Catholic Metropolitan Cemeteries Trust

Preliminary Geotechnical, Groundwater and Salinity Assessment: Proposed Nepean Gardens, Wallacia, NSW

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

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

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1 Development and Investigation Scope

1.1 Overview

The proposed development details and investigation scope are summarised in Table 1.

Table 1: Summary of proposed development and investigation scope.

Item	Details
Property Address	Wallacia Golf Course, 13 Park Road, Wallacia, NSW ('the site')
Lot / DP	Lot 2 in DP 1108408
LGA	Penrith City Council (PCC)
Assessment Purpose	To support DA submission for a proposed cemetery in the eastern portion of the property (the 'site')
Site Area	Approximately 21.3 ha based on Six Maps
Proposed development	Proposed site development as a cemetery
Investigation scope of work	3 boreholes and 5 test pits (refer Attachment B). 8 Dynamic Cone Penetrometer (DCP) tests (refer Attachment D). Monitoring of 6 groundwater monitoring wells previously installed within the property. Investigation locations are shown in Drawing PS02-J100, Attachment A.
Other Assessments (MA, 2017)	A preliminary Geotechnical, Groundwater and Salinity Assessment was previously carried out by Martens and Associates (MA) at the property. Results are presented in MA report reference P1706171JR01V01.

1.2 Assessment Objectives

1.2.1 Geotechnical Assessment

The objective of the geotechnical assessment is to:

- Determine site geotechnical conditions and any associated risks which may affect the site and the proposed development. Recommendations to minimise identified risks and also adequacy of the site for use as a cemetery are to be provided accordingly.
- Determine indicative soil and bedrock depths across the site to help locate suitable areas for burial plots.

- Provide preliminary design advice and recommendations relating to construction of proposed pavements as part of the provision of design services for obtaining Construction Certificate (CC) from PCC.

1.2.2 Groundwater Assessment

The objective of the groundwater assessment is to determine permanent groundwater levels at the site based on local groundwater bore search and field investigations, including on-site borehole observation and groundwater monitoring. All bases of burial plots need to be a minimum 1.0 m above highest natural groundwater level (World Health Organisation, 1998).

1.2.3 Salinity Assessment

The objective of the salinity assessment is to ensure that consideration is given to local prevailing salinity conditions, the potential impacts of any site salinity on the development and the potential impacts of the proposed development on salinity. Recommendations to minimise identified risks are provided accordingly in light of requirements of the Level 3 Salinity Management Response (WSROC, 2004).

2 Findings

2.1 Site Details and Conditions

General site details are summarised in Table 2.

Table 2: Summary of site details based on desktop review and site investigations.

Item	Description
Site development	There is an existing telecommunications tower in the central northern portion of the site. The remain
Surrounding land uses	The site is bordered by rural allotments to the east, Park Road to the south and a golf course to the
Topography	The site is located within highly undulating terrain, with general grades of 5-10% and slightly steepe The site has a northerly aspect and varies from approximately 65 mAHD near the eastern site bou the site.
Expected geology	The Penrith 1:100,000 Geological Sheet 9030 (1991) indicates the site is underlain by Wianamatta medium grained lithic sandstone, rare coal and tuff. (Refer attachment A, Drawing PS02-J103).
Soil Landscape	The NSW Environment and Heritage eSPADE website identifies that the site is associated with Ludde moderately deep red podzolic soils on upper slopes, and moderately deep yellow podzolic soils a
Drainage	The investigation site generally drains via overland flow into a drainage depression near the centr
Vegetation	Site vegetation generally consists of golf course lawns and scattered trees.
Generalised sub-surface soil / rock units	Unit A: Topsoil comprising very stiff and hard silt up to approximately 0.4 mbgl. Unit B: Residual soil, generally stiff to very stiff grading to hard clay up to approximately 3.5 mbgl. Unit C: Weathered rock comprising inferred extremely to distinctly weathered, extremely low to m TC-bit refusal at 2.6 to >3.5 mBGL to comprise medium strength Shale. This should be confirmed / re

3 Geotechnical Assessment

3.1 Sub-surface Conditions

3.1.1 Borehole Investigations

The investigation area has been divided into two generalised zones based on the encountered soil depth and depth to top of weathered rock and bedrock as follows:

Zone A: Soil over shallow weathered rock (< 2.5 mBGL).

Zone B: Soil over deep weathered rock (> 2.5 mBGL).

Table 3 summarises generalised depths of encountered sub-surface units in each zone.

Attachment A, drawing PS02-J105 provides indicative extents of these zones.

Considering excavation of burial plots by a hydraulic excavator, excavation is expected to refuse on bedrock.

Table 3: Generalised zones of inferred sub-surface profile

Unit	Indicative depth range (mBGL)	
	Zone A – Shallow weathered rock	Zone B - Deeper weathered rock/deep bedrock
1 – Topsoil	0.0 – 0.4	0.0 – 0.3
2 – Residual Soil	0.2 – 2.2	0.3 – 3.5
3 – Weathered Rock	<2.5	>2.5
4 [1] – Bedrock	<2.5	>2.5

Notes:

1. Medium strength bedrock based on TC bit refusal; may comprise higher strength layers below investigation termination depth.

3.2 Laboratory Testing

Four soil samples were collected from four locations and submitted to Resource Laboratories, *a* National Association of Testing Authority (NATA) accredited laboratory, for Atterberg limits testing. Tests were conducted in accordance with AS 1289.1.1, 2.1.1, 3.1.2, 3.2.1, 3.31 and 3.4.1. Test results are summarised in Table 4. A laboratory test certificate is provided in Attachment D.

Table 4: Summary of laboratory test results for Atterberg Limits.

BH ID / Depth	Material	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Plasticity Classification
TP111/ 0.5	CLAY, trace of gravel	70	19	51	16.5	High
BH115 / 0.5	CLAY, trace of gravel	53	15	38	15.5	High
BH108 / 1.5	CLAY	41	15	26	11.0	Medium
BH110 / 0.5	CLAY, trace of gravel	64	16	48	16.5	High

Atterberg limits and linear shrinkage data indicate that the tested soil samples are of generally high plasticity with marginal to critical expansive ratings. Soil treatment and stabilization may be required for construction of structures in these soils.

3.3 Geotechnical Parameters

Strength properties for the site soils and rock have been estimated using *in-situ* DCP testing and borehole derived data. Results are summarised in Table 5. Preliminary results from penetration testing conducted across the site suggest that the site's silty clays and clays are generally very stiff to hard. A detailed DCP log sheet is provided as Attachment C with DCP number corresponding to borehole and test pit location.

Table 5: Preliminary estimates of soil strength properties on-site

Soil Type	D_d (kN/m^3)[1]	C_u (kPa) [2]
Clayey silt/silty clay/silt (topsoil)	17	50
Clay (residual, firm)	16	25
Clay (residual, stiff)	17	50
Clay (residual, very stiff)	17	100
Clay (residual, hard)	18	200
Weathered rock	22	-

Notes:

1. Dry density, estimate of likely value only.
2. Undrained shear strength, estimate of likely value only.

3.4 Geotechnical Site Limitations

3.4.1 Soil landscape limitations

Limitations associated with the Luddenham soil landscape identified in the investigated area are summarised below:

- The erosion hazard for non-concentrated flows ranges from moderate to very high. Soil erosion hazard for concentrated flows is high to very high.
- Moderately reactive soils. Soils are deep and have high clay content. Clay often has low to moderate shrink-swell potential.
- Low to moderate capacity for urban development. Low to moderate capacity for urban development.

3.4.2 Clay soil profile

We consider that high plasticity clay soils at the site are likely to have high susceptibility to shrinkage and swell movement resulting from changes in soil moisture content. There is a localised dispersion risk within the clay soils.

3.4.3 Water logged Soils

Water logged soils may pose a geotechnical constraint for the proposed development. Areas where waterlogged soils may be encountered include:

- Along local drainage depressions where topography is flat and slopes are less than 1-2%.
- Drainage confluences (i.e. where drainage depressions converge).

We note that the extent and severity of water logging will be dependent on rainfall and climate conditions. Development in these areas should be avoided where possible. Where development does occur (i.e. roads, car parks), design and construction should take into account the water logged soils and subsequent low strengths of the clay subsoils. Sub soil drains may need to be installed.

3.4.4 Risks of Slope Instability

No evidence of former ground movement was observed at the site during our walkover:

- There was no evidence of subsidence or recent gross slope instability onsite.
- The existing buildings showed no significant visible cracking or settlement. A detailed dilapidation survey was not undertaken.
- Other site features showed no signs of being impacted by ground instability.

We consider the risk in the investigation area to property and loss of life by potential slope instability, such as landslide or soil creep, to be very low subject to the recommendations in this report and adoption of relevant engineering standards and guidelines. A detailed slope risk assessment in accordance with Australian Geomechanics Society's Landslide Risk Management Guidelines (2007) was not undertaken.

3.5 Preliminary Pavement Thickness Design

3.5.1 Overview

Preliminary pavement thickness design was undertaken in accordance with PCC's Engineering Guide for Development PCC (2013).

3.5.2 Design Parameters

ESA value of 5 x 10^4 was adopted for design of the proposed internal access road (PCC, 2013).

Two bulk soil samples were collected from locations shown in PS02-J100, Attachment A, and submitted to Resource Laboratories for CBR testing. A four day soaked CBR test was conducted in accordance with AS 1289.1.1, 2.1.1, 5.1.1 and 6.1.1. Test results are summarised in Table 7. A laboratory test certificate is provided in Attachment D.

Table 7: CBR test results.

Sampling Number	Material	Sample Depth (mBGL)	CBR [1] Value (%)
TP109/CBR:0.2-0.7m	CLAY	0.2 – 0.7	2.5
TP112/CBR:0.2-0.7m	CLAY	0.2 – 0.7	2.5

Notes:

[1] Four day soak, compacted to 98 % SMDD (±2 % of OMC), applying a 4.5 kg surcharge.

A CBR value of 2.5 %, is considered typical for clay of high plasticity that is generally encountered in the site area.

Given the limited laboratory test results, DCP-CBR correlations were carried out using Austroads (2012). Subgrade materials at test locations were assessed to have CBR values ranging between 3 % and 30 %. Considering the variation in DCP 'N' counts resulting from varying material types and consistency conditions, particularly for soil up to 1.0 mBGL across the proposed development area, the likely variable cut and fill requirements across the site and the requirements of council, we have adopted a CBR value of 3 % for preliminary design purposes. Where inferior material is uncovered during excavation, additional stabilisation with lime to achieve a minimum CBR value of 3 % may be required. Similarly, where material of inferior quality is uncovered during excavation in remaining site areas, lower CBR values may be applicable and subgrade treatment may be required and / or pavement material thickness may need to be revised.

Additional CBR testing is recommended to provide a better indication of subgrade conditions across pavement areas considering final design alignments and levels, to confirm suitability of adopted CBR value and / or provide statistical means to support a higher CBR design value. The additional testing may be undertaken at Construction Certification stage. Verification of adopted CBR value is to be undertaken during construction by a geotechnical engineer and further on-site / laboratory testing.

3.5.3 Pavement Thickness

Table 8 presents recommended pavement types and material thicknesses for the proposed roads.

Table 8: Preliminary pavement material thickness design for CBR 3 %.

Road Type	Total Thickness (mm)	Layer	Thickness (mm)	Materials
Residential - private / community title roads	500	Wearing Course	50	7 mm primer + 10 mm one coat flush seal + 40 mm Asphalt Concrete (AC10)
		Base	175	DGB20
		Sub-base	275	CSS40 or DGS40

4 Hydrogeological Assessment

4.1 NSW Government Natural Resource Atlas

Review of NSW Department of Primary Industries - Office of Water's database indicated one local government groundwater bores (with limited information) located within 500 m of the site boundaries (Table 9).

Table 9: Available hydrogeological information.

Groundwater Bore Identification	Direction and Distance	Standing Water Level (m)	Intended Use	Water Bearing Zone Substrate
GW109120	Southwest (100 m)	45	Domestic Stock	ND[1]

Notes

[1] ND – No data available

4.2 Borehole groundwater observation

No groundwater was encountered during excavation and drilling. Soils are generally moist to dry. Five (5) boreholes drilled in the western portion of the property were left open overnight. Groundwater levels in each borehole were measured on the following day. Groundwater levels in each borehole are summarised in Table 10.

Table 10: Overnight borehole groundwater levels.

Borehole location [2]	Groundwater depth during drilling measured on 18.9.17 (mbgl)	Groundwater depth >24 hrs after drilling measured on 19.9.17 (mbgl)	Groundwater depth measured on 22.09.2017 (mbgl)	Borehole depth (m)
BH102	NE[1]	3.60	3.40	5.5
BH115	NE[1]	2.10	1.60	2.6
BH117	NE[1]	2.85	NE[1]	3.1
BH118	NE[1]	5.45	5.40	5.7
BH119	NE[1]	4.50	3.93	5.5

Notes:

1. Not encountered.
2. Refer to Attachment A drawing PS02-J100 for BH locations.
3. Not applicable.

4.3 Groundwater well monitoring

Six (6) groundwater monitoring wells were installed in MW102, MW104, MW105, MW107, MW117 and MW119 on 22 September 2017. We note that none of these wells are located within the proposed cemetery footprint however provide representative groundwater information for design purposes. Groundwater levels in each well have been continuously monitored using groundwater level data loggers at a 15 minute frequency. Groundwater levels in each monitoring well are summarised in Table 11.

Table 11: Monitoring well groundwater levels.

	Groundwater Level (mBGL)					
Date	**MW102**	**MW104**	**MW105**	**MW107**	**MW117**	**MW119**
22/09/2017	3.4[1]	NR[2]	NR[2]	NR[2]	NR[2]	3.93[1]
29/09/2017	Dry	2.35	Dry	Dry	2.05	Dry
10/10/2017	3.92[3]	2.47	Dry	D	2.02	Dry
23/10/2017	3.9[3]	2.59	Dry	D	1.7	Dry
22/12/2017	4.0[3]	3.15	Dry	2.88[3]	2.06	Dry
25/01/2018	4.0[3]	3.46	Dry	2.87[3]	2.03	Dry
2/03/2018	3.9[3]	3.78	2.98[3]	2.85[3]	2.07	Dry
16/04/2018	Dry	Dry	Dry	2.87[3]	2.11	Dry
18/06/2018	Dry	Dry	2.97[3]	2.88[3]	2.34	Dry
12/07/2018	Dry	Dry	2.98[3]	2.88[3]	2.43	Dry
30/08/2018	Dry	Dry	Dry	Dry	2.51	Dry
25/10/2018	Dry	Dry	Dry	Dry	2.49	Dry
5/12/2018	3.69[5]	Dry	3.00[3]	Dry	2.42	Dry
28/2/2019	NR[6]	Dry	Dry	Dry	2.32	Dry

Notes:

1. Levels assumed to have been influenced by inflow i.e. drilling water and / or water used for well installation which was not completely purged from boreholes, not natural groundwater level.
2. Not recorded (NR).
3. Represent dry or effectively dry MW (non-draining small sump at well base).
4. Groundwater well locations and elevation to be surveyed to obtain more accurate groundwater data.

5. Groundwater level likely influenced by surface water entering well. This is to be confirmed following next data collection.
6. Unable to locate well due to soil and vegetation cover over well or well being removed by others.

Water was encountered continuously at MW117 which is located within a drainage depression. Preliminary investigations indicate that groundwater levels are possibly as a result of either groundwater perched over top of bedrock or present within fractured bedrock. We note that monitoring has been carried out during a dry weather period. Groundwater levels will vary in the short term predominantly with minor atmospheric pressure and rainfall infiltration effects.

4.4 Water Quality Monitoring Results

Groundwater quality samples were collected on 22.09.2017 with results summarised in Table 12.

Table 12: Summary of groundwater water quality results.

Location	pH	EC[1] (µS/cm)	SO4[2] (mg/L)	TKN[3] (mg/L)	BOD[4] (mg/L)	NOx[5] (mg/L)	TP[6] (mg/L)
MW104	6.9	3,800	37	1.3	<5	0.2	0.1
MW117	6.8	8,500	1,200	4.4	<5	0.1	0.8

Notes:
[1] EC = electrical conductivity.
[2] SO4 = sulphates.
[3] TKN = total kjeldahl nitrogen.
[4] BOD = biochemical oxygen demand.
[5] NOx = nitrogen oxide.
[6] TP = total phosphorous.

4.5 Conclusions

Groundwater levels were measured between approximately 2.0 and 4.0 mBGL in areas adjacent and upslope of Jerrys Creek and within a minor drainage depression.

Based on the limited groundwater assessment results, the risk to the site from adverse groundwater conditions is considered to be low across the proposed development area of the site. Similarly, the base of burial plots will be able to maintain a minimum 1 m buffer from groundwater over the majority of the site.

5 Salinity Assessment

5.1 Documented Salinity Risk Potential

The 1:100,000 *Salinity Potential in Western Sydney Map* (DIPNR, 2002) indicates the site to be located in an area of very low salinity potential with some low-lying areas having a moderate salinity potential (Attachment A, drawing PS02-J104).

5.2 Broad Scale Salinity Processes

In producing the Salinity Potential Map, the Western Sydney Regional Organisation of Councils (WSROC) developed a number of alternative models of processes by which salinity may occur in Western Sydney (WSROC, 2003, pgs. 16 to 20).

A list of key broad scale salinity processes likely to impact the site, including summarised descriptions of each process, is presented in Table 13.

5.3 Signs of Potential Saline Soils at the site

No obvious signs of saline conditions were observed across the site:

- Vegetation growth appeared healthy and uninhibited.
- No water marks or salt crystals were observed on the ground surface at the time of the investigation.
- No evidence of concentrated surface erosion was observed.

5.4 Assessed Salinity Risk Potential

In Table 13, the broad scale salinity processes have been assessed in terms of likelihood of occurring at the site, considering the proposed development, site observations and investigation findings.

Table 13: Potential for broad scale salinity processes at the site.

Key salinity process	Description	Potential at subject site
Localised concentration of salinity	Localised concentration of salts due to relatively high evaporation rates. Usually associated with waterlogged soil and poor drainage. Exacerbated by increased water use and / or blocking of surface and subsurface water flow associated with urban development.	Moderate - No evidence of localised salt concentration. However, drainage depressions are located at the site. Increased seasonal evaporation rates and groundwater seepage could potentially generate saline soils.
Shale soil landscapes	In poorly drained duplex (texture contrast) soils, shallow subsurface water flows laterally across a clayey upper B-Horizon with salt usually accumulating in the clayey subsoil. Salt concentrations may increase where subsurface water accumulates and evaporates, e.g. on lower slopes or natural and constructed flats in mid-slope. Exacerbated by subsoils exposure through deep cutting, by installing buildings into the B-horizon and by impeding subsurface water flows. Highly dispersive, erodible and poorly draining sodic soils due to salinity.	Moderate – The site is underlain by low permeable clay overlying shale. No evidence of impeded surface vegetation growth and surface soil erosion observed.
Deep groundwater salinity	Brackish or saline groundwater rises to a level where, through capillary action in the soil, the water with dissolved salts reaches the ground surface and evaporates, resulting in localised salt concentration. Groundwater rises are typically caused by increased water infiltration, e.g. above average rainfall, vegetation loss, irrigation, increased water use in urban areas, construction of surface pits. Exacerbated by buildings or infrastructure intercepting the zone of groundwater level fluctuation.	Low – Groundwater was not encountered in the boreholes and test pits up to 3.5 mBGL. The future development is unlikely to intercept groundwater levels. Future structures are to be constructed with appropriate drainage measures installed where required.
Deeply weathered soil landscape	High salt loads with high sulphate levels related to un-mapped deeply weathered soil landscapes beneath fluvial gravel, sand and clay. Usually in mid-slope or on hilltops affected by perched saline groundwater.	Low – No evidence of deeply weathered soils observed. Encountered site soils are residual.

5.5 Laboratory Testing

5.5.1 Overview

Twelve soil samples and two water samples were collected from the boreholes, test pits and monitoring wells and submitted to Envirolab

Services, a NATA accredited laboratory, for salinity and aggressivity testing (Electrical Conductivity (EC), pH and soluble SO_4). The testing was carried out for salinity classification and to assess an exposure classification for design of buried concrete structures. Sampling was targeted to achieve a representative coverage of site conditions in line with assessed subsurface profiles, proposed earthworks and the limited investigation scope.

5.5.2 Results – Salinity Classification

Laboratory test results for salinity classification are summarised in Table 14. A laboratory test certificate is provided in Attachment D.

Table 14: Salinity test results.

Sample ID [1]	Material	$EC_{(1:5)}$ (dS/m)	EC_e (dS/m) [2]	Salinity Classification [3]
TP109/1.0	Clay	0.53	3.18	Slightly Saline
BH110/1.0	Clay	0.12	0.72	Non – Saline
TP111/0.4	Clay	0.028	0.168	Non – Saline
TP111/1.5	Clay	0.27	1.62	Non – Saline
TP112/0.4	Clay	0.16	0.96	Non – Saline
TP112/2.0	Clay	0.79	4.74	Moderately Saline
TP113/0.1	Sandy Silt	0.034	0.476	Non – Saline
TP113/2.0	Clay	0.1	0.6	Non – Saline
TP114/2.0	Clay	0.46	2.76	Slightly Saline
BH115/0.2	Sandy SILT	0.12	1.68	Non – Saline
BH115/0.5	Clay	1.3	7.8	Moderately Saline
BH115/1.6	Clay	0.51	3.06	Slightly Saline

Notes:

1 Borehole#/Depth (mBGL)

2 Based on EC to EC_e multiplication factors from Table 6.1 in DLWC (2002).

3 Based on Table 6.2 of DLWC (2002) where EC_e <2 dS/m = non-saline, EC_e of 2-4 dS/m = slightly saline, EC_e of 4-8 dS/m = moderately saline, EC_e of 8-16 dS/m = very saline and EC_e of >16 dS/m = highly saline.

Results indicate sub-surface materials at the site can generally be categorised as non-saline to slightly saline. Moderately saline soil tested in TP112 and BH115, is likely to be associated with the location of the borehole / testpit within a low lying area and drainage depression.

5.5.3 Results – Exposure Classification

Test results for exposure classification are summarised in Table 15. The laboratory test certificate is provided in Attachment D.

Table 15: Exposure classification test results.

Sample ID[1]	EC_e (dS/m) [2]	pH	Sulphate (SO_4) (mg/kg)	Exposure Classification [3]
TP109/1.0	3.18	4.7	110	A2
BH110/1.0	0.72	5.3	78	A2
TP111/0.4	0.168	5.6	30	A1
TP111/1.5	1.62	7.5	<10	A1
TP112/0.4	0.96	5.0	160	A2
TP112/2.0	4.74	4.8	490	A2
TP113/0.1	0.476	5.6	20	A1
TP113/2.0	0.6	5.1	27	A2
TP114/2.0	2.76	4.9	130	A2
BH115/0.2	1.68	6.4	10	A1
BH115/0.5	7.8	5.7	190	B1
BH115/1.6	3.06	6.6	100	A1

Notes:

1 Borehole#/Depth (mBGL)

2 From column 4 of Table 14.

3 Exposure classification for buried reinforced concrete based on Tables 4.8.1 and 4.8.2 of AS 3600 (2009).

An exposure classification of 'A2' should be adopted for preliminary design of buried concrete structures in accordance with AS3600 (2009). Higher classification (B1) may apply to low lying areas / drainage depressions.

5.6 Conclusion – Salinity Potential

Results indicate sub-surface materials at the site can generally be categorised as having a slight salinity risk potential with low lying areas having a moderate risk potential. Therefore specific saline soil management strategies are required at the site where development occurs in low lying areas.

Additional assessments would need to be carried out to confirm and improve characterisation of the site salinity conditions, such as in low lying areas / drainage depressions.

6 Site Recommendations

We recommend further investigation and/or site specific analysis are conducted in the vicinity of any proposed structures to provide more accurate geotechnical design parameters for structural design at detailed design stage.

General geotechnical recommendations for the proposed development are provided in Attachment D. Further site specific recommendations include:

6.1 Site Classification

Based on preliminary field investigations, a large portion of the site consists of a deep highly plastic clay profile greater than 1.8 m depth. Therefore, the site maintains a preliminary classification of 'H1' in accordance with AS 2870 (2011). Areas where the clay profile is less than 1.8 m deep may be classified as 'M', subject to further laboratory testing. Classifications will vary depending on site cutting and filling.

6.2 Excavations

Excavation works for the development will involve excavating clayey subsoil materials with some excavation areas likely to encounter rock of various strengths, depending on location.

Zone A comprises shallow bedrock (<2.5 mBGL) and possible ephemeral perched groundwater, subject to further detailed investigations. Zone B comprises deep residual soil (>2.5 mBGL). Refer to Attachment A, drawing PS02-J105 for indicative zone locations.

6.3 Footings and Foundations

We consider that the observed clay soils at the site are able to support structures such as buildings and roads with a range of commonplace structural solutions. Footing and foundation design should take into consideration preliminary soil strengths provided in Table 5. Depending on the final structural loads and tolerance to differential movements, shallow pad, strip or stiffened slab footings may be appropriate if founding on at least stiff natural clay. Allowable end bearing pressures of 100 kPa and 300 kPa may be adopted for stiff clay and weathered rock respectively.

Clay soils at the site may have high shrink-swell susceptibility and future investigations or designs are required to address this constraint to building construction.

6.4 Retaining Structures

Excavations in burial plots will likely remain open for less than 24 hours. Temporary shoring or appropriate grave shoring inserts will unlikely be required during excavation works unless excavations remain open for a longer period (greater than 2 days) or during prolonged or heavy rainfall periods.

If the proposed development requires construction of retaining structures, it is recommended that retaining structures greater than 0.75 m are individually assessed and designed by an appropriate engineer. Active, Passive and at-rest earth pressure coefficients of 0.4, 2.6 and 0.56 respectively, may be adopted for preliminary design.

6.5 Earthworks

6.5.1 Subgrade Preparation

To achieve the minimum required CBR value, the subgrade may require treatment, such as by one of the following methods subject to the future detailed design:

- Removal of topsoil and other unsuitable materials such as brick fragment containing soils, and replacement with approved fill under geotechnical engineer's direction.
- *In-situ* stabilisation with cement / lime or similar binding agent to a depth of at least 500 mm below finished level. Use of this method and extent will depend on the condition of material to be stabilized.
- Installation of a geotextile bridging layer.

6.5.2 Subsoil Drainage

Surface and sub-soil drainage is to be provided in accordance with PCC requirements. Sub-surface drains are to be installed at the minimum on the upslope side of roads and generally extend minimum 600 mm below subgrade level.

6.5.3 Placement and Testing of Pavement Material

Road subgrade is to be compacted with density testing at a rate of 1 test per 50 m of road length. Minimum relative density of subgrade shall be 100 % Maximum Dry Density (MDD) at a standard compactive effort within 2 % of optimum moisture content (OMC). Prior to placement of pavement material, the subgrade shall be proof rolled and approved by a geotechnical engineer.

Pavement materials shall be placed in layers (when compacted) not thicker than 200 mm or less than 100 mm. Pavement materials shall be compacted to the following condition:

- Sub-base - Minimum 98 % MDD at modified compactive effort (±2% OMC).
- Base - Minimum 98% MDD at modified compactive effort (±2% OMC).

Compaction testing shall be undertaken by a NATA accredited laboratory in accordance with procedures as outlined in PCC Construction Specification for Civil Works, 2016, and at a rate of no less than 1 per 50 linear metres, or per 250 m^2, whichever is the greater, with a minimum of 2 tests in any one length. Each pavement and subgrade replacement layer shall be proof rolled under Geotechnical Engineers' or GITA supervision. Subsequent pavement and subgrade replacement layers shall not be placed prior to approval of underlying layer by the Geotechnical Engineer.

6.5.4 Fill Placement

Should filling be required to raise site levels, site-won excavated residual soils may be considered, subject to stringent moisture conditioning and placement controls and further advice by a Geotechnical Engineer. Alternatively, and to raise pavement subgrade levels, suitable granular fill, approved for use by a Geotechnical Engineer should be adopted. All earthworks specification is to be prepared by the supervising engineer and be implemented by the contractor.

6.6 Saline Soil Management Recommendations

We recommend that saline soil management strategies are prepared at construction certificate stage following review of proposed development levels. There may also be a need to undertake additional sampling, depending on the proposed cut / fill and final development levels. Preliminary management strategies should include a combination of, but not be limited to, the following:

- Maintaining natural water balance.
- Limiting irrigation.
- Limiting soil disturbance, such as cut and fill, so saline or sodic subsoils are not exposed or groundwater is not intercepted.
- Planting of suitable salt-tolerant plant species.
- Retention of existing deep-rooted vegetation.

- Offset landscaping and gardens from building and retaining walls.
- Treating soils with gypsum before landscaping to suit selective species.
- Where consistent with future land use and landscaping plan, planting of deep-rooted, preferably native, trees to increase water absorption.
- Sealing, e.g. by lining, of stormwater detention ponds and water features to reduce infiltration.
- Preparing sediment and erosion control plans that take into account saline soils.
- Replacing excavated soils in their original order.
- Any long term irrigation or watering on-site is to be at a level that does not cause groundwater to become perched.

Typical management strategies for new buildings and services include:

- Limiting soil disturbance, such as compaction of soils, cutting and filling.
- Designing and building structures to limit interference with natural water flow on site.
- Using appropriate construction materials and techniques to salt proof buildings and infrastructure.
- Utilising damp proof courses and water proofing of slabs.
- Using exposure grade bricks / masonry below damp course or in retaining walls.
- Providing concrete strength and cover to steel reinforcing in accordance with AS 3600 (2009) and the exposure classifications outlined in
-
- Table 15.
- Limiting excess surface water infiltration into the soil by designing, installing and maintaining appropriate stormwater drainage (gutters, downpipes, pits and pipes).
- Further assessment including laboratory testing, to improve characterisation of site salinity conditions, particularly in proposed development areas, and assess potential ensuing implications on the proposed development and mitigation requirements.

7 Conclusion

From a geotechnical perspective, we consider the investigation area to be suitable for the proposed development, subject to the recommendations outlined above.

8 Proposed Additional Assessments

The following further investigations are recommended at the detailed design (or equivalent) stage:

- Further borehole / test pit to refine indicative soil profile zone delineations.
- Additional penetration testings such as Standard Penetration Test (SPT) and/or Dynamic Cone Penetration Test (DCP) to determine more accurate strength of sub-surface materials for future structural design.
- Further salinity investigation, including lab testing, to improve understanding of saline conditions and exposure classifications to proposed excavation depths.

9 References

Australian Standard 1289 (1997), *6.3.2 Determination of the Penetration Resistance of a Soil using the 9 kg Dynamic Cone Penetrometer.*

Australian Standard 1726 (2017), *Geotechnical Site Investigations.*

Australian Standard 2870 (2011), *Residential Slabs and Footings.*

Australian Geomechanics Society (2007), *Landslide Risk Management Concepts and Guidelines.*

Catholic Metropolitan Cemeteries Trust (2017), *Wallacia Golf Course & Memorial Park Masterplan*.

Department of Natural Resources (2002), *Map of Salinity Potential in Western Sydney.*

Department of Land and Water Conservation (2002), *Site Investigations for Urban Salinity.*

Florence Jaquet Landscape Architect (2017), *Survey Plan*, Job no:1703, dated 22 August 2017.

NSW Department of Mines (1991), *The Penrith 1:100,000 Geological Sheet 9030.*

NSW Department of Mines (2000), *The Penrith 1:100,000 Soil Landscape Series Sheet 9030.*

Penrith City Council (2016), *Engineering Construction Specification for Civil Works*.

Penrith City Council (2013), *Design guidelines for engineering works for subdivisions and developments*.

Western Sydney Regional Organisation of Councils (2004), *Western Sydney Salinity Code of Practice.*

World Health Organisation (1998), *Annex 7- Cemeteries*.

10 Attachment A – Plans

Wallacia Golf Course & Memorial Park Masterplan

PARK ROAD, WALLACIA

LEGEND

- EXISTING TREES
- PROPOSED STREET TREES
- PROPOSED INDIGENOUS TREES
- SCREEN PLANTING (MEDIUM)
- BUFFER PLANTING (TALL)
- LAWN
- WATER BODIES
- EXISTING WATERCOURSES
- PROPOSED ROADS AND CARPARKS
- PROPOSED PATH
- BUILDINGS
- 8 FAIRWAYS
- SCULPTURE
- SITE BOUNDARY

0 50 100m

SCORECARD

Hole	Par	Length
1	4	360mtrs
2	4	268
3	4	305
4	3	155
5	5	460
6	3	140
7	4	356
8	4	363
9	5	463
OUT	36	2870

Hole	Par	Length
10	–	–
11	–	–
12	–	–
13	–	–
14	–	–
15	–	–
16	–	–
17	–	–
18	–	–
IN	0	0
OUT	36	2870
TOTAL	36	2870

Lengths in metres

PROJECT: PROPOSED NEPEAN GARDENS

PLANSET: GEOTECHNICAL GROUNDWATER AND SALINITY MAPPING

CLIENT: CATHOLIC METROPOLITAN CEMETERIES TRUST

DRAWING LIST		
DWG No.	REV	DWG TITLE
GENERAL		
PS02-A000	A	COVERSHEET
GEOTECH AND CONTAMINATION		
PS02-J100	A	GEOTECHNICAL SITE INVESTIGATION LOCATIONS (AERIAL IMAGE)
PS02-J101	A	GEOTECHNICAL SITE INVESTIGATION LOCATIONS (CONTOUR SURVEY)
PS02-J102	A	INDICATIVE SOIL LANDSCAPE UNITS
PS02-J103	A	INDICATIVE GEOLOGICAL UNITS
PS02-J104	A	INDICATIVE SALINITY MAPPING
PS02-J105	A	INDICATIVE SOIL PROFILE ZONE

LOCALITY PLAN
N.T.S.

LGA: PENRITH CITY COUNCIL

WALLACIA GOLF COURSE, PARK ROAD, WALLACIA, NSW

DEVELOPMENT APPLICATION

REV	DESCRIPTION	DATE	DRAWN	DESIGNED	CHECKED	APPRVD
A	INITIAL RELEASE	26/09/2019	GM	CGL	CGL	GT

SCALE

GRID | DATUM | PROJECT MANAGER: GT

CLIENT: CATHOLIC METRO. CEMETERIES TR.

PROJECT NAME/PLANSET TITLE: PROPOSED NEPEAN GARDENS
GEOTECHNICAL GROUNDWATER AND SALINITY MAPPING
WALLACIA GOLF COURSE, PARK ROAD, WALLACIA, NSW

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DRAWING TITLE: COVER SHEET

PROJECT NO.	PLANSET NO.	RELEASE NO.	DRAWING NO.	REVISION
P1706171	PS02	R01	PS02-A000	A

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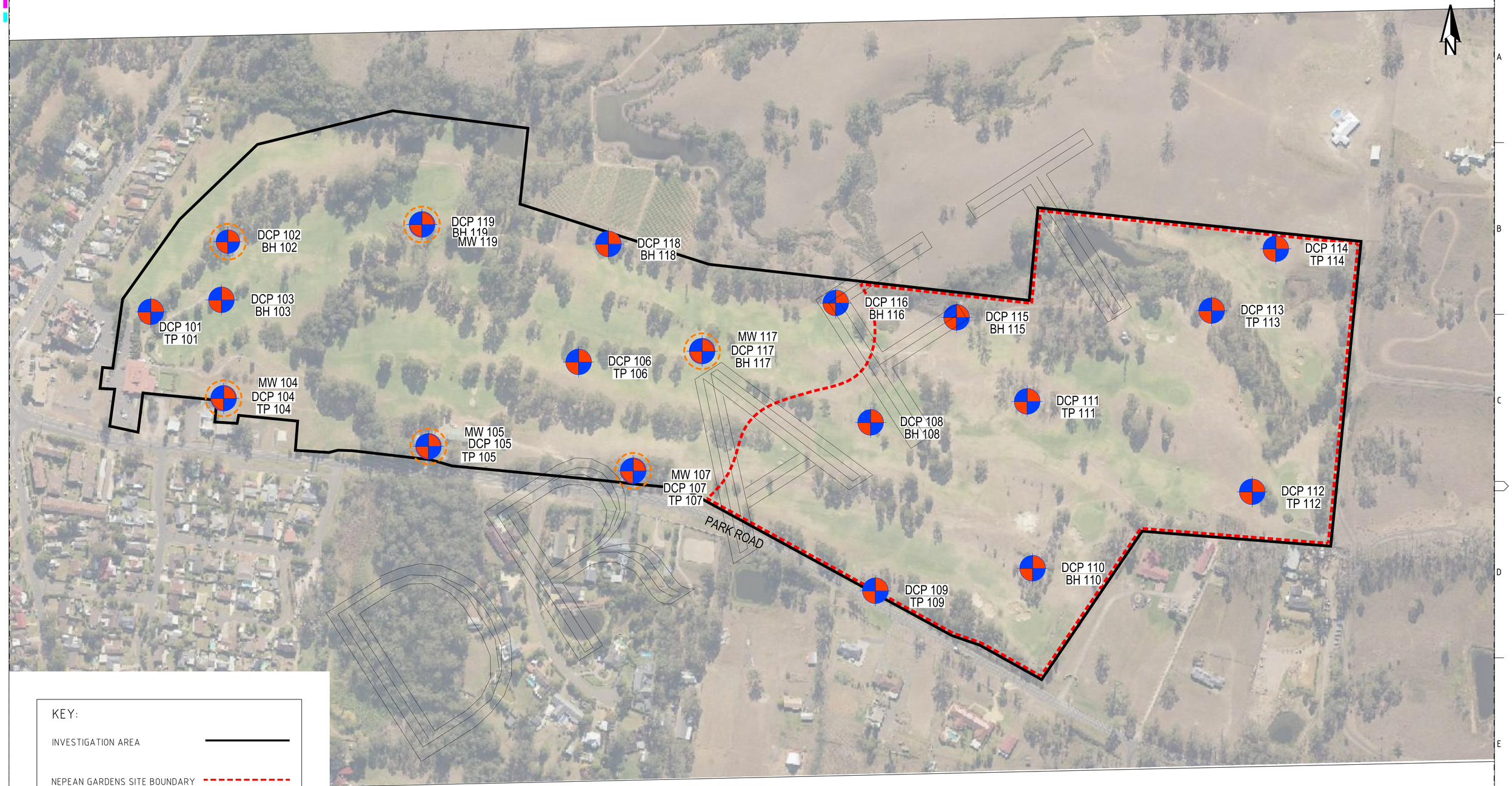
DRAWING ID: P1706171-PS02-R01-A000



KEY:

INVESTIGATION AREA

NEPEAN GARDENS SITE BOUNDARY

GROUNDWATER MONITORING WELL

INDICATIVE MA BORE HOLE / DCP / TEST PIT LOCATION

SOURCE:
DOUGLAS PARTNERS, PROJECT 76652.01 (JUNE 2017)

DEVELOPMENT APPLICATION

REV	DESCRIPTION	DATE	DRAWN	DESIGNED	CHECKED	APPRVD
A	INITIAL RELEASE	26/09/2019	GM	CGL	CGL	GT

SCALE
0 20 40 60 80 100 120 140 160 180 200 METRES
A1 (A3) 1:2,000 (1:4,000)

GRID	DATUM	PROJECT MANAGER
MGA	mAHD	GT

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CLIENT
CATHOLIC METRO. CEMETERIES TR.

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DRAWING TITLE
GEOTECHNICAL SITE INVESTIGATION LOCATIONS (AERIAL IMAGE)

PROJECT NO.	PLANSET NO.	RELEASE NO.	DRAWING NO.	REVISION
P1706171	PS02	R01	PS02-J100	A

DRAWING ID: P1706171-PS02-R01-J100

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SCALE: 0 10 20 30 40 50 60 70 80 90 100 METRES
A1 (A3) 1:1,000 (1:2,000)

GRID: MGA
DATUM: mAHD
PROJECT MANAGER: GT

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DRAWING TITLE: GEOTECHNICAL SITE INVESTIGATION LOCATIONS (CONTOUR SURVEY)

PROJECT NO.	PLANSET NO.	RELEASE NO.	DRAWING NO.	REVISION
P1706171	PS02	R01	PS02-J101	A

DRAWING ID: P1706171-PS02-R01-J101

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DCP 116
BH 116

DCP 115
BH 115

DCP 114
TP 114

DCP 113
TP 113

MW 117
DCP 117
BH 117

DCP 111
TP 111

DCP 108
BH 108

DCP 112
TP 112

PARK ROAD

DCP 110
BH 110

DCP 109
TP 109

D.P.404562

KEY:

LUDDENHAM (LU)
EROSIONAL LANDSCAPE UNIT WITH DEEP, STONY SOIL AND LOW WATER HOLDING CAPACITY.

INVESTIGATION AREA

NEPEAN GARDENS SITE BOUNDARY

NOTE:
SOIL LANDSCAPE SERIES FROM NSW OFFICE OF ENVIRONMENT AND HERITAGE, PENRITH 1: 100,000 SOIL LANDSCAPE SERIES.

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SCALE
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DRAWING TITLE
INDICATIVE SOIL LANDSCAPE UNITS

PROJECT NO.	PLANSET NO.	RELEASE NO.	DRAWING NO.	REVISION
P1706171	PS02	R01	PS02-J102	A

DRAWING ID: P1706171-PS02-R01-J102

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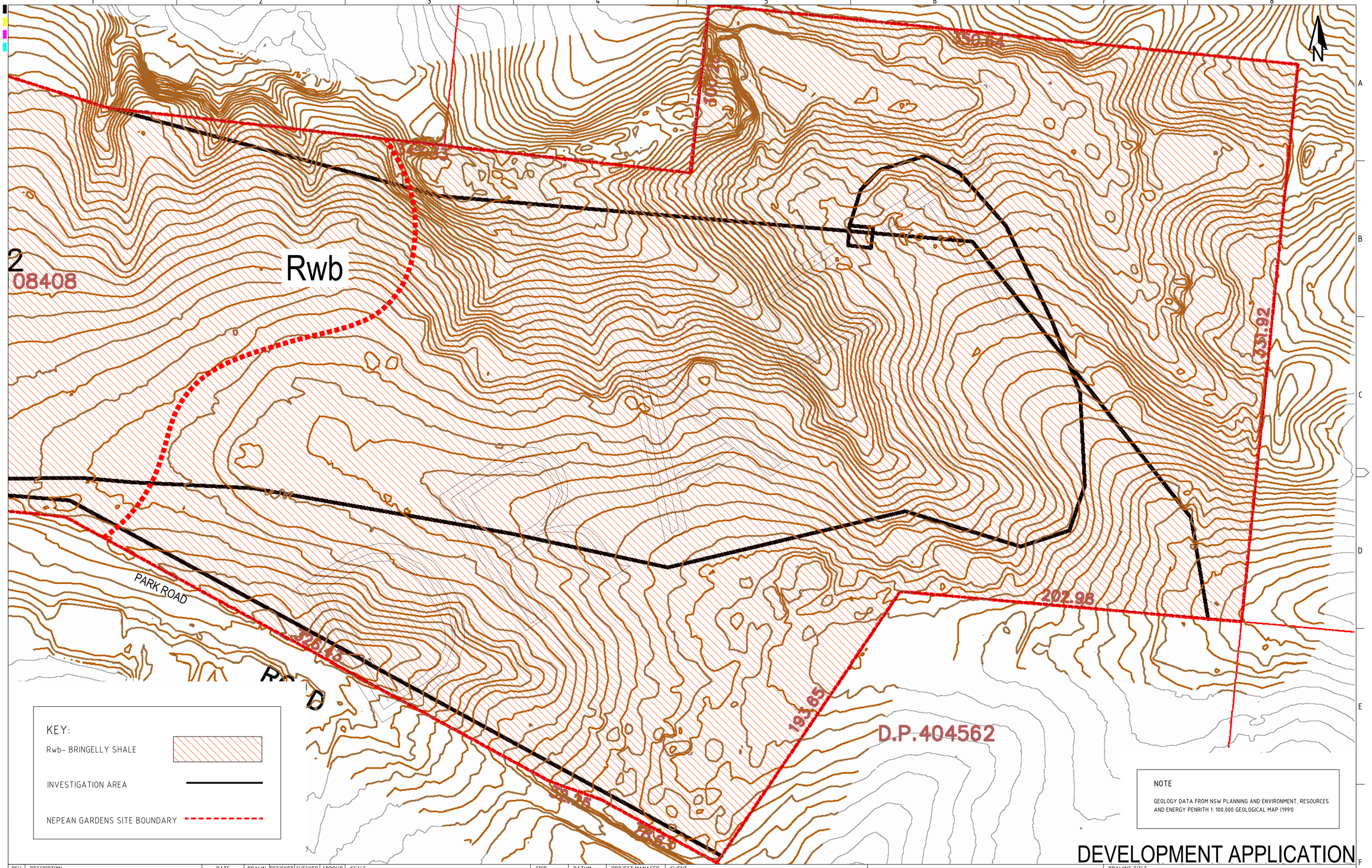

DEVELOPMENT APPLICATION

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A	INITIAL RELEASE	26/09/2019	GM	CGL	CGL	GT

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GRID	DATUM	PROJECT MANAGER
MGA	mAHD	GT

CLIENT: CATHOLIC METRO. CEMETERIES TR.

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DRAWING ID: P1706171-PS02-R01-J103

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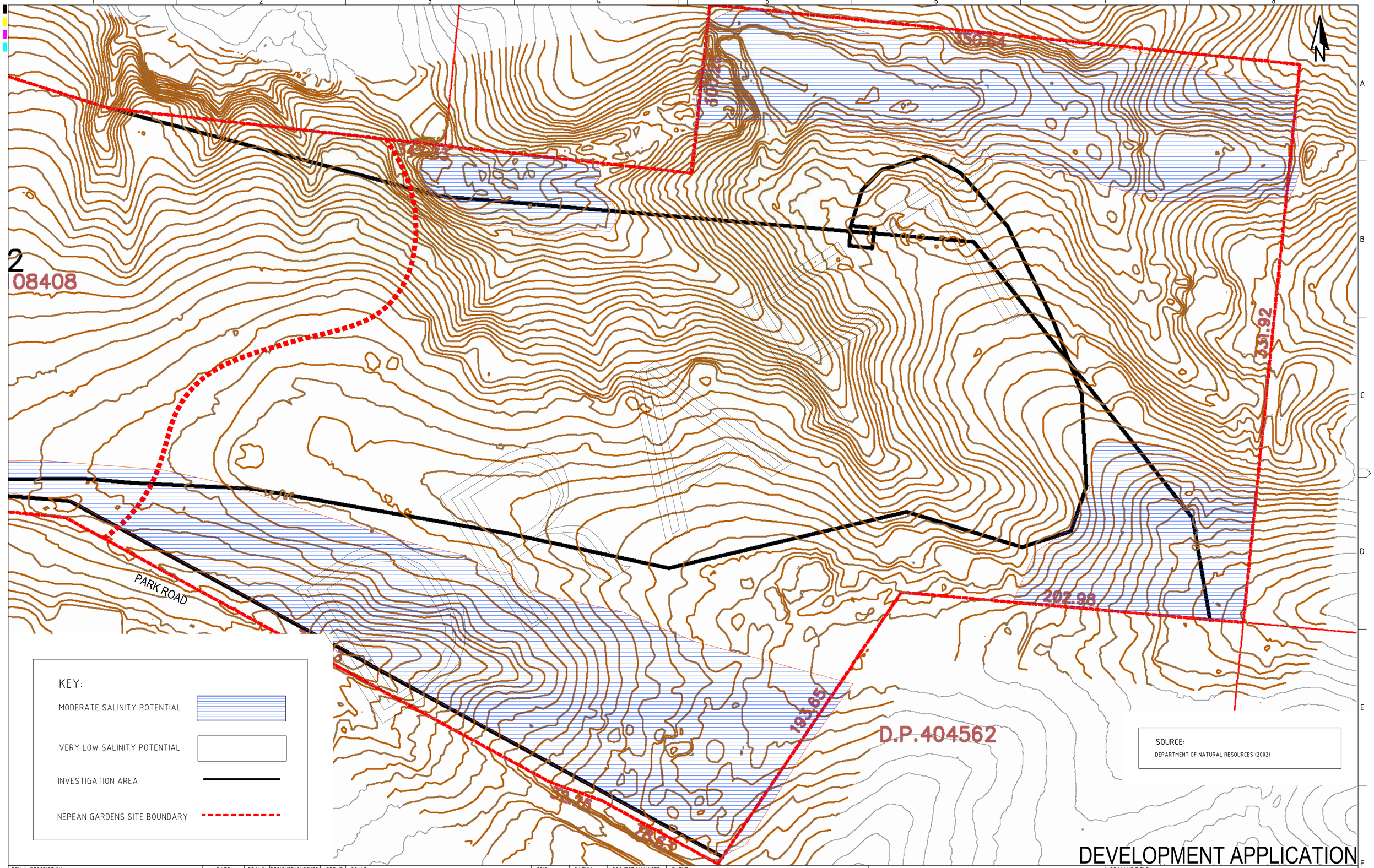

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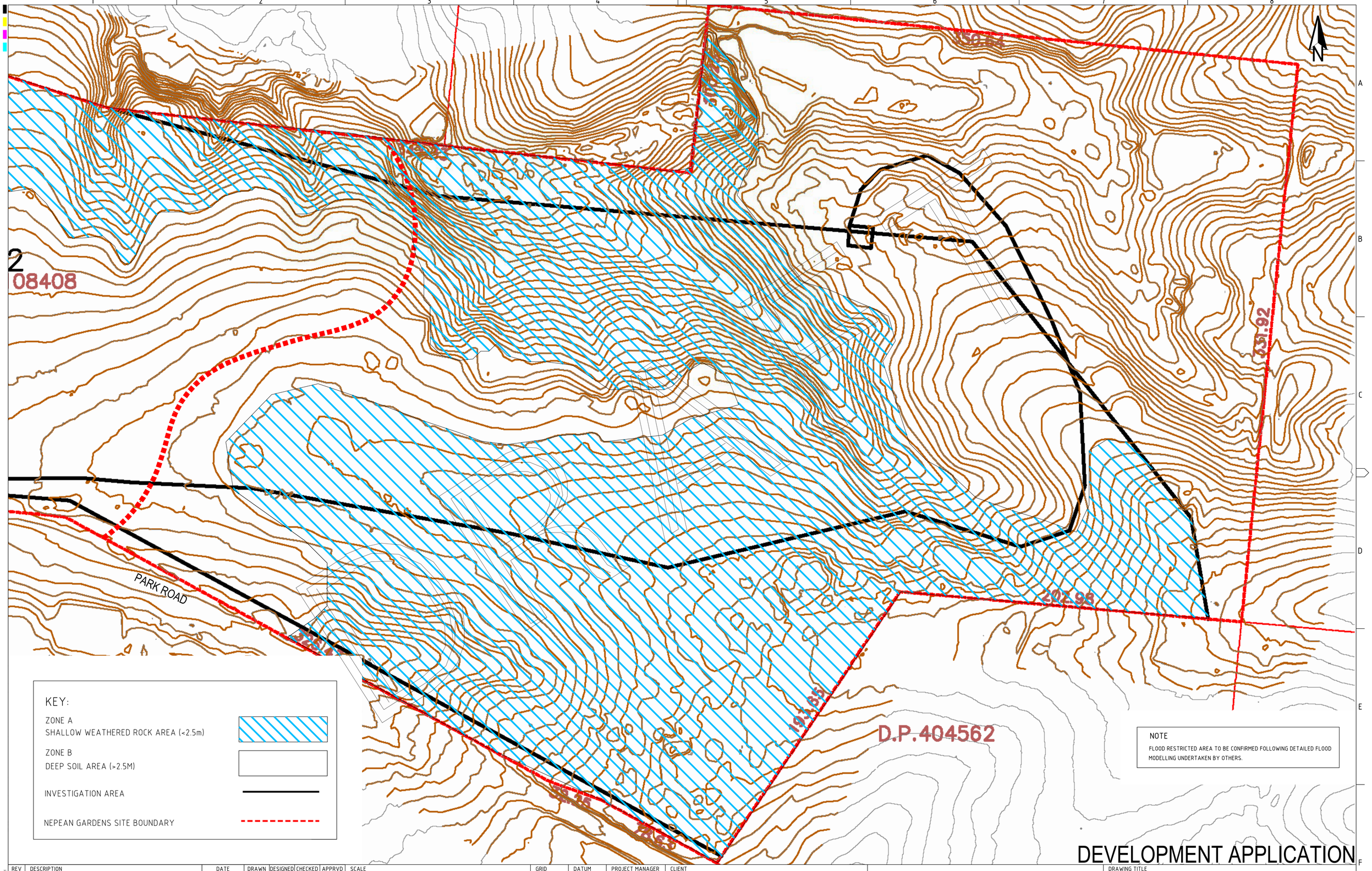

REV	DESCRIPTION	DATE	DRAWN	DESIGNED	CHECKED	APPRVD
A	INITIAL RELEASE	26/09/2019	GM	CGL	CGL	GT

SCALE: 0 10 20 30 40 50 60 70 80 90 100 METRES
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DRAWING TITLE: INDICATIVE SOIL PROFILE ZONE

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P1706171	PS02	R01	PS02-J105	A

DRAWING ID: P1706171-PS02-R01-J105

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A1 / A3 LANDSCAPE (A1LC_v02.0.01)

11 Attachment B – Borehole, Groundwater monitoring well and Test pit logs

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH102**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	40 m	DATUM AHD
EXCAVATION DIMENSIONS		Ø75 mm x 5.50 m depth	NORTHING		ASPECT	Northeast	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V				40.00				ML	TOPSOIL: SILT, low liquid limit, brown, with some clay, trace gravel.	D	VSt	TOPSOIL
				0.60 39.40	6171/BH102/0.5/S/1 D 0.50 m			CH	Sandy CLAY, high plasticity, orange, brown.			RESIDUAL SOIL
	M		1	*1.00* 39.00	6171/BH102/1.0/S/1 D 1.00 m			CH	CLAY, high plasticity, red, grey, with some sand, trace gravel.		VSt and H	
			2	*2.00* 38.00					From 2.0 m: More grey.			
			3							M		
		22/09/2017										
		19/09/2017										
	H		4								H	
		18/09/17	5									
				5.50					Hole Terminated at 5.50 m (Target depth reached)			

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

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH103**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	44 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 4.00 m depth	NORTHING		ASPECT	Northeast	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V		Not Encountered		44.00				ML	TOPSOIL: SILT, low liquid limit, dark brown to grey, trace clay.	D	VSt	TOPSOIL
				0.30	6171/BH103/0.2/S/1 D 0.20 m							
				43.70				CH	Sandy CLAY, high plasticity, brown, with some gravel.			RESIDUAL SOIL
					6171/BH103/0.5/S/1 D 0.50 m					M	H	
			1	1.00								
				43.00	6171/BH103/1.0/S/1 D 1.00 m			CH	Gravelly CLAY, high plasticity, red, grey.			
	M			1.50							VSt	
				42.50					From 1.5 m: More red.			
			2									
			3		6171/BH103/3.0/S/1 D 3.00 m						H	
	H											
			4	4.00					Hole Terminated at 4.00 m (Target depth reached)			
			5									

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

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH108**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	55 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 1.60 m depth	NORTHING		ASPECT	North	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V		Not Encountered		55.00				ML	TOPSOIL: SILT, low liquid limit, brown, with some clay, gravel.		H	TOPSOIL
				0.30								
	M			54.70				CH	CLAY, high plasticity, grey, red, trace sand, gravel.	D	St and VSt	RESIDUAL SOIL
	H		1	*1.60*					Hole Terminated at 1.60 m (Target depth reached)		H	1.60: V-bit refusal on inferred medium strength shale.
			2									
			3									
			4									
			5									

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

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH110**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	61 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 1.40 m depth	NORTHING		ASPECT	Northeast	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V		Not Encountered		61.00				ML	TOPSOIL: SILT, low liquid limit, brown, trace clay, gravel.	D	VSt	TOPSOIL
				0.30								
	M			60.70	6171/BH110/0.5/S/1 D 0.50 m			CH	CLAY, high plasticity, grey, red, with some sand, gravel.	M	H	RESIDUAL SOIL
				1.00								
	H		1	60.00	6171/BH110/1.0/S/1 D 1.00 m				From 1.0 m: More red.			
				1.40					Hole Terminated at 1.40 m (Target depth reached)			1.40: V-bit refusal on inferred medium strength shale.
			2									
			3									
			4									
			5									

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust	COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH115**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment	LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW	GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT	4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	43 m	DATUM AHD
EXCAVATION DIMENSIONS	ø75 mm x 2.60 m depth	NORTHING		ASPECT	Northeast	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V				43.00				ML	TOPSOIL: SILT, low liquid limit, brown, trace clay, gravel.	D	VSt	TOPSOIL
				0.40	6171/BH115/0.2/S/1 D 0.20 m							
	M		1	42.60	6171/BH115/0.5/S/1 B 0.50 m 6171/BH115/0.5/S/1 D 0.50 m			CH	CLAY, high plasticity, brown, grey, trace gravel.	M	St - VSt	RESIDUAL SOIL
	H	22/09/17			6171/BH115/1.6/S/1 D 1.60 m						H	
				1.80								
AD/T	M	19/09/17	2	41.20					SHALE, dark grey, low to medium strength, distinctly weathered.			WEATHERED ROCK 1.80: V-bit refusal.
	H			*2.60*								
									Hole Terminated at 2.60 m (Target depth reached)			2.60: TC-bit refusal on inferred medium strength shale.
			3									
			4									
			5									

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH116**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	46 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 1.80 m depth	NORTHING		ASPECT	Northeast	SLOPE 8-10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V	M	Not Encountered	1	46.00	6171/BH116/0.1/S/1 D 0.10 m			ML	TOPSOIL: SILT, low liquid limit, brown, trace gravel, trace clay.	D	VSt and H	TOPSOIL
				0.50 45.50	6171/BH116/0.6/S/1 D 0.60 m			CH	CLAY, high plasticity, red, with some sand, gravel.			RESIDUAL SOIL
	H			*0.80* 45.20					From 0.8 m: More grey.	M	H	
				1.80					Hole Terminated at 1.80 m (Target depth reached)			1.80: V-bit refusal on inferred low strength shale.
			2									
			3									
			4									
			5									

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH117**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	49 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 3.10 m depth	NORTHING		ASPECT	North	SLOPE 15%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
				49.00								
	L			*0.20*				MH	TOPSOIL: Clayey SILT, high liquid limit, dark brown, trace gravel.	D		TOPSOIL
				48.80	6171/BH117/0.2/S/1 D 0.20 m			CH	CLAY, high plasticity, grey, red, trace gravel.		F	RESIDUAL SOIL
					6171/BH117/0.5/S/1 D 0.50 m						St - VSt	
			1	*1.00* 48.00					From 1.00 m: More grey.			
AD/V	M				6171/BH117/1.1/S/1 D 1.10 m						VSt	
										M	VSt - H	
			2									
				2.30 46.70					From 2.30 m: Dark grey.		H	
	H	19/09/17			6171/BH117/2.5/S/1 D 2.50 m							
				2.80 46.20					SHALE, dark grey, inferred low strength, distinctly weathered.			WEATHERED ROCK 2.80: V-bit refusal.
AD/T			3	*3.10*					Hole Terminated at 3.10 m (Target depth reached)			3.10: TC-bit refusal on inferred medium strength shale. Well and diver installed for groundwater monitoring.
			4									
			5									

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH118**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	47 m	DATUM AHD
EXCAVATION DIMENSIONS		⌀.75 mm x 5.70 m depth	NORTHING		ASPECT	Northeast	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V				47.00				ML	TOPSOIL: SILT, low liquid limit, brown, with some gravel, clay.	D		TOPSOIL
				0.40	BH118/6171/0.2/S/1 D 0.20 m							
				46.60	BH118/6171/0.5/S/1 D 0.50 m			CH	CLAY, high plasticity, red, with some gravel, sand.		VSt	RESIDUAL SOIL
			1							M		
											H	
				1.80								
AD/T	M		2	45.20					SHALE, red, very low to low strength, extremely weathered to highly weathered.			WEATHERED ROCK 1.80: V-bit refusal on inferred low strength shale.
				2.30								
			3	44.70					From 2.3 m: Grey.			
			4									
			5									
		22/09/2017 19/09/2017		*5.70*								
									Hole Terminated at 5.70 m (Target depth reached)			5.70: Borehole terminated on inferred low strength shale.

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF BH119**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	38 m	DATUM AHD
EXCAVATION DIMENSIONS		Ø75 mm x 5.50 m depth	NORTHING		ASPECT	East	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V	M			38.00				ML	TOPSOIL: SILT, low liquid limit, brown, trace gravel.	D		TOPSOIL
				0.30								
				37.70				CH	Gravelly CLAY, high plasticity, red, trace sand.			RESIDUAL SOIL
					6171/BH119/0.5/S/1 D 0.50 m							
				0.90							H - VSt	
			1	37.10					From 0.9 m: Grey, red, trace gravel.			
					6171/BH119/1.0/S/1 D 1.00 m							
					6171/BH119/1.5/S/1 D 1.50 m					M		
			2	*2.00* 36.00					From 2.0 m: More grey.		H	
				2.70								
AD/T	M	22/09/17		35.30					SHALE, grey, inferred low strength, distinctly weathered.			WEATHERED ROCK 2.70: V-bit refusal on inferred low strength shale.
			3									
		19/09/17	4									
		18/09/17	5		6171/BH119/5.0/R/1 D 5.00 m							
				5.50								
									Hole Terminated at 5.50 m (Target depth reached)			

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Engineering Log - BOREHOLE

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	22/09/2017	**REF MW102**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	40 m	DATUM AHD
EXCAVATION DIMENSIONS		Ø75 mm x 4.00 m depth	NORTHING		ASPECT	Northeast	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V				40.00				ML	TOPSOIL: SILT, low liquid limit, brown, with some clay, trace gravel.	D	VSt	TOPSOIL
				0.60 39.40				CH	Sandy CLAY, high plasticity, orange, brown.			RESIDUAL SOIL
	M		1	*1.00* 39.00				CH	CLAY, high plasticity, red, grey, with some sand, trace gravel.		VSt and H	
			2	*2.00* 38.00					From 2.0 m: More grey.	M		
	H		3								H	
		23/10/2017 10/10/2017	4	*4.00*					Hole Terminated at 4.00 m (Target depth reached)			
			5									

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Engineering Log - TEST

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	22/09/2017	**REF MW104**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	45 m	DATUM AHD
EXCAVATION DIMENSIONS		Ø75 mm x 4.00 m depth	NORTHING		ASPECT	North	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
	L			45.00				ML	TOPSOIL: SILT, low liquid limit, dark brown, with some clay.	D	St	TOPSOIL
				0.20 44.80				CH	Sandy CLAY, high plasticity, red brown, with some gravel.			RESIDUAL SOIL
	M		1								VSt and H	
AD/V			2	*2.00* 43.00					From 2.0 m: Red and grey.	M		
		29/09/2017 10/10/2017 23/10/2017										
	H		3								H	
			4	*4.00*					Hole Terminated at 4.00 m (Target depth reached)			
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	22/09/2017	**REF MW105**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	45 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 3.00 m depth	NORTHING		ASPECT	North	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
				45.00				ML	FILL: SILT, with fine sand, light brown, concrete rubble (<20mm).	D		FILL
	M			*1.00*								
AD/V		Not Encountered	1	44.00				CH	CLAY, high plasticity, red brown, trace silt.	M	H	RESIDUAL SOIL
	H		2									
			3	*3.00*					Hole Terminated at 3.00 m (Target depth reached)			
			4									
			5									

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Engineering Log - TEST

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	22/09/2017	**REF MW107**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	53 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 3.00 m depth	NORTHING		ASPECT	North	SLOPE 5%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V		Not Encountered		53.00				ML	TOPSOIL: SILT, low liquid limit, brown.	D		TOPSOIL
				0.20								
				52.80				CH	CLAY, high plasticity, red with grey mottled, with some gravel.		VSt	RESIDUAL SOIL
	M		1	*1.00* 52.00					Grey and red.	M		
			2								H	
	H		3	*3.00*					Hole Terminated at 3.00 m (Target depth reached)			
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	18/09/2017	**REF MW117**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	49 m	DATUM AHD
EXCAVATION DIMENSIONS		ø75 mm x 3.00 m depth	NORTHING		ASPECT	North	SLOPE 15%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
	L			49.00				MH	TOPSOIL: Clayey SILT, high liquid limit, dark brown, trace gravel.	D		TOPSOIL
				0.20								
				48.80				CH	CLAY, high plasticity, grey, red, trace gravel.		F	RESIDUAL SOIL
											St - VSt	
				1.00								
			1	48.00					From 1.00 m: More grey.			
AD/V	M										VSt	
		23/10/17								M		
											VSt - H	
		10/10/2017 29/09/2017	2									
				2.30								
				46.70					From 2.30 m: Dark grey.		H	
	H											
				2.80								
AD/T				46.20					SHALE, dark grey, inferred low strength, distinctly weathered.			WEATHERED ROCK 2.80: V-bit refusal.
				3.00								
			3						Hole Terminated at 3.00 m (Target depth reached)			3.00: TC-bit refusal on inferred medium strength shale. Well and diver installed for groundwater monitoring.
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	22/09/2017	COMPLETED	22/09/2017	**REF MW119**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		4WD ute-mounted hydraulic dril rig	EASTING		RL SURFACE	38 m	DATUM AHD
EXCAVATION DIMENSIONS		Ø75 mm x 4.00 m depth	NORTHING		ASPECT	East	SLOPE 10%

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/V	M	Not Encountered	0	38.00				ML	TOPSOIL:SILT, low liquid limit, brown, trace gravel.	D		TOPSOIL
				0.30								
				37.70				CH	Gravelly CLAY, high plasticity, red, trace sand.			RESIDUAL SOIL
				0.90							H - VSt	
			1	37.10					From 0.9 m: Grey, red, trace gravel.	M		
				2.00								
			2	36.00					From 2.0 m: More grey.		H	
				2.70								
AD/T				35.30					SHALE, grey, inferred low strength, distinctly weathered.			WEATHERED ROCK 2.70: V-bit refusal on inferred low strength shale.
			3									
				4.00								
			4						Hole Terminated at 4.00 m (Target depth reached)			
			5									

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Engineering Log - TEST

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP101**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	49 m	DATUM AHD
EXCAVATION DIMENSIONS		3.50 m depth	NORTHING		ASPECT	Northeast	SLOPE 8%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E		Not Encountered		49.00	6171/TP10/0.1/S/1 D 0.10 m			SM	FILL: Silty SAND, with trace clay, dark brown, brick, concrete, sandstone, fine to medium gravels.	D	St	FILL
				0.40 48.60	6171/TP10/0.5/S/1 D 0.50 m			CH	Silty CLAY, high plasticity, brown/red, fine to medium gravels.		St - VSt	RESIDUAL SOIL
	M		1								VSt - H	
				1.50 47.50	6171/TP10/1.5/S/1 D 1.50 m			CH	CLAY, high plasticity, red/brown, with grey mottled, trace silt.			
			2	*2.00* 47.00					From 2.0 m: More grey at depth.	M		
				2.50 46.50					From 2.5 m: Some claystone gravels.		H	
	H		3	*3.50*								
									Hole Terminated at 3.50 m (Target depth reached)			
			4									
			5									

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

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Engineering Log - TEST PIT

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP104**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	45 m	DATUM AHD
EXCAVATION DIMENSIONS		0.60 m depth	NORTHING		ASPECT	North	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
	L	Not Encountered		45.00				ML	TOPSOIL: SILT, low liquid limit, dark brown, with some clay.	D	St	TOPSOIL
				0.20								
E	M			44.80				CH	Sandy CLAY, high plasticity, red brown, with some gravel.	M	VSt and H	RESIDUAL SOIL
				0.60								
									Hole Terminated at 0.60 m Terminated due to water pipe encountered			

1
2
3
4
5

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Engineering Log - TEST PIT

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP105**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	45 m	DATUM AHD
EXCAVATION DIMENSIONS		1.80 m depth	NORTHING		ASPECT	North	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered	1	45.00	6171/TP105/0.1/S/1 D 0.10 m			ML	FILL: SILT with fine sand, light brown, concrete rubble, (<200mm).			FILL
				0.40 44.60	6171/TP105/0.5/S/1 D 0.50 m			ML	FILL: SILT with trace clay, red/brown, fine to medium sandstone and ironstone gravels, (50mm).	D	H	
				1.00 44.00	6171/TP105/1.2/S/1 D 1.20 m			CH	CLAY, with trace silt, high plasticity, red/brown.			RESIDUAL SOIL
	H			*1.40* 43.60	6171/TP105/1.5/S/1 D 1.50 m			CH	CLAY, high plasticity, grey with red mottled, medium shale gravels.	M		
			2	*1.80*					Hole Terminated at 1.80 m Terminated on weathered rock.			
			3									
			4									
			5									

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Engineering Log - TEST PIT

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP106**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	49 m	DATUM AHD
EXCAVATION DIMENSIONS		0.90 m depth	NORTHING		ASPECT	East	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered		49.00	6171/TP106/0.1/S/1 D 0.10 m			ML	TOPSOIL: SILT, low liquid limit, brown, organic materials, tree roots.	D		TOPSOIL
				0.30 48.70	6171/TP106/0.4/S/1 D 0.40 m			CH	CLAY, high plasticity, red with grey, fine to medium gravels, ironstone.	M	H	RESIDUAL SOIL
				0.70 48.30	6171/TP106/0.8/S/1 D 0.80 m				From 0.7 m: More grey, possibly extremely weathered rock.			
			1	*0.90*					Hole Terminated at 0.90 m Terminated on weathered rock.			
			2									
			3									
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP107**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	53 m	DATUM AHD
EXCAVATION DIMENSIONS		2.50 m depth	NORTHING		ASPECT	North	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E				53.00				ML	TOPSOIL: SILT, low liquid limit, brown, organic materials, roots.	D		TOPSOIL
				0.20	6171/TP107/0.1/S/1 D 0.10 m							
				52.80				CH	CLAY, high plasticity, red with grey mottled, fine to medium gravels.			RESIDUAL SOIL
					6171/TP107/0.4/S/1 D 0.40 m						VSt	
	M	Not Encountered	1	*1.00* 52.00					From 1.0 m: Grey and red.	M		
			2								H	
	H				6171/TP107/2.2/S/1 D 2.20 m							2.20: Shards of weathered rock.
				2.50					Hole Terminated at 2.50 m Terminated on weathered rock.			
			3									
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP109**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	52 m	DATUM AHD
EXCAVATION DIMENSIONS		1.20 m depth	NORTHING		ASPECT	North	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered		52.00				ML	TOPSOIL: SILT, low liquid limit, light brown, organic materials, (tree roots), fine to medium gravels.	D	VSt - H	TOPSOIL
				0.20 51.80	6171/TP109/0.1/S/1 D 0.10 m			CI	CLAY, medium plasticity, red with grey, fine to medium shale gravels.			RESIDUAL SOIL
					6171/TP109/0.4/S/1 D 0.40 m							
				0.60 51.40				CI	CLAY, medium plasticity, grey with red, organic materials (tree roots).	M	H	
			1		6171/TP109/1.0/S/1 D 1.00 m							
				1.20					Hole Terminated at 1.20 m Terminated on weathered rock.			
			2									
			3									
			4									
			5									

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Engineering Log - TEST PIT

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP111**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	55 m	DATUM AHD
EXCAVATION DIMENSIONS		2.20 m depth	NORTHING		ASPECT	West	SLOPE 10%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered	1	55.00	6171/TP111/0.1/S/1 D 0.10 m			ML	TOPSOIL: SILT, low liquid limit, light brown, fine gravels.	D		TOPSOIL
				0.20 54.80				CH	CLAY, high plasticity, red with grey mottled, fine to medium gravels.			RESIDUAL SOIL
					6171/TP111/0.4/S/1 D 0.40 m						VSt - H	
	M			*0.80* 54.20					From 0.8 m: Grey.			
				1.50 53.50	6171/TP111/1.5/S/1 D 1.50 m				From 1.5 m: Some extremely weathered shale gravels.	M	H	
	H		2	*2.20*								
									Hole Terminated at 2.20 m Terminated on weathered rock.			
			3									
			4									
			5									

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Engineering Log - TEST PIT

CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP112**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	62 m	DATUM AHD
EXCAVATION DIMENSIONS		2.20 m depth	NORTHING		ASPECT	West	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered	1	62.00				ML	TOPSOIL: SILT, low liquid limit, light brown, fine to medium gravels.	D		TOPSOIL
				0.20	6171/TP112/0.1/S/1 D 0.10 m							
				61.80				CH	CLAY, high plasticity, red with grey, fine gravels.			RESIDUAL SOIL
					6171/TP112/0.4/S/1 D 0.40 m						VSt	
				0.90								
				61.10					From 0.9 m: Grey with mottled red.	M		
	H		2		6171/TP112/2.0/S/1 D 2.00 m						H	
				2.20					Hole Terminated at 2.20 m Terminated on weathered rock.			
			3									
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP113**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	56 m	DATUM AHD
EXCAVATION DIMENSIONS		3.50 m depth	NORTHING		ASPECT	West	SLOPE 10%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered	0	56.00	6171/TP113/0.1/S/1 D 0.10 m			ML	TOPSOIL: SILT, low liquid limit, light brown, fine gravels.	D		TOPSOIL
				0.30								
				55.70				CH	CLAY, high plasticity, red with grey, fine gravels.		VSt	RESIDUAL SOIL
			1		6171/TP113/0.5/S/1 D 0.50 m						VSt - H	
			2							M		
			3								H	
	H			*3.30*					From 3.3 m: Trace of weathered shale gravels.			
				52.70								
				3.50					Hole Terminated at 3.50 m Terminated on weathered rock.			
			4									
			5									

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CLIENT	Catholic Metropolitan Cemeteries Trust		COMMENCED	18/09/2017	COMPLETED	18/09/2017	**REF TP114**
PROJECT	Prelim. geotechnical, groundwater & salinity assessment		LOGGED	OT	CHECKED	RE	Sheet 1 OF 1
SITE	Proposed Cemetery, Wallacia, NSW		GEOLOGY	Bringelly Shale	VEGETATION	Grass	PROJECT NO. P1706171
EQUIPMENT		Excavator	EASTING		RL SURFACE	56 m	DATUM AHD
EXCAVATION DIMENSIONS		2.50 m depth	NORTHING		ASPECT	North	SLOPE 5%

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E	M	Not Encountered	1	56.00	6171/TP114/0.1/S/1 D 0.10 m			ML	TOPSOIL: SILT, low liquid limit, light brown, fine gravels.	D	VSt	TOPSOIL
				0.30 55.70				CH	CLAY, high plasticity, red with trace grey, medium gravels.			RESIDUAL SOIL
				0.60 55.40	6171/TP114/0.5/S/1 D 0.50 m				From 0.6 m: Grey.		St - VSt	
	H		2		6171/TP114/2.0/S/1 D 2.00 m						H	
				2.30 53.70					From 2.3: Trace of weathered shale gravels.			
			3	*2.50*					Hole Terminated at 2.50 m Terminated on weathered rock.			
			4									
			5									

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Engineering Log - TEST PIT

12 Attachment C – DCP log

Dynamic Cone Penetrometer Test Log Summary

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Site	Proposed Wallacia Cemetery, NSW	**DCP Group Reference**	P1706171JS01V01
Client	Catholic Metropolitan Cemeteries Trust	**Log Date**	18.09.2017
Logged by	OT	**Sheet**	1 of 3
Checked by	RE		
Comments	DCP cone tip penetrated 50 mm into soil prior to testing.		

TEST DATA

Depth Interval (m)	DCP101	DCP102	DCP103	DCP104	DCP105	DCP106	DCP107	
0.15	8	18	8	5	17	26	22	
0.30	6	12	17	16	30 + +	19	15	
0.45	4	14	18	12	30 + +	17	16	
0.60	7	25	18	10	Terminated due to high 'N' counts	27	17	
0.75	10	22	14	11		30 + +	11	
0.90	17	10	8	15		30 + +	13	
1.05	19	13	9	11		Terminated due to high 'N' counts	17	
1.20	19	20	10	16			22	
1.35	18	21	10	10			25	
1.50	20	21	11	15			23	
1.65	27	30 + +	15	20			30 + +	
1.80	30 + +	Terminated due to high 'N' counts	30 / 130 mm	24			Terminated due to high 'N' counts	
1.95	Terminated due to high 'N' counts		Double bounce at 1.83 mBGL	27				
2.10				30 + +				
2.25				Terminated due to high 'N' counts				
2.40								
2.55								
2.70								
2.85								
3.00								

Dynamic Cone Penetrometer Test Log Summary

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Site	Proposed Wallacia Cemetery, NSW	**DCP Group Reference**	P1706171JS01V01
Client	Catholic Metropolitan Cemeteries Trust	**Log Date**	18.09.2017
Logged by	OT	**Sheet**	2 of 3
Checked by	RE		
Comments	DCP cone tip penetrated 50 mm into soil prior to testing.		

TEST DATA

Depth Interval (m)	DCP108	DCP109	DCP110	DCP111	DCP112	DCP113	DCP114	
0.15	13	19	15	18	14	15	15	
0.30	13	19	22	18	10	17	14	
0.45	9	23	25	20	13	16	11	
0.60	6	21	20	14	17	13	8	
0.75	7	22	20	14	14	14	8	
0.90	6	22	18	16	12	20	8	
1.05	8	29	26	12	9	21	9	
1.20	27	30 + +	30 + +	12	21	16	29	
1.35	30 + +	Terminated due to high 'N' counts	Terminated due to high 'N' counts	30 + +	30 + +	21	22	
1.50	Terminated due to high 'N' counts			Terminated due to high 'N' counts	Terminated due to high 'N' counts	18	30 + +	
1.65						19	Terminated due to high 'N' counts	
1.80						26		
1.95						26		
2.10						29		
2.25						30 + +		
2.40						Terminated due to high 'N' counts		
2.55								
2.70								
2.85								
3.00								

Dynamic Cone Penetrometer Test Log Summary

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Site	Proposed Wallacia Cemetery, NSW	**DCP Group Reference**	P1706171JS01V01
Client	Catholic Metropolitan Cemeteries Trust	**Log Date**	18.09.2017
Logged by	OT	**Sheet**	3 of 3
Checked by	RE		
Comments	DCP cone tip penetrated 50 mm into soil prior to testing.		

TEST DATA

Depth Interval (m)	DCP115	DCP116	DCP117	DCP118	DCP119			
0.15	18	22	2	11	25			
0.30	11	18	3	7	44			
0.45	11	12	3	8	27			
0.60	8	12	6	15	14			
0.75	10	19	8	13	13			
0.90	6	36	7	15	10			
1.05	7	27	5	17	10			
1.20	8	20	13	25	12			
1.35	10	21	15	7 / 5 mm	11			
1.50	30 + +	10 / 50 mm	19	Double bounce at 1.25 mBGL	15			
1.65	Terminated due to high 'N' counts	Double bounce at 1.45 mBGL	23		13			
1.80			17		26			
1.95			16		30 / 100 mm			
2.10			36 / 100 mm		Double bounce at 1.95 mBGL			
2.25			Double bounce at 2.1 mBGL					
2.40								
2.55								
2.70								
2.85								
3.00								

13 Attachment D – Laboratory Test Certificates

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Fax:** (02) 9674 7755 | **Email:** info@resourcelab.com.au

Test Report

Customer: Martens & Associates Pty Ltd
Job number: 17-0093
Project: P1706171
Report number: 1
Location: Engineering Services: Proposed Cemetery - Wallacia, NSW
Page: 1 of 1

California Bearing Ratio

Sampling method: Samples tested as received
Test method(s): AS 1289.1.1, 2.1.1, 5.1.1, 6.1.1

	Results			
Laboratory sample no.	12732	12733	12734	
Customer sample no.	6171/TP106/ CBR:0.2-0.7m	6171/TP109/ CBR:0.2-0.7m	6171/TP112/ CBR:0.2-0.7m	
Date sampled	18/09/2017	18/09/2017	18/09/2017	
Material description	CLAY, mottled red/grey/yellow-brown	CLAY, red mottled yellow-brown/grey	CLAY, mottled red/grey	
Maximum dry density (t/m^3)	1.62	1.58	1.64	
Optimum moisture content (%)	21.5	23.7	20.5	
Field moisture content (%)	n/a	n/a	n/a	
Oversize retained on 19.0mm sieve (%)	1	1	0	
Minimum curing time (hours)	168	96	168	
Dry density before soak (t/m^3)	1.59	1.55	1.60	
Dry density after soak (t/m^3)	1.52	1.50	1.56	
Moisture content before soak (%)	21.1	23.4	21.0	
Moisture content after soak (%)	26.0	27.8	24.3	
Moisture content after test - top 30mm (%)	33.1	30.4	27.9	
Moisture content after test - remaining depth (%)	23.6	26.4	23.3	
Density ratio before soaking (%)	98.0	98.0	97.5	
Moisture ratio before soaking (%)	98.0	99.0	102.5	
Period of soaking (days)	4	4	4	
Compactive effort	Standard	Standard	Standard	
Mass of surcharge applied (kg)	4.5	4.5	4.5	
Swell after soaking (%)	5.0	3.5	2.5	
Penetration (mm)	5.0	2.5	5.0	
CBR Value (%)	**1.0**	**2.5**	**2.5**	

Notes: Specified LDR: 98 ±1%

Method of establishing plasticity level - Visual / tactile

Approved Signatory:  E. Maldonado **Date:** 04/10/2017

NATA ACCREDITED FOR TECHNICAL COMPETENCE
Accredited for compliance with ISO/IEC 17025.

NATA Accredited Laboratory Number: **17062**

resource laboratories
AGGREGATE, ROCK, AND SOIL TESTING
ABN: 25 131 532 020
Sydney: 12/1 Boden Road Seven Hills NSW 2147 | PO Box 45 Pendle Hill NSW 2145
Ph: (02) 9674 7711 | **Fax:** (02) 9674 7755 | **Email:** info@resourcelab.com.au

Test Report

Customer: Martens & Associates Pty Ltd
Job number: 17-0093
Project: P1706171
Report number: 2
Location: Engineering Services: Proposed Cemetery - Wallacia, NSW
Page: 1 of 1

Soil Index Properties

Sampling method: Samples tested as received
Test method(s): AS 1289.1.1, 2.1.1, 3.1.2, 3.2.1, 3.3.1 .3.4.1

	Results				
Laboratory sample no.	12766	12767	12768	12769	
Customer sample no.	6171/BH111/0.5m	6171/BH115/0.5m	6171/BH108/1.5m	6171/BH110/0.5m	
Date sampled	18/09/2017	18/09/2017	18/09/2017	18/09/2017	
Material description	CLAY, trace of gravel, mottled red/brown/grey	CLAY, trace of gravel, brown mottled grey	CLAY, brown mottled grey	CLAY, trace of gravel, mottled brown/grey	
Liquid limit (%)	70	53	41	64	
Plastic limit (%)	19	15	15	16	
Plasticity index (%)	51	38	26	48	
Linear shrinkage (%)	16.5	15.5	11.0	16.5	
Cracking / Curling / Crumbling	-	-	-	Curling	
Sample history	Air dried	Air dried	Air dried	Air dried	
Preparation	Dry sieved	Dry sieved	Dry sieved	Dry sieved	

Approved Signatory: E. Maldonado **Date:** 11/10/2017

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025.

NATA Accredited Laboratory Number: **17062**

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 177001

Client Details

Client	Martens & Associates Pty Ltd
Attention	Orson Thien
Address	Suite 201, 20 George St, Hornsby, NSW, 2077

Sample Details

Your Reference	**P1706171JCOC04V01**
Number of Samples	2 Water
Date samples received	04/10/2017
Date completed instructions received	04/10/2017

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	11/10/2017
Date of Issue	11/10/2017

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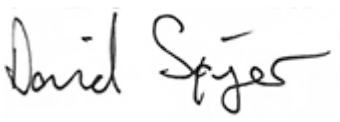
Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Long Pham, Team Leader, Metals
Nick Sarlamis, Inorganics Supervisor

Authorised By



David Springer, General Manager

Miscellaneous Inorganics			
Our Reference		177001-1	177001-2
Your Reference	UNITS	6171/BH104	6171/BH117
Date Sampled		29/09/2017	29/09/2017
Type of sample		Water	Water
Date prepared	-	04/10/2017	04/10/2017
Date analysed	-	04/10/2017	04/10/2017
pH	pH Units	6.9	6.8
Electrical Conductivity	µS/cm	3,800	8,500
Sulphate, SO4	mg/L	37	1,200
TKN in water	mg/L	1.3	4.4
BOD	mg/L	<5	<5
NOx as N in water	mg/L	0.2	0.1

Metals in Waters - Total			
Our Reference		177001-1	177001-2
Your Reference	UNITS	6171/BH104	6171/BH117
Date Sampled		29/09/2017	29/09/2017
Type of sample		Water	Water
Date prepared	-	05/10/2017	05/10/2017
Date analysed	-	06/10/2017	06/10/2017
Phosphorus - Total	mg/L	0.1	0.8

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25°C in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-055	Nitrate - determined colourimetrically. Soils are analysed following a water extraction.
Inorg-062	TKN - determined colourimetrically based on APHA latest edition 4500 Norg. Alternatively, TKN can be derived from calculation (Total N - NOx).
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.
Inorg-091	BOD - Analysed in accordance with APHA latest edition 5210 D and in house INORG-091.
Metals-020	Determination of various metals by ICP-AES.

QUALITY CONTROL: Miscellaneous Inorganics						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			04/10/2017	[NT]	[NT]	[NT]	[NT]	04/10/2017	[NT]
Date analysed	-			04/10/2017	[NT]	[NT]	[NT]	[NT]	04/10/2017	[NT]
pH	pH Units		Inorg-001	[NT]	[NT]	[NT]	[NT]	[NT]	99	[NT]
Electrical Conductivity	µS/cm	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Sulphate, SO4	mg/L	1	Inorg-081	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
TKN in water	mg/L	0.1	Inorg-062	<0.1	[NT]	[NT]	[NT]	[NT]	103	[NT]
BOD	mg/L	5	Inorg-091	<5	[NT]	[NT]	[NT]	[NT]	85	[NT]
NOx as N in water	mg/L	0.005	Inorg-055	<0.005	[NT]	[NT]	[NT]	[NT]	105	[NT]

QUALITY CONTROL: Metals in Waters - Total						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-W1	[NT]
Date prepared	-			05/10/2017	[NT]	[NT]	[NT]	[NT]	05/10/2017	[NT]
Date analysed	-			06/10/2017	[NT]	[NT]	[NT]	[NT]	06/10/2017	[NT]
Phosphorus - Total	mg/L	0.05	Metals-020	<0.05	[NT]	[NT]	[NT]	[NT]	108	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
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customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 176117

Client Details

Client	Martens & Associates Pty Ltd
Attention	Orson Thien
Address	Suite 201, 20 George St, Hornsby, NSW, 2077

Sample Details

Your Reference	**P1706171COC02V01**
Number of Samples	30 soils
Date samples received	21/09/2017
Date completed instructions received	21/09/2017

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	28/09/2017
Date of Issue	26/09/2017

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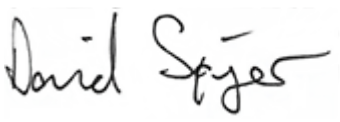
Results Approved By
Priya Samarawickrama, Senior Chemist

Authorised By



David Springer, General Manager

Misc Inorg - Soil						
Our Reference		176117-1	176117-2	176117-3	176117-4	176117-5
Your Reference	UNITS	6171/TP111/0.4/S/01	6171/TP107/0.1/S/01	6171/TP112/0.4/S/01	6171/TP114/2.0/S/01	6171/TP105/1.5/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	5.6	5.8	5.0	4.9	5.1
Electrical Conductivity 1:5 soil:water	µS/cm	28	36	160	460	34
Sulphate, SO4 1:5 soil:water	mg/kg	30	<10	160	130	<10

Misc Inorg - Soil						
Our Reference		176117-6	176117-7	176117-8	176117-9	176117-10
Your Reference	UNITS	6171/TP106/0.8/S/01	6171/TP105/0.5/S/01	6171/TP107/2.2/S/01	6171/TP109/1.0/S/01	6171/TP111/1.5/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	5.0	5.3	4.7	4.7	7.5
Electrical Conductivity 1:5 soil:water	µS/cm	140	36	350	530	270
Sulphate, SO4 1:5 soil:water	mg/kg	26	36	100	110	<10

Misc Inorg - Soil						
Our Reference		176117-11	176117-12	176117-13	176117-14	176117-15
Your Reference	UNITS	6171/TP112/2.0/S/01	6171/TP113/0.1/S/01	6171/TP101/0.5/S/01	6171/TP113/2.0/S/01	6171/TP101/1.5/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	4.8	5.6	5.8	5.1	5.7
Electrical Conductivity 1:5 soil:water	µS/cm	790	34	59	100	47
Sulphate, SO4 1:5 soil:water	mg/kg	490	20	91	27	27

Misc Inorg - Soil						
Our Reference		176117-16	176117-17	176117-18	176117-19	176117-20
Your Reference	UNITS	6171/BH115/0.2/S/01	6171/BH110/1.0/S/01	6171/BH117/0.2/S/01	6171/BH117/0.5/S/01	6171/BH103/3.0/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	6.4	5.3	5.5	5.0	4.7
Electrical Conductivity 1:5 soil:water	µS/cm	120	120	74	170	330
Sulphate, SO4 1:5 soil:water	mg/kg	10	78	33	49	<10

Misc Inorg - Soil						
Our Reference		176117-21	176117-22	176117-23	176117-24	176117-25
Your Reference	UNITS	6171/BH116/0.1/S/01	6171/BH102/1.0/S/01	6171/BH103/1.0/S/01	6171/BH117/1.0/S/01	6171/BH118/0.5/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	6.0	5.6	5.1	5.1	5.2
Electrical Conductivity 1:5 soil:water	µS/cm	29	66	290	190	58
Sulphate, SO4 1:5 soil:water	mg/kg	<10	<10	<10	59	30

Misc Inorg - Soil						
Our Reference		176117-26	176117-27	176117-28	176117-29	176117-30
Your Reference	UNITS	6171/BH119/1.5/S/01	6171/BH102/0.5/S/01	6171/BH115/1.6/S/01	6171/BH101/1.3/S/01	6171/BH115/0.5/S/01
Date Sampled		18/09/2017	18/09/2017	18/09/2017	18/09/2017	18/09/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
Date analysed	-	22/09/2017	22/09/2017	22/09/2017	22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units	5.3	5.7	6.6	6.0	5.7
Electrical Conductivity 1:5 soil:water	µS/cm	120	22	510	200	1,300
Sulphate, SO4 1:5 soil:water	mg/kg	24	<10	100	190	190

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25°C in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.

QUALITY CONTROL: Misc Inorg - Soil						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	176117-2
Date prepared	-			22/09/2017	1	22/09/2017	22/09/2017		22/09/2017	22/09/2017
Date analysed	-			22/09/2017	1	22/09/2017	22/09/2017		22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	1	5.6	5.5	2	100	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	1	28	30	7	97	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	1	30	34	12	100	89

QUALITY CONTROL: Misc Inorg - Soil						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-2	176117-22
Date prepared	-			[NT]	11	22/09/2017	22/09/2017		22/09/2017	22/09/2017
Date analysed	-			[NT]	11	22/09/2017	22/09/2017		22/09/2017	22/09/2017
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	11	4.8	4.5	6	101	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	[NT]	11	790	810	2	98	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	[NT]	11	490	530	8	110	91

QUALITY CONTROL: Misc Inorg - Soil						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	[NT]	[NT]
Date prepared	-			[NT]	21	22/09/2017	22/09/2017		[NT]	[NT]
Date analysed	-			[NT]	21	22/09/2017	22/09/2017		[NT]	[NT]
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	21	6.0	6.1	2	[NT]	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	[NT]	21	29	30	3	[NT]	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	[NT]	21	<10	<10	0	[NT]	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
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Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

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Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

14 Attachment E – General Geotechnical Recommendations

Geotechnical Recommendations

Important Recommendations About Your Site (1 of 2)

These general geotechnical recommendations have been prepared by Martens to help you deliver a safe work site, to comply with your obligations, and to deliver your project. Not all are necessarily relevant to this report but are included as general reference. Any specific recommendations made in the report will override these recommendations.

Batter Slopes

Excavations in soil and extremely low to very low strength rock exceeding 0.75 m depth should be battered back at grades of no greater than 1 Vertical (V) : 2 Horizontal (H) for temporary slopes (unsupported for less than 1 month) and 1 V : 3 H for longer term unsupported slopes.

Vertical excavation may be carried out in medium or higher strength rock, where encountered, subject to inspection and confirmation by a geotechnical engineer. Long term and short term unsupported batters should be protected against erosion and rock weathering due to, for example, stormwater run-off.

Batter angles may need to be revised depending on the presence of bedding partings or adversely oriented joints in the exposed rock, and are subject to on-site inspection and confirmation by a geotechnical engineer. Unsupported excavations deeper than 1.0 m should be assessed by a geotechnical engineer for slope instability risk.

Any excavated rock faces should be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete, is required.

Earthworks

Earthworks should be carried out following removal of any unsuitable materials and in accordance with AS3798 (2007). A qualified geotechnical engineer should inspect the condition of prepared surfaces to assess suitability as foundation for future fill placement or load application.

Earthworks inspections and compliance testing should be carried out in accordance with Sections 5 and 8 of AS3798 (2007), with testing to be carried out by a National Association of Testing Authorities (NATA) accredited testing laboratory.

Excavations

All excavation work should be completed with reference to the *Work Health and Safety (Excavation Work) Code of Practice (2015)*, by Safe Work Australia. Excavations into rock may be undertaken as follows:

1. Extremely low to low strength rock - conventional hydraulic earthmoving equipment.

2. Medium strength or stronger rock - hydraulic earthmoving equipment with rock hammer or ripping tyne attachment.

Exposed rock faces and loose boulders should be monitored to assess risk of block / boulder movement, particularly as a result of excavation vibrations.

Fill

Subject to any specific recommendations provided in this report, any fill imported to site is to comprise approved material with maximum particle size of two thirds the final layer thickness. Fill should be placed in horizontal layers of not more than 300 mm loose thickness, however, the layer thickness should be appropriate for the adopted compaction plant.

Foundations

All exposed foundations should be inspected by a geotechnical engineer prior to footing construction to confirm encountered conditions satisfy design assumptions and that the base of all excavations is free from loose or softened material and water. Water that has ponded in the base of excavations and any resultant softened material is to be removed prior to footing construction.

Footings should be constructed with minimal delay following excavation. If a delay in construction is anticipated, we recommend placing a concrete blinding layer of at least 50 mm thickness in shallow footings or mass concrete in piers / piles to protect exposed foundations.

A geotechnical engineer should confirm any design bearing capacity values, by further assessment during construction, as necessary.

Shoring - Anchors

Where there is a requirement for either soil or rock anchors, or soil nailing, and these structures penetrate past a property boundary, appropriate permission from the adjoining land owner must be obtained prior to the installation of these structures.

Shoring - Permanent

Permanent shoring techniques may be used as an alternative to temporary shoring. The design of such structures should be in accordance with the findings of this report and any further testing recommended by this report. Permanent shoring may include [but not be limited to] reinforced block work walls, contiguous and semi contiguous pile walls, secant pile walls and soldier pile walls with or without reinforced shotcrete infill panels. The choice of shoring system will depend on the type of structure, project budget and site specific geotechnical conditions.

Permanent shoring systems are to be engineer designed and backfilled with suitable granular

material and free-draining drainage material. Backfill should be placed in maximum 100 mm thick layers compacted using a hand operated compactor. Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls.

Shoring design should consider any surcharge loading from sloping / raised ground behind shoring structures, live loads, new structures, construction equipment, backfill compaction and static water pressures. All shoring systems shall be provided with adequate foundation designs.

Suitable drainage measures, such as geotextile enclosed 100 mm agricultural pipes embedded in free-draining gravel, should be included to redirect water that may collect behind the shoring structure to a suitable discharge point.

Shoring - Temporary

In the absence of providing acceptable excavation batters, excavations should be supported by suitably designed and installed temporary shoring / retaining structures to limit lateral deflection of excavation faces and associated ground surface settlements.

Soil Erosion Control

Removal of any soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in any formal stormwater drainage system, on neighbouring land and in receiving waters. Where possible, this may be achieved by one or more of the following means:

1. Maintain vegetation where possible
2. Disturb minimal areas during excavation
3. Revegetate disturbed areas if possible

All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods in accordance with Landcom (2004) shall be required.

Trafficability and Access

Consideration should be given to the impact of the proposed works and site subsurface conditions on trafficability within the site e.g. wet clay soils will lead to poor trafficability by tyred plant or vehicles.

Where site access is likely to be affected by any site works, construction staging should be organised such that any impacts on adequate access are minimised as best as possible.

Vibration Management

Where excavation is to be extended into medium or higher strength rock, care will be required when using a rock hammer to limit potential structural distress from excavation-induced vibrations where nearby structures may be affected by the works.

To limit vibrations, we recommend limiting rock hammer size and set frequency, and setting the hammer parallel to bedding planes and along defect planes, where possible, or as advised by a geotechnical engineer. We recommend limiting vibration peak particle velocities (PPV) caused by construction equipment or resulting from excavation at the site to 5 mm/s (AS 2187.2, 2006, Appendix J).

Waste – Spoil and Water

Soil to be disposed off-site should be classified in accordance with the relevant State Authority guidelines and requirements.

Any collected waste stormwater or groundwater should also be tested prior to discharge to ensure contaminant levels (where applicable) are appropriate for the nominated discharge location.

MA can complete the necessary classification and testing if required. Time allowance should be made for such testing in the construction program.

Water Management - Groundwater

If the proposed works are likely to intersect ephemeral or permanent groundwater levels, the management of any potential acid soil drainage should be considered. If groundwater tables are likely to be lowered, this should be further discussed with the relevant State Government Agency.

Water Management – Surface Water

All surface runoff should be diverted away from excavation areas during construction works and prevented from accumulating in areas surrounding any retaining structures, footings or the base of excavations.

Any collected surface water should be discharged into a suitable Council approved drainage system and not adversely impact downslope surface and subsurface conditions.

All site discharges should be passed through a filter material prior to release. Sump and pump methods will generally be suitable for collection and removal of accumulated surface water within any excavations.

Contingency Plan

In the event that proposed development works cause an adverse impact on geotechnical hazards, overall site stability or adjacent properties, the following actions are to be undertaken:

1. Works shall cease immediately.
2. The nature of the impact shall be documented and the reason(s) for the adverse impact investigated.
3. A qualified geotechnical engineer should be consulted to provide further advice in relation to the issue.

15 Attachment F – Notes About This Report

Information

Important Information About Your Report (1 of 2)

These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all are necessarily relevant to all reports but are included as general reference.

Engineering Reports - Limitations

The recommendations presented in this report are based on limited investigations and include specific issues to be addressed during various phases of the project. If the recommendations presented in this report are not implemented in full, the general recommendations may become inapplicable and Martens & Associates accept no responsibility whatsoever for the performance of the works undertaken.

Occasionally, sub-surface conditions between and below the completed boreholes or other tests may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact Martens & Associates.

Relative ground surface levels at borehole locations may not be accurate and should be verified by on-site survey.

Engineering Reports – Project Specific Criteria

Engineering reports are prepared by qualified personnel. They are based on 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 (e.g. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (e.g. 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, which 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 not consulted.

Engineering Reports – Recommendations

Your report is based on the assumption that site conditions, as may be revealed through selective point sampling, are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced. 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 investigations 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.

Martens 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 a site assessment and 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), desktop studies 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 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 in relation 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 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 logged 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, Martens will be pleased to assist with investigation or providing 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 / assessment.

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, Martens 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 Martens report, retain Martens to work with other project professionals 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 – Geo-environmental 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 Martens' proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geo-environmental 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

Geo-environmental 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 recognise 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 relates. 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.

Soil Data

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 typically based on Australian Standard 1726 and the Unified Soil Classification System (USCS) – refer Soil Data Explanation of Terms (2 of 3). In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

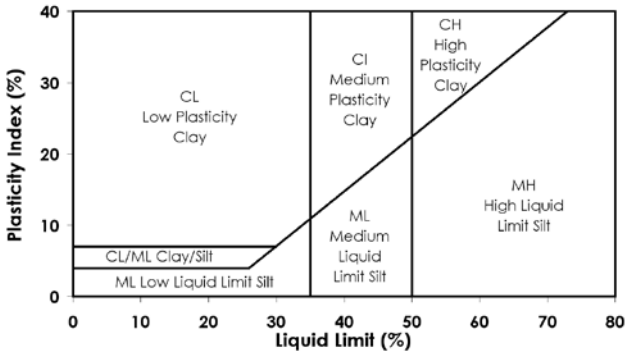
Particle Size

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

Division	Subdivision	Size (mm)
BOULDERS		>200
COBBLES		63 to 200
GRAVEL	Coarse	20 to 63
	Medium	6 to 20
	Fine	2.36 to 6
SAND	Coarse	0.6 to 2.36
	Medium	0.2 to 0.6
	Fine	0.075 to 0.2
SILT		0.002 to 0.075
CLAY		< 0.002

Plasticity Properties

Plasticity properties of cohesive soils can be assessed in the field by tactile properties or by laboratory procedures.



Moisture Condition

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and damp and is darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

Term	C_u (kPa)	Approx. SPT "N"	Field Guide
Very Soft	<12	2	A finger can be pushed well into the soil with little effort. Sample extrudes between fingers when squeezed in fist.
Soft	12 - 25	2 – 4	A finger can be pushed into the soil to about 25mm depth. Easily moulded in fingers.
Firm	25 - 50	4 – 8	The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong pressure in the figures.
Stiff	50 - 100	8 – 15	The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers.
Very Stiff	100 - 200	15 – 30	The surface of the soil can be marked, but not indented with thumb pressure. Difficult to cut with a knife. Thumbnail can readily indent.
Hard	> 200	> 30	The surface of the soil can be marked only with the thumbnail. Brittle. Tends to break into fragments.
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 standard penetration test (SPT) or Dutch cone penetrometer test (CPT) results as below:

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

* Values may be subject to corrections for overburden pressures and equipment type.

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. Soil properties little or no different to general properties of primary component.	Coarse grained soils: < 5 % Fine grained soils: < 15 %
With some	Presence easily detectable by feel or eye. Soil properties little different to general properties of primary component.	Coarse grained soils: 5 – 12 % Fine grained soils: 15 – 30 %

Soil Data

Explanation of Terms (2 of 3)

martens consulting engineers

Symbols for Soils and Other

SOILS


COBBLES/BOULDERS


GRAVEL (GP OR GW)


SILTY GRAVEL (GM)


CLAYEY GRAVEL (GC)


SAND (SP OR SW)


SILTY SAND (SM)


CLAYEY SAND (SC)


SILT (ML OR MH)


ORGANIC SILT (OH)


CLAY (CL, CI OR CH)


SILTY CLAY


SANDY CLAY


PEAT


TOPSOIL

OTHER


FILL


TALUS


ASPHALT


CONCRETE

Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					USCS	Primary Name
COARSE GRAINED SOILS More than 50 % of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm.	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Gravel
				Predominantly one size or a range of sizes with more intermediate sizes missing	GP	Gravel
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	Silty Gravel
				Plastic fines (for identification procedures see CL below)	GC	Clayey Gravel
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of intermediate sizes missing.	SW	Sand
				Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Sand
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM	Silty Sand
				Plastic fines (for identification procedures see CL below)	SC	Clayey Sand

FINE GRAINED SOILS More than 50 % of material less than 63 mm is smaller than 0.075 mm	IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
	DRY STRENGTH (Crushing Characteristics)	DILATANCY	TOUGHNESS	DESCRIPTION	USCS	Primary Name
	None to Low	Quick to Slow	None	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Silt
	Medium to High	None	Medium	Inorganic clays of low to medium plasticity [1], gravely clays, sandy clays, silty clays, lean clays	CL [2]	Clay
	Low to Medium	Slow to Very Slow	Low	Organic slits and organic silty clays of low plasticity	OL	Organic Silt
	Low to Medium	Slow to Very Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	Silt
	High	None	High	Inorganic clays of high plasticity, fat clays	CH	Clay
	Medium to High	None	Low to Medium	Organic clays of medium to high plasticity	OH	Organic Silt
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	Peat

Notes:

1. Low Plasticity – Liquid Limit W_L < 35 % Medium Plasticity – Liquid limit W_L 35 to 60 % High Plasticity - Liquid limit W_L > 60 %.
2. CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

Soil Data

Explanation of Terms (3 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
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

Rock Data

Explanation of Terms (1 of 2)

Symbols for Rock

SEDIMENTARY ROCK


BRECCIA


CONGLOMERATE


CONGLOMERATIC SANDSTONE


SANDSTONE/QUARTZITE


SILTSTONE


MUDSTONE/CLAYSTONE


SHALE


COAL


LIMESTONE


LITHIC TUFF

IGNEOUS ROCK


GRANITE


DOLERITE/BASALT

METAMORPHIC ROCK


SLATE, PHYLLITE, SCHIST


GNEISS


METASANDSTONE


METASILTSTONE


METAMUDSTONE

Definitions

Descriptive terms used for Rock by Martens are based on AS1726 and encompass rock substance, defects and mass.

Rock Substance In geotechnical engineering terms, rock substance is any naturally occurring aggregate of minerals and organic matter which cannot 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 of decline in rock structure and grain property and can be determined in the field.

Term	Symbol	Definition
Residual soil[1]	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[1]	EW	Rock substance affected by weathering to the extent that the rock exhibits soil properties - i.e. 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[2]	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[2]	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

Notes:
1 Rs and EW material is described using soil descriptive terms.
2. The term "Distinctly Weathered" (DW) may be used to cover the range of substance weathering between EW and SW

Rock Strength

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

Term	Is (50) MPa	Field Guide	Symbol
Very low	>0.03 ≤0.1	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VL
Low	>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.	L
Medium	>0.3 ≤1.0	A piece of core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	M
High	>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.	H
Very high	>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.	VH
Extremely high	>10	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	EH

Rock Data

Explanation of Terms (2 of 2)

Degree of Fracturing

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

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

Rock Core Recovery

TCR = Total Core Recovery

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\%$$

SCR = Solid Core Recovery

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\%$$

RQD = Rock Quality Designation

$$= \frac{\sum \text{Axial lengths of core} > 100\text{ mm long}}{\text{Length of core run}} \times 100\%$$

Rock Strength Tests

▼ Point load strength Index (Is50) - axial test (MPa)

▶ Point load strength Index (Is50) - diametral test (MPa)

● Unconfined compressive strength (UCS) (MPa)

Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)

BP	Bedding plane parting
FL	Foliation
CL	Cleavage
JT	Joint
FC	Fracture
SZ/SS	Sheared zone/ seam (Fault)
CZ/CS	Crushed zone/ seam
DZ/DS	Decomposed zone/ seam
FZ	Fractured Zone
IS	Infilled seam
VN	Vein
CO	Contact
HB	Handling break
DB	Drilling break

Planarity

Pl	Planar
Cu	Curved
Un	Undulating
St	Stepped
Ir	Irregular
Dis	Discontinuous

Roughness

Pol	Polished
Sl	Slickensided
Sm	Smooth
Ro	Rough
VR	Very rough

Thickness

Zone	> 100 mm
Seam	> 2 mm < 100 mm
Plane	< 2 mm

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Vnr	Veneer
Fe	Iron Oxide
X	Carbonaceous
Qz	Quartzite
MU	Unidentified mineral

Inclination

Inclination of defect is measured from perpendicular to and down the core axis.
Direction of defect is measured clockwise (looking down core) from magnetic north.

Test, Drill and Excavation Methods

Explanation of Terms (1 of 3)

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 or excavation 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 sampling tube, e.g. U_{50} (50 mm internal diameter thin walled tube), into 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 / Excavation Methods

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

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

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

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils and, if it is safe to descend into the pit, collection of bulk disturbed samples. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

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

Continuous Sample Drilling (Push Tube) - the hole is advanced by pushing a 50 - 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength *etc.* is only marginally affected.

Continuous Spiral Flight Augers - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

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

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

In-situ Testing and Interpretation

Cone Penetrometer Testing (CPT)

Cone penetrometer testing (sometimes referred to as Dutch Cone) described in this report has been carried out using an electrical friction cone penetrometer.

The test is described in AS 1289.6.5.1-1999 (R2013). In the test, a 35 mm 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 a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the push rod centre to an amplifier and recorder unit mounted on the control truck. As penetration occurs (at a rate of approximately 20 mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records. The information provided on the charts comprises:

(i) Cone resistance (q_c) - the actual end bearing force divided by the cross sectional area of the cone, expressed in MPa.

(ii) Sleeve friction (q_f) - the frictional force of the sleeve divided by the surface area, expressed in kPa.

(iii) 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:

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6)\ N \text{ (blows/300 mm)}$$

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.

Standard Penetration Testing (SPT)

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 1289.6.3.1-2004. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm penetration depth increments and the 'N' value is taken as the number of blows for the last two 150 mm depth increments (300 mm total penetration). In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued. The test results are reported in the following form:

(i) Where full 450 mm penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7 blows:

as 4, 6, 7
N = 13

(ii) 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 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

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 (PSP) - a 16 mm diameter flat ended rod is driven with a 9 kg hammer, dropping 600 mm. The test, described in AS 1289.6.3.3-1997 (R2013), was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

Cone penetrometer (DCP) - sometimes known as the Scala Penetrometer, a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm. The test, described in AS 1289.6.3.2-1997 (R2013), was developed initially for pavement sub-grade investigations, with correlations of the test results with California Bearing Ratio published by various Road Authorities.

Pocket Penetrometers

The pocket (hand) penetrometer (PP) is typically a light weight spring hand operated device with a stainless steel loading piston, used to estimate unconfined compressive strength, q_u, (UCS in kPa) of a fine grained soil in field conditions. In use, the free end of the piston is pressed into the soil at a uniform penetration rate until a line, engraved near the piston tip, reaches the soil surface level. The reading is taken from a gradation scale, which is attached to the piston via a built-in spring mechanism and calibrated to kilograms per square centimetre (kPa) UCS. The UCS measurements are used to evaluate consistency of the soil in the field moisture condition. The results may be used to assess the undrained shear strength, C_u, of fine grained soil using the approximate relationship:

$$q_u = 2 \times C_u.$$

It should be noted that accuracy of the results may be influenced by condition variations at selected test surfaces. Also, the readings obtained from the PP test are based on a small area of penetration and could give misleading results. They should not replace laboratory test results. The use of the results from this test is typically limited to an assessment of consistency of the soil in the field and not used directly for design of foundations.

Test Pit / Borehole Logs

Test pit / borehole log(s) presented herein are an engineering and / or geological interpretation of the subsurface conditions. Their reliability will depend to some extent on frequency of sampling and methods 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 test pit / borehole logs 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 test pits / boreholes, the frequency of sampling and the possibility of other than 'straight line' variation between the test pits / boreholes.

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.

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.

Test, Drill and Excavation Methods

Explanation of Terms (3 of 3)

DRILLING / EXCAVATION METHOD

HA	Hand Auger	RD	Rotary Blade or Drag Bit	NQ	Diamond Core - 47 mm
AD/V	Auger Drilling with V-bit	RT	Rotary Tricone bit	NMLC	Diamond Core – 51.9 mm
AD/T	Auger Drilling with TC-Bit	RAB	Rotary Air Blast	HQ	Diamond Core – 63.5 mm
AS	Auger Screwing	RC	Reverse Circulation	HMLC	Diamond Core – 63.5 mm
HSA	Hollow Stem Auger	CT	Cable Tool Rig	DT	Diatube Coring
S	Excavated by Hand Spade	PT	Push Tube	NDD	Non-destructive digging
BH	Tractor Mounted Backhoe	PC	Percussion	PQ	Diamond Core - 83 mm
JET	Jetting	E	Tracked Hydraulic Excavator	X	Existing Excavation

SUPPORT

Nil	No support	S	Shotcrete	RB	Rock Bolt
C	Casing	Sh	Shoring	SN	Soil Nail
WB	Wash bore with Blade or Bailer	WR	Wash bore with Roller	T	Timbering

WATER

▽ Water level at date shown ◁ Partial water loss

▷ Water inflow ◀ Complete water loss

GROUNDWATER NOT OBSERVED (NO)	The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.
GROUNDWATER NOT ENCOUNTERED (NX)	The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

PENETRATION / EXCAVATION RESISTANCE

L	Low resistance: Rapid penetration possible with little effort from the equipment used.
M	Medium resistance: Excavation possible at an acceptable rate with moderate effort from the equipment used.
H	High resistance: Further penetration possible at slow rate & requires significant effort equipment.
R	Refusal/ Practical Refusal. No further progress possible without risk of damage/ unacceptable wear to digging implement / machine.

These assessments are subjective and dependent on many factors, including equipment power, weight, condition of excavation or drilling tools, and operator experience.

SAMPLING

D	Small disturbed sample	W	Water Sample	C	Core sample
B	Bulk disturbed sample	G	Gas Sample	CONC	Concrete Core

U63 Thin walled tube sample - number indicates nominal undisturbed sample diameter in millimetres

TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11	4,7,11 = Blows per 150mm.
N=18	'N' = Recorded blows per 300mm penetration following 150mm seating
DCP	Dynamic Cone Penetration test to AS1289.6.3.2-1997. 'n' = Recorded blows per 150mm penetration

Notes:

RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB 30/80mm	Hammer double bouncing on anvil after 80 mm penetration
N=18	Where practical refusal occurs, report blows and penetration for that interval

CPT	Static cone penetration test
CPTu	CPT with pore pressure (u) measurement
PP	Pocket penetrometer test expressed as instrument reading (kPa)
FP	Field permeability test over section noted
VS	Field vane shear test expressed as uncorrected shear strength (sv = peak value, sr = residual value)
PM	Pressuremeter test over section noted
PID	Photoionisation Detector reading in ppm
WPT	Water pressure tests

SOIL DESCRIPTION

Density		Consistency		Moisture	
VL	Very loose	VS	Very soft	D	Dry
L	Loose	S	Soft	M	Moist
MD	Medium dense	F	Firm	W	Wet
D	Dense	St	Stiff	Wp	Plastic limit
VD	Very dense	VSt	Very stiff	Wl	Liquid limit
		H	Hard		

ROCK DESCRIPTION

Strength		Weathering	
VL	Very low	EW	Extremely weathered
L	Low	HW	Highly weathered
M	Medium	MW	Moderately weathered
H	High	SW	Slightly weathered
VH	Very high	FR	Fresh
EH	Extremely high		