 °	
ابا	EX	CAV	/AT	ION DA					MA	TERIAL DA	ATA					SA	MPLIN	G & TEST	ING	
METHOD	SUPPORT	WATER	MOISTURE	DEPTH(M)	L PENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a intamination, odou	asticity, rocks, oxidation and minor components,	n,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	AD		TS AND BSERVATIONS	
PT	Nil	N	М	0.1			* * * *	SM	ORGANIC SILTY SAN	ID - Brown, n	noist, soft, rootlet	S.			PT	0.05	2193/7	/0.05		
РТ	Nil	N	М	- - - - 0.6				SC	CLAYEY SAND - Lig		low, moist, loose				PT	0.4	2193/7	/0.4		-
PT I	Vil	N	М					RS - EW	EXTREMELY W Grey, clay like prop (orange		ndstone gravels				РТ	1.0	2193/7/	1.0		1.0
									Borehole t extremely to mode	erminated at erately weath										
N X BH E HA S PT A	Na Ex Ex Ha Ha Pus	tural edisting okhoe cavate and aug and spa sh tub	expos excar buck or ger ade e	ure SH vation SC et RB	Roo	oring otcrete ck Bolt suppo	ts <u>V</u> Wate ort → Wate → Wate	neasur r level r outflo	ved D Dry L Lov ed M Moist M Mo W Wet H Higi Wp Plastic limit R Ref ow WI Liquid limit	v VS V derate S S h F I usal St S VSt V H F F	Soft L Loo Firm MD Mec Litiff D Den Very Stiff VD Very lard riable	ry Loose use dium Dense use y Dense	e U Undis D Distu M Moist Ux Tube	r sample sample sturbed s rbed san ure conte sample	ample nple ent 'x mm)	S VS DC FD WS	Vane shea P Dynamic penetrom Field dens Water sam	enetration test r cone neter ty	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural	4.0

CL	IEN	Т	M	ALBEC	PRO	PER	TIES P	TY L	TD			COMMEN	ICED	9/9/08		COMPLE	TED	9/9/08	3			REF	BH8	
PR	OJE	СТ	PF	RELIMI	NARY	GE	OTECH	HNICA	AL AS	SESSN	MENT	LOGGED)	JSF		CHECKE	D	ASN				Sheet 1		
SI	ΓE		JC	NSSO	N ROA	۹D,	MUND	AMIA				GEOLOG	Υ	SANDSTO	ΝE	VEGETA	TION	GRAS	SS			PROJECT NO	. 2193	
EQI	JIPME	NT					TED PUS					EASTING	}	NA		RL SURF	ACE	NA						
EXC	AVAT	ION I	DIMEN	ISIONS	Ø 50m	m x 12	200mm dep	oth				NORTHI	NG	NA		ASPECT		NE				SLOPE	< 2°	
	EX	CA	/AT	ION DA							MA	TERIA	L DA	ΛTA						SA	MPLIN	G & TEST	ING	
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION L DESISTANCE	AESISI ANCE	GRAPHIC LOG	CLASSIFICATION	Soil ty parti	pe, texture cle charact	teristics, orga	nottling, col	our, pla ndary a	sticity, rocks and minor cor	oxidation, nponents,	CONSISTENCY		DENSILY INDEX	TYPE	DEPTH(M)	ΑС		TS AND BSERVATIONS	
PT	Nil	N	М	0.15		ů	*	SP	OR	GANIC	SILTY SA	AND - Br	own,	grey, mo	st, soft.				PT	0.1	2193/	8/0.1		_
PT	Nil	N	М	_ _ _ 0.5		× × ×	× × × × × × × × × × × × × × × × × × ×	ML	(CLAYEY	Y SILT - (Orange/ I	orowi	n, moist, s	oft.				PT	0.3	2193/8	3/0.3		-
PT	Nil	N	м					CL		CL	.AY - Gre	y, moist,	firm,	plastic.					PT PT	0.7	2193/8 2193/8			- - 1.0
	OUIP	MENT	- / ME		UPPORT		WATER		MOI	Bore				m on clay	DENSITY	SAM	PLING	\$ & TES	STING				CLASSIFICATION	
E S F	E E Barrell Ba	ackhoe ccavat and au and sp ish tub uger	e exca e buck or iger oade e	vation So et R	H Shorin C Shotci B Rock I il No su	rete Bolts	N None X Not r ▼ Wate Wate	neasure er level er outflov	M W Wp	Dry Moist Wet Plastic lim Liquid limi		derate h usal	S S F F St S VSt V H H	Soft Firm tiff	VL Very Loos L Loose MD Medium D D Dense VD Very Dens	B E Dense U U D E E M N	Bulk sa Jndistu Disturb Noistur	sample mple irbed sa ed sam e conte ample (x	ple nt	S VS DC FD	Standard p Vane shea P Dynamic penetron Field dens Water san	cone neter ity	SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural	ON
	C Cor	crete	corer			ΕX	CAVATION	ON LO	Э ТО В	E READ	IN CONJU	INCTION	WITH	ACCOMP	ANYING REF	PORT NOT	TES A	ND AE	BBRE\	/IATI	ONS			
			_												ES PTY I TD									

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CL	EN	Г	М	ALBEC	PR	OPE	RTIES P	TY	LTD	COMMENCED	9/9/08	COMPLET	ED 9/9	/08			REF	ВН9
PR	OJE	СТ	PF	RELIMIN	IAR	Y G	EOTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CHECKE	AS	N			Sheet 1 c	of 1
SIT	E		JC	NSSON	IRC)AD	, MUNDA	\MIA	<i></i>	GEOLOGY	SANDSTONE	VEGETAT	ION GR	ASS			PROJECT NO	2193
EQU	IPMEI	NT			4WE	MOU	INTED PUS	H TUB	E	EASTING	NA	RL SURFA	CE NA				•	
EXC	AVAT	ION E	DIMEN	ISIONS	Ø 50	mm x	1100mm dep	oth		NORTHING	NA	ASPECT	NE				SLOPE	< 2 °
	EX	CAV	/AT	ION DA					MA	TERIAL DA	ATA				SA	AMPLIN	IG & TEST	ING
МЕТНОБ	SUPPORT	WATER	MOISTURE	DEPTH(M)	DENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, planics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	AI	RESULI ODITIONAL O	S AND BSERVATIONS
PT	Nil	N	М	0.1			× × ×	SM	ORGANIC SILTY SAN	ND - Brown, r	noist, soft, rootlets.			PT	0.05	2193/	9/0.05	
PT	Nil	0.3 <u>Y</u> Y	М	- - - - - 0.7				sc	CLAYEY SAND - Ora with minor	inge, moist(w sandstone g				PT	0.4	2193/	Ground wate	or at 0.3m.
PT	Nil	Υ	w	0.9				MW	MODERATELYW	'EATHERED	SANDSTONE							
PT	Nil	Υ	w	1.0 1.1			P 7 1	EW	EXTREMELY WEAT	HERED SAN arse grained.	IDSTONE - White			PT	1.0	2193/	9/1.0	1 <u>.</u>
				1.1					coa Borehole te		.1m on							2_
N X Bl	Na Ex H Ba	itural e kisting ckhoe	expos exca buck	ure SH vation SC et RB	Roc	ring tcrete k Bolts	s 🔽 Wate	obser neasur er level	ved D Dry L Low ed M Moist M Mo W Wet H Higl	VS V derate S :	ISTENCY DENSITY /ery Soft VL Very L Soft L Loose rirm MD Medium	oose A A B Bi n Dense U U	PLING & T ger samp lik samplein ndisturbed	le sample	pp S VS	Vane she	penetration test ar	CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
E H S P	Ex A Ha Ha F Pu Au	cavate ind au ind sp sh tub iger	or ger ade e			suppor	water t	er outfle	Wp Plastic limit R Ref ow Wl Liquid limit	usal St S VSt V H F	tiff D Dense /ery Stiff VD Very De lard riable	D D ense M M	isturbed sa pisture co ube sample	ample ntent	DC FD	P Dynami penetror Field dens S Water sar	c cone neter sity	Y USCS N Agricultural
CC	Con	crete (corer			E	EXCAVATION	ON LO	OG TO BE READ IN CONJU		I ACCOMPANYING R		ES AND	ABBRE	VIATI	IONS		

C	LIE	NT		M	ALBEC	PR	OPE	RTIES	PTY	LTD	COMMENCED	9/9/08	COMPLETE	9/9/0	8			REF	BH10
F	RO	JEC	т	PF	RELIMI	NAR	Y G	EOTEC	HNIC	CAL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1 of	
S	ITE			JC	NSSO	N R	DAC	, MUND	AMI.	A	GEOLOGY	SANDSTONE	VEGETATI	ON GRA	ss			PROJECT NO.	2193
E	QUIP	MENT	Г			4WI	D MOL	JNTED AUG	SER		EASTING	NA	RL SURFA	CE NA				•	
Е	XCAV	ATIO	N D	IMEN	SIONS	Ø 9	5mm x	2800mm de	pth		NORTHING	NA	ASPECT	NE				SLOPE	< 3°
Г	E	хс	A۷	/AT	ION DA	TΑ				MA	TERIAL DA	ATA				SA	AMPLIN	IG & TESTIN	G
	MEIHOD	SUPPORI	WATER	MOISTURE	DEPTH (M)	NOIT A GTENEDA	RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, r particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ontamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	ΑC	RESULTS DDITIONAL OBS	
	1 A	lii	N	М	_ _ 0.3			* * * * * * * * * * * * * * * * * * *	SM	SILTY SAN	D - Brown, m	oist, soft.			А	0.1	2193	/10/0.1	-
	1 A	lil .	N	М	_ _ _ _ 0.7				cs	CLAYEY S.	AND - Orang	e, moist.			A	0.4	2193/	10/0.4	- - -
L	A N	lil	N	М	1.0				CL	SANDY/ SILTY CLAY sandstone	- Orange,witl e floaters, firm	n red mottles, some n, moist.			А	0.9	2193/1	0/0.9	- - 1.0
	۸ ۸	-	1.7 Ψ	w				C	CEW CANCEL COMPANY CONTRACTOR CON	SANDY CLAY - sandstone/ grav moist (red mottled			А	1.5 2.£		10/1.5 Ground water :	at 1.7m
								50-0-0			erminated at 2 weathered sar								3.0 - - - - - -
	FOI	IIPME	-NT	/ MF	- 4.0 - - -	UPPO	RT	WATER		MOISTURE PENET	RATION CONS	ISTENCY DENSITY	SAMPI	LING & TE	STING			-	4.0 4.0 - - - - -
	N X BH E HA S PT A	Natu Exis	iral e sting shoe avato d aug d spa tube er	exposi excav bucke or ger ger ade	ure S vation S et R	H Sho C Sho B Roo il No	oring otcrete ck Bolt	N Non x Not ts <u>V</u> Wat	e obse measu er leve	rved D Dry L Lov red M Moist M Mo I W Wet H Hig Wp Plastic limit R Ref low WI Liquid limit R	v VS \ derate S S h F F usal St S VSt \ H F	ISTENCY DENSITY Fory Soft VL Very Loos Soft L Loose Firm MD Medium De titiff D Dense fory Stiff VD Very Dense lard riable	e A Au B Bul ense U Un D Dis M Mo	ger sample k sample disturbed s turbed sar isture cont be sample	e sample nple ent	S VS DC	Pocket per Standard p Vane sheat P Dynamid penetror Field dens S Water sar	netrometer Spenetration test S	EASSIFICATION SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural
Г								EXCAVAT	ON I	OG TO BE READ IN CONJU	INCTION WITH	I ACCOMPANYING REP	ORT NOTE	S AND A	BBRF	VIATI	IONS		
-)								ASSOCIATES PTY LTD						o vino d	

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Engineering Log -Borehole

CL	IEN	Г	M	ALBEC	PRO	PE	RTIES P	ΤY	LTD	COMMENCED	9/9/08	COMPLETE	9/9/0	08			REF	BH11	
PR	OJE	СТ	PF	RELIMIN	IARY	' GE	OTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1		
SIT			JC	ONSSON					1	GEOLOGY	SANDSTONE	VEGETATION	_	ASS			PROJECT NO	2193	
	IPME						NTED AUG			EASTING	NA	RL SURFAC	_					1	
EXC				ISIONS		nm x 1	1500mm dep	th		NORTHING	NA .	ASPECT	NE				SLOPE	< 3 °	_
	EX	CAN	/AT	ION DA				_	M.A	TERIAL DA	ATA				SA	MPLIN	IG & TEST	ING	
МЕТНОВ	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	ΑC	RESUL DDITIONAL O	TS AND BSERVATIONS	
Α	Nil	N	М	0.1			× × ×	SP	ORGANIC SILTY SA	ND - Brown,	grey, moist, soft.			А	0.1	2193	/11/0.1		
А	Nil	N	М					CS		AND - Orange				A	0.5	2193/			-
А	Nil	Z	м					CL- EW	SANDY CLAY - sandstone gravels,					А	1.2	2193/	11/1.2		1.0
	QUIP	MENT	-/ ME	- 2.0 	PPORT		WATER			ered sandsto		SAMP	ING & TE	STING					
N X B E H S P A	E: H Ba Ex A Ha Ha T Pu At	ckhoe cavate nd au ind sp sh tub iger	e exca e buck or ger eade e	vation SC et RB Nil	Shori Shoto Rock No su	rete Bolts		neasui r level r outfl	ed M Moist M Moi W Wet H High Wp Plastic limit R Ref ow WI Liquid limit	derate S S n F F usal St S VSt \ H F	Very Soft VL Very Loos Soft L Loose Firm MD Medium Di Stiff D Dense Very Stiff VD Very Dense lard riable	ense U Un D Dis e M Mo	ger sample k sample disturbed turbed sa sture con e sample	sample mple tent	S VS DC FD	Standard power shear Vane shear P Dynamic penetror Field dense Water san	c cone neter sity	SYMBOLS AND SOIL DESCRIPTION Y USCS N Agricultural	1
C	C Con	crete (Corer			_	VC A\/A T'	70114	OC TO BE BEAD IN CONTIN	NICTION WIT	A A C C ON A DANIVINO DED	ODT NOTE	C VVID	\DDDC	\/I ^ T'	ONC			_
\vdash			_			E	ACAVATI(JN L(OG TO BE READ IN CONJU		ACCOMPANYING REP	OKINOIE	S AND A	4RRKE	v IA I I	ONS			_

CL	IEN	Т	M	ALBEC	PRO	PE	RTIES P	TY	LTD	COMMENCED	9/9/08	COMPLETED	9/9/0	8			REF BH12
PR	OJE	СТ	PF	RELIMIN	NARY	' GE	OTECH	HNIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1 of 1
SIT	Έ		JC	NSSO	V RO	AD,	MUNDA	AMIA	4	GEOLOGY	SANDSTONE	VEGETATIO	GRA	SS			PROJECT NO. 2193
EQU	IPME	NT					NTED AUG			EASTING	NA	RL SURFACE	NA				
EXC	AVAT	ION E	DIMEN	SIONS	Ø 95n	nm x 1	1500mm dep	oth		NORTHING	NA	ASPECT	NE				SLOPE <3°
	ΕX	CA	/AT	ION DA	TA				MA	TERIAL DA	ATA				SA	MPLIN	IG & TESTING
METHOD	SUPPORT	WATER	MOISTURE	DEPTH (M)	L PENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	AC	RESULTS AND DITIONAL OBSERVATIONS
Α	Nil	N	М	0.15			x x x x x x x x	SP	ORGANIC SILTY SA	AND - Brown,	grey, moist, soft.			А	0.1	2193	/12/0.1
А	Nil	N	М	- - - - - 1.0				CL	SANDY/ SILTY CLAY sandstone	- Orange,with	n red mottles, some n, moist.			A	0.3	2193/	
А	Nil	N	М	- - - 1.5				CL- EW	SANDY CLAY - sandstone / gravels,					А	1.4	2193/	
EZ			-/ ME		JPPOR 1		WATER N None	o observ	MOISTURE PENET!	ered sandstor		SAMPLII se A Auge				Pocket ne	2.0 2.0 3.0 3.0 4.0 4.0 Automater SYMBOLS AND
X B E H S P A C	H Ba Ex A Ha Ha T Pu At	ckhoe cavate and au and sp sh tub uger	bucki or ger ade e	et RE	Shote Rock No si	Bolts		er level er outfle	W Wet H High Wp Plastic limit R Ref ow WI Liquid limit	n F F usal St S VSt \ H F	Soft L Loose Firm MD Medium Di titif D Dense (ery Stiff VD Very Dense and riable	D Distu	sturbed s rbed san ure cont	nple ent	VS DC FD	Vane sheat P Dynamic penetror Field dens Water sar	cone Y USCS neter iity N Agricultural
	Con	crete	corer			F	XCAVATI	ONIC	OG TO BE READ IN CONJU	NCTION WITH	ACCOMPANYING REP	ORT NOTES	AND A	BBRF	VIATIO	ONS	
\vdash			_					J. 7 L(ASSOCIATES PTY LTD	110120	1	\L			

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CL	IEN ⁻	Г	M	ALBEC	PR	OPE	RTIES P	ΤY	LTD	COMMENCED	9/9/08	COMPLETE	9/9/0)8			REF	BH13
PR	OJE	СТ	PF	RELIMIN	IAR	ΥG	EOTECH	INIC	AL ASSESSMENT	LOGGED	JSF	CHECKED	ASN				Sheet 1	
SIT	Έ		JC	NSSON	IRO	DAD	, MUNDA	MI	4	GEOLOGY	SANDSTONE	VEGETATION	ON GRA	SS			PROJECT NO). 2193
EQU	IPMEI	NT					INTED AUG			EASTING	NA	RL SURFAC	E NA					
EXC	AVAT	ION E	DIMEN	ISIONS	Ø 95	imm x	1500mm dep	th		NORTHING	NA	ASPECT	NE				SLOPE	< 3°
	EX	CAV	/AT	ION DA					MA	TERIAL DA	ATA				SA	MPLIN	G & TEST	ING
METHOD	SUPPORT	WATER	MOISTURE	DEPTH(M)	DENETRATION	H RESISTANCE	GRAPHIC LOG	CLASSIFICATION	Soil type, texture, structure, n particle characteristics, orga	PTION OF STR nottling, colour, pla anics, secondary a ntamination, odou	asticity, rocks, oxidation, and minor components,	CONSISTENCY	DENSITY INDEX	TYPE	DEPTH (M)	ΑD	RESUL' DITIONAL O	TS AND BSERVATIONS
А	Nil	N	М	0.3			* * * * * * * * * * * * * * * * * * *	SP	ORGANIC SILTY SA	AND - Brown,	grey, moist, soft.			А	0.2	2193/1	3/0.2	-
А	Nil	N	М					cs	CLAYEYS	AND - Orang	e, moist.			A	0.5	2193/1	3/0.5	1.0
А	Nil	N	М	_ _ _ _ 1.5			 	CL	SANDY/ SILTY CLAY sandstone	- Orange,with floaters, firm	n red mottles, some , moist.			A	1.4	2193/	13/1.4	
EZ		MENT		- 2.0 - 2.0 	PPOF	ring	WATER N None	obse		RATION CONS	istency density Very Soft VL Very Loos		ING & TE		pp	Pocket per	netrometer	2.0 2.0 3.0 3.0 4.0 CLASSIFICATION SYMBOLS AND
X B E H S P A	H Ba Ex A Ha Ha T Pu:	ckhoe cavate nd au ind sp sh tub iger	buck or ger ade e	et RB Nil	Roc	tcrete k Bolts suppor	s 🔽 Wate	er leve er outfl	I W Wet H Higl Wp Plastic limit R Ref low WI Liquid limit	n F F usal St S VSt \ H F	Soft L Loose Firm MD Medium Di titff D Dense Very Stiff VD Very Dense lard riable	ense U Un D Dis e M Mo	k sample disturbed sa turbed sa isture con be sample	mple tent	VS DC FD	Standard p Vane shea P Dynamic penetron Field dens Water san	cone neter ity	SOIL DESCRIPTION Y USCS N Agricultural
C	C Con	crete (corer			F	XCAVATIO	ON LO	OG TO BE READ IN CONJU	INCTION WITH	I ACCOMPANYING REP	ORT NOTE	S AND A	ABBRE'	VIATION	ONS		
			- ~								ACCOCIATE OFFICE TO	J	1					

9 Attachment C – Laboratory Report





Soil Conservation Service

SOIL TEST REPORT

Page 1 of 2

Scone Research Centre

REPORT NO: SCO10/324R1

REPORT TO: Ben Rose

Martens & Associates Pty Ltd

6 / 37 Leighton Place Hornsby NSW 2077

REPORT ON: Six soil samples

Ref: 2761

PRELIMINARY RESULTS

ISSUED: Not issued

REPORT STATUS: Final

DATE REPORTED: 10 November 2010

METHODS: Information on test procedures can be obtained from Scone

Research Centre

TESTING CARRIED OUT ON SAMPLE AS RECEIVED THIS DOCUMENT MAY NOT BE REPRODUCED EXCEPT IN FULL

SR Young

SR young

(Laboratory Manager)

SOIL AND WATER TESTING LABORATORY Scone Research Centre

Page 2 of 2

Report No: SCO10/324R1 Client Reference: Ben Rose

Martens & Associates Pty Ltd

6 / 37 Leighton Place Hornsby NSW 2077

Lab No	Method	P18B/2	2 AWC
	Sample Id	0.3bar (%)	15bar (%)
1	2761/4/0.4	9.9	5.4
2	2761/8/0.3	16.8	12.1
3	2761/6/0.5	23.2	11.6
4	2761/2/1.0	15.1	8.0
5	2761/3/0.35	19.7	8.9
6	2761/5/0.1	19.1	9.9

AWC = moisture content (%) by weight

SR Young

END OF TEST REPORT

10 Attachment D - Notes About This Report





Important Information About Your Report

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

Engineering Reports - Limitations

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

Engineering Reports – Project Specific Criteria

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

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

Engineering Reports – Recommendations

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

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

Engineering Reports – Use For Tendering Purposes

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

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

Engineering Reports – Data

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

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

Engineering Reports – Other Projects

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

Subsurface Conditions - General

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

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



policy by statutory authorities.

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

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

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

Subsurface Conditions - Changes

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

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

Subsurface Conditions - Site Anomalies

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

Report Use By Other Design Professionals

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

Subsurface Conditions - Geoenvironmental Issues

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

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

Responsibility

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

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

Site Inspections

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

Explanation of Terms (1 of 3)

Definitions

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

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

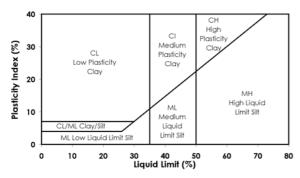
Particle Size

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

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

Plasticity Properties

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



Moisture Condition

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

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

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

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

Term	C₀ (kPa)	Approx SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	2 to 4	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail.
Friable	-		Crumbles or powders when scraped by thumbnail

Density of Granular Soils

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

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

Minor Components

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

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





Soil Data

Explanation of Terms (2 of 3)

Soil Agricultural Classification Scheme

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

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



Symbols for Soil and Rock

SOIL		SEDIMENTARY ROCK		IGNEOUS ROCK	IGNEOUS ROCK
COBBLES / BOULDERS	X X SILT (ML or MH)	BOULDER CONGLOMERATE	CLAYSTONE	+ + + + GRANITE	SLATE, PHYLLITE SCHIST
GRAVEL (GP or GW)	CLAY (CL or CI)	CONGLOMERATE	SHALE	DOLERITE / BASALT	GNEISS
SILTY GRAVEL (GM)	ALLUVIUM	CONGLOMERATE SANDSTONE	COAL		
CLAYEY GRAVEL (GC)	FILL	SANDSTONE, QUARTZITE	LIMESTONE		
SAND (SP or SW)	TALUS	SILTSTONE	TUFF		
SILTY SAND (SM)	TOPSOIL	LAMINITE			
CLAYEY SAND (SC)		MUDSTONE			

Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					uscs	Primary Name		
0.075		AN VELS or no	Wi	Wide range in grain size and substantial amounts of all intermediate particle sizes.		GW	Gravel	
yer than FELS Coarse fra 2.0 mm.	CLEAN GRAVELS (Little or no fines)		Predominantly one size or a range of sizes with more intermediate sizes missing		GP	Gravel		
SOILS 3 mm is Iar	<u></u>	GRAVELS More than half of coarse fraction is larger than 2.0 mm.	GRAVELS WITH FINES (Appreciable amount of fines)		Non-plastic fin	es (for identification procedures see ML below)	GM	Silty Gravel
SRAINED SC ss than 63 i mm	aked ey	More th	GRAVE WITH FIN (Apprecie amount fines)		Plastic fines (for identification procedures see CL below)			Clayey Gravel
COARSE GRAINED naterial less than 6 mm	to the n	ction is	AN DS or no s)		Wide range in grair	sizes and substantial amounts of intermediate sizes missing.	SW	Sand
CO⁄a s of mate	m is More than 50 % of material less than 63 mm is larger than 0.075 mm about the smallest particle visible to the naked eye) SANDS More than half of coarse fraction is smaller than 2.0 mm. larger than 2.0 mm.	CLEAN SANDS (Little or no fines)		Predominantly one size or a range of sizes with some intermediate sizes missing		SP	Sand	
han 50 %		SAN an half of maller tho	WITH ES ciable int of ss)		Non-plastic fin	es (for identification procedures see ML below)	SM	Silty Sand
More t	ne smalle	More th	SANDS WITH FINES (Appreciable amount of fines)		Plastic fines (for identification procedures see CL below)		SC	Clayey Sand
	± toc		IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
3 mm is	.≥	DRY STRENG (Crushing Characteristi	DILATANO	Υ	TOUGHNESS	DESCRIPTION	uscs	Primary Name
LS s than 6 mm	(A 0.075 mm particle	None to Lo	Quick to Slow	0	None	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Silt
VED SOILS prial less th 0.075 mr	775 mm	Medium t High	o None		Medium	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL	Clay
FINE GRAINED SOILS 50 % of material less the smaller than 0.075 mm	(A 0.0	Low to Medium	Slow to Ve Slow	ery	Low	Organic slits and organic silty clays of low plasticity	OL	Organic Silt
FINE GRAINED SOILS More than 50 % of material less than 63 mm is smaller than 0.075 mm		Low to Medium	Low to Slow to V Medium Slow		Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	МН	Silt
ore tho		High	High None		High	High Inorganic clays of high plasticity, fat clays		Clay
Σ	Medium to High		to None		Low to Medium	Organic clays of medium to high plasticity	ОН	Organic Silt
HIGHLY ORGANIC Readily identified by colour, odour, spongy feel and frequently by fibrous texture SOILS					Pt	Peat		
Low Plastici	ty – Lie	quid Limit W _L	< 35 % Medi	ium P	lasticity – Liquid I	mit W_L 35 to 60 % High Plasticity - Liquid limit V	V _L > 60 %	



Explanation of Terms (1 of 2)

Definitions

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

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

isotropic or anisotropic.

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

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

defects, or one or more substances with one or more defects.

Degree of Weathering

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

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

Rock Strength

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

Term	Is (50) MPa	Field Guide	Symbol
Extremely weak	< 0.03	Easily remoulded by hand to a material with soil properties.	EW
Very weak	0.03 - 0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VW
Weak	0.1 - 0.3	A piece of core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	W
Medium strong	0.3 - 1	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	MS
Strong	1 - 3	A piece of core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife.	S
Very Strong	3 - 10	A piece of core 150mm long x 50mm diameter may be broken readily with hand held hammer. Cannot be scratched with pen knife.	VS
Extremely strong	> 10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	ES





Explanation of Terms (2 of 2)

Degree of Fracturing

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

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



Test Methods

Explanation of Terms (1 of 2)

Sampling

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

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

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

Drilling Methods

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

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

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

<u>Test Pits</u> - these are 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. A potential disadvantage is the disturbance caused by the excavation.

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

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

<u>Continuous Spiral Flight Augers</u> - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or *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 or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and

returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

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

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

Standard Penetration Tests

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

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

The test results are reported in the following form:

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

as 4, 6, 7

N = 13

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

as 15, 30/40 mm.

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

CONE PENETROMETER TESTING AND INTERPRETATION

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

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

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



Test Methods

Explanation of Terms (2 of 2)

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

The information provided on the charts comprises: Cone resistance - the actual end bearing force divided by

the cross sectional area of the cone - expressed in MPA.

Sleeve friction - the frictional force of the sleeve divided by the surface area - expressed in kPa.

Friction ratio - the ratio of sleeve friction to cone resistance - expressed in percent.

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

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

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

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

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

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

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

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

DYNAMIC CONE (HAND) PENETROMETERS

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

Perth sand penetrometer - a 16 mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS 1289 - Test F 3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

Cone penetrometer (sometimes known as the Scala Penetrometer) - a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289 - Test F 3.2). The test was developed initially for pavement sub-grade investigations, with correlations of the test results with California bearing ratio published by various Road Authorities.

LABORATORY TESTING

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

TEST PIT / BORE LOGS

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

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

GROUND WATER

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

In low permeability soils, ground water although present, may enter the hole slowly, or perhaps not at all during the time it is left open.

A localised perched water table may lead to an erroneous indication of the true water table.

Water table levels will vary from time to time with seasons or recent prior weather changes. They may not be the same at the time of construction as are indicated in the report.

The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

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

