Douglas Partners
Geotechnics / Environment / Groundwater

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Project 86050.01
14 May 2018
R.001.Rev0
SCP:cm

Attention: Tim Dowe

Email: Tim.Dowe@smctnsw.com.au

Dear Tim Dowe

Preliminary Geotechnical Investigation
Proposed Extension of Existing Cemetery
Prince of Wales Drive, Matraville

1. Introduction

This letter report presents the results of a preliminary geotechnical investigation undertaken by Douglas Partners Pty Ltd (DP) for a proposed extension of the existing cemetery at Prince of Wales Drive, Matraville. The investigation was commissioned on behalf of the Southern Metropolitan Cemeteries Trust in an email dated 28 March 2018 by Ms Kate Ryan of Urbis Pty Ltd (Urbis), planners for the project, and was undertaken in accordance with DP proposal SYD170399 dated 15 March 2018.

The preliminary geotechnical investigation follows after an initial geotechnical desktop assessment of the site, reported in DP Report 86050.00.R.001.Rev1, dated January 2018. The investigation was undertaken to assess the geotechnical model developed in the desktop assessment, and is intended to be read in conjunction with that report.

The preliminary investigation comprised cone penetration tests and sampling and testing using hand-held equipment, followed by laboratory testing of selected samples. Test locations were limited by access and by the existing services at the site. Details of the field and laboratory work are given in this letter report.

2. Background

A preliminary contamination site investigation for the site was undertaken in March 2018, and the resulting report (Report 54725/114752 Rev0, dated 4 May 2018, by JBS&G Australia Pty Ltd (JBS&G)) was provided to DP by Urbis to assist with the current report. Test locations from that investigation have been superimposed on Drawing 1, attached.

The investigation included 15 boreholes to depths of 0.6 m to 1.1 m, and 4 test pits to depths of up to 3.1 m across the site. Rock was not encountered at test locations.

The JBS&G test locations generally encountered filling for the full depth of investigation, although natural sands were recorded below depths of 0.6 m to 2.2 m at four locations around the perimeter of the site. The filling typically comprised poorly graded, fine to medium grained silty sand filling with inclusions, typically including building rubble, metal, piping, plastic, rock and slag, while the 'natural' sands were generally medium grained. The ground conditions at JBS&G-BH10 may potentially include filling to greater depth than indicated on the logs, given the past reclamation works at the site, although likely of different origin than the upper filling.

3. Field Work

3.1 Methods

The field work for the current investigation comprised testing at ten locations, with tests including:

- Six cone penetration tests (CPTs), comprising a 35 mm diameter cone with a 130 mm long friction sleeve pushed continuously into the soil from a ballasted truck mounted test rig. Strain gauges in the cone and sleeve measure resistance to penetration. Interpretation of the results provides information on the strength and consistency of the underlying soils. The CPTs were taken to the depth of refusal.
- Four hand-augered boreholes, to visually inspect the subsurface soils, and for soil sampling. The hand augers were taken to depths of up to 1.0 m, with augering rates in the filling limited by the presence of gravelly materials and rubble.
- Four dynamic penetrometer tests (DPTs), involving driving a flat-tipped steel rod into the ground using a 9kg hammer dropping 600 mm, with the number of blows required to penetrate successive 150 mm depth increments recorded. These blow counts can then be correlated to the density or consistency of the soils.

The co-ordinates and ground surface level of test locations were determined relative to Australian Height Datum (AHD) by sub-metre GPS, and locations are shown on Drawing 1, attached.

3.2 Results

The detailed results of DP's field work, including borehole logs, interpreted CPT strata and DPT results are attached, together with relevant notes on classification terms and CPT interpretation.

The results of the fieldwork can be summarised as follows:

- **Filling** – to depths of up to 2.3 m, generally apparently moderately to well compacted; underlain by
- **Sand and Silty Sand** – generally loose and medium dense, with some very loose to loose and dense layers, to depths of up to 8.6 m; underlain by,
- **Clay, Silty Clay and Sandy Silt** – up to 1 m thick (at CPT 6 and CPT 9);

- **Inferred Bedrock –** inferred from CPT refusal (very high resistance to penetration) or excessive bending of the cone, from depths of 2.3 m to 8.6 m.

Groundwater was not observed during the investigation, although hole collapse following the withdrawal of CPT rods (with collapse at depths of up to 7.8 m) precluded observations to the full depth of testing.

4. Laboratory Tests

Four samples were obtained for laboratory testing, and sieve tests undertaken to assess the particle size distribution of the coarse grained proportion. The laboratory test results are attached, and interpolated results are summarised in Table 1.

Table 1: Summary Results of Particle Size Distribution Tests

Test Location	Depth (m)	Material	D_x, Grain size for which X% of grains are smaller (mm)			Comment
			D_{10}	D_{30}	D_{60}	
2	1.0	Filling – sand	0.18	0.28	0.35	Medium, poorly graded
4	0.25	Filling – sand	0.09	0.35	3.5	Medium to Coarse, Poorly graded
7	0.5	Sand	0.18	0.25	0.35	Medium, Poorly graded
10	0.3	Filling – gravelly sand	0.16	0.24	0.43	Fine to Medium Sand, Fine gravel Poorly graded

The above results suggest that the near-surface natural soils on the site are likely to comprise poorly graded sands. The test results of Bore 2 are considered to be relatively consistent with those of Bore 7. While the sand at Bore 2 is considered to be filling, this is due to the historical photographs, and known reclamation in the area of Bore 2. The results suggest that the reclaimed material may be similar to the natural sands in the eastern part of the site.

5. Comments

5.1 Revised Geotechnical Model

The results of the investigation are considered to be relatively consistent with the ground conditions expected from the geotechnical model based on the desktop study, although they indicate that the depth of filling at the site is generally greater than that assessed in the original models. The test results have also provided additional information on the consistency and depth of the existing soils underlying the filling.

The geotechnical model has therefore been slightly revised, to the models outlined in the following sections. Some revisions to the inferred 'areas' are shown in Drawing 1, but the model is still defined with respect to the following areas:

- **Western Area** – the area towards the western site boundary, generally below approximately RL 5 to RL 7.0 m;
- **Central Area** – the central part of the site from the southern waterfront boundary, to the northern boundary with Military Road, generally of higher level; and,
- **Eastern Area –** the eastern part of the site.

The revised models are outlined in the following sections, together with brief comment on where revisions have been made in comparison to the models previously provided in DP Report 86050.00.R.001.Rev1.

5.2 Western Area

As per the previous model, the geotechnical model of the Western Area is dominated by the land reclamation undertaken for the Port Expansion at and west of the site. The limited results of laboratory testing suggest that the reclaimed sand materials, at least at shallow depth, are likely to have been sourced from sands similar to the shallow soils in the Eastern Area.

The model has been slightly revised to consider the general absence of topsoil materials, presence of non-reclamation filling in several locations, and to provide some further detail on the consistency or density of the soils based on the results of testing.

Ground conditions in this area are expected to comprise:

- **Filling -** Sand filling with gravel, building rubble and other inclusions, absent in some areas, though present to depths of up to 1 m in others, typically comprising gravelly sand and sand soils, where present; underlain by,
  Reclamation filling, medium grained sand, to estimated depths of 2 m to 7 m, possibly with some near-surface, typically poorly compacted within 0.3 m of ground surface, then moderately and well compacted to at least 2 m depth; underlain by,
- **Sand** - Possible natural Aeolian or colluvial sands, present locally but expected to be of limited thickness; underlain by,
- **Hawkesbury Sandstone** – Likely medium and high strength, generally below approximately RL 2 , but potentially stepping up towards the Central Area as buried clifflines.

Anticipated groundwater and acid sulphate soil conditions are unchanged from our original report.

5.3 Central Area

As per the previous model, the Central Area is characterised by the presence of Hawkesbury Sandstone, which is visible in clifflines and outcrops, particularly towards the southern end of the area. The results of the field investigation have generally indicated that the depth of filling and depth to sandstone is generally greater than estimated in the desktop study, but confirm that sandstone levels are generally shallower within the Central area.

The revised geotechnical model for the Central area comprises:

- **Filling -** Sand, gravelly sand and silty sand filling with gravel, building rubble and other inclusions, generally to depths of at least 1.0 m, absent in some areas at the southern end of the area (as evidenced by outcrops and sand slopes), but to depths of more than 3.0 m in some areas, typically comprising gravelly sand and sand soils, where present; underlain by,
- **Sand -** Aeolian sand soils, generally loose and medium dense with some very loose and some dense sand bands, down to levels as deep as RL 4.5 m, with some bands of stiff and very stiff clay towards the base of the layer, up to 1 m thick;
- **Hawkesbury Sandstone** – Likely medium and high strength, with some very low strength bands. An upper layer of extremely low strength (very stiff to hard clay) to very low strength rock may be present in some areas.

The previous comments in relation to historic excavation and groundwater within the Central Area are unchanged from the earlier geotechnical model.

5.4 Eastern Area

As per the previous model, the Eastern Area is characterised by an increasing depth of soil. Following the preliminary investigation, the depth of filling is slightly greater than indicated by the previous model, and depth of soil is known with greater confidence.

The revised geotechnical model for the Eastern area comprises:

- **Filling -** Sand, gravelly sand and silty sand filling with gravel, building rubble and other inclusions, generally to depths of approximately 1.0 m, but increasing up to approximately 2 m at some locations and possibly locally deeper; underlain by,
- **Sand -** Aeolian sand soils, generally loose and medium dense with some very loose and some dense sand bands, with some bands of stiff and very stiff clay towards the base of the layer, up to 1 m thick;
- **Hawkesbury Sandstone** – Likely medium and high strength, with some very low strength bands from RL 4.5 m dipping down towards the east and south-east to RL 0.9 m (at CPT 10) and possibly deeper closer to the shoreline. An upper layer of extremely low strength (very stiff to hard clay) to very low strength rock may be present in some areas.

Measured depths of hole collapse, without any groundwater observed, suggest that long-term groundwater levels are deeper than RL 2.4 m to RL 3.4 m at the test locations in this area, although higher groundwater levels may occur.

6. General Geotechnical Issues

The revision to the geotechnical model does not significantly alter the comments in relation to geotechnical issues raised during the desktop study (Sections 4.2 to Section 4.10).

Given the results of laboratory testing, the application of Hazen's formula suggests an approximate permeability in the order of $5x10^{-4}$ m/s to $5x10^{-5}$ m/s within the sand soils at the site. The permeability of the soils may influence some of the subsurface drainage requirements for the site, but depending on the proposed development at the site.

As noted in the earlier report, further investigation will be warranted at the site, depending on the proposed development.

7. Limitations

Douglas Partners (DP) has prepared this report for this project at in accordance with DP's proposal dated 15 March 2018 and acceptance received from Urbis Pty Ltd dated 28 March 2018. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations

or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Please contact the undersigned if you have any questions on this matter.

Yours faithfully
Douglas Partners Pty Ltd

Reviewed by

Sally Peacock
Geotechnical Engineer/Associate

Michael J Thom
Principal

Attachments:
- About this Report
- Site Drawing
- Notes on Sampling Methods, Soil Descriptions, Symbols and Abbreviations
- Borehole Logs, Dynamic Penetrometer Tests
- Notes on CPT Interpretation
- CPT Results
- Laboratory Test Results

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

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

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

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements 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.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

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

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

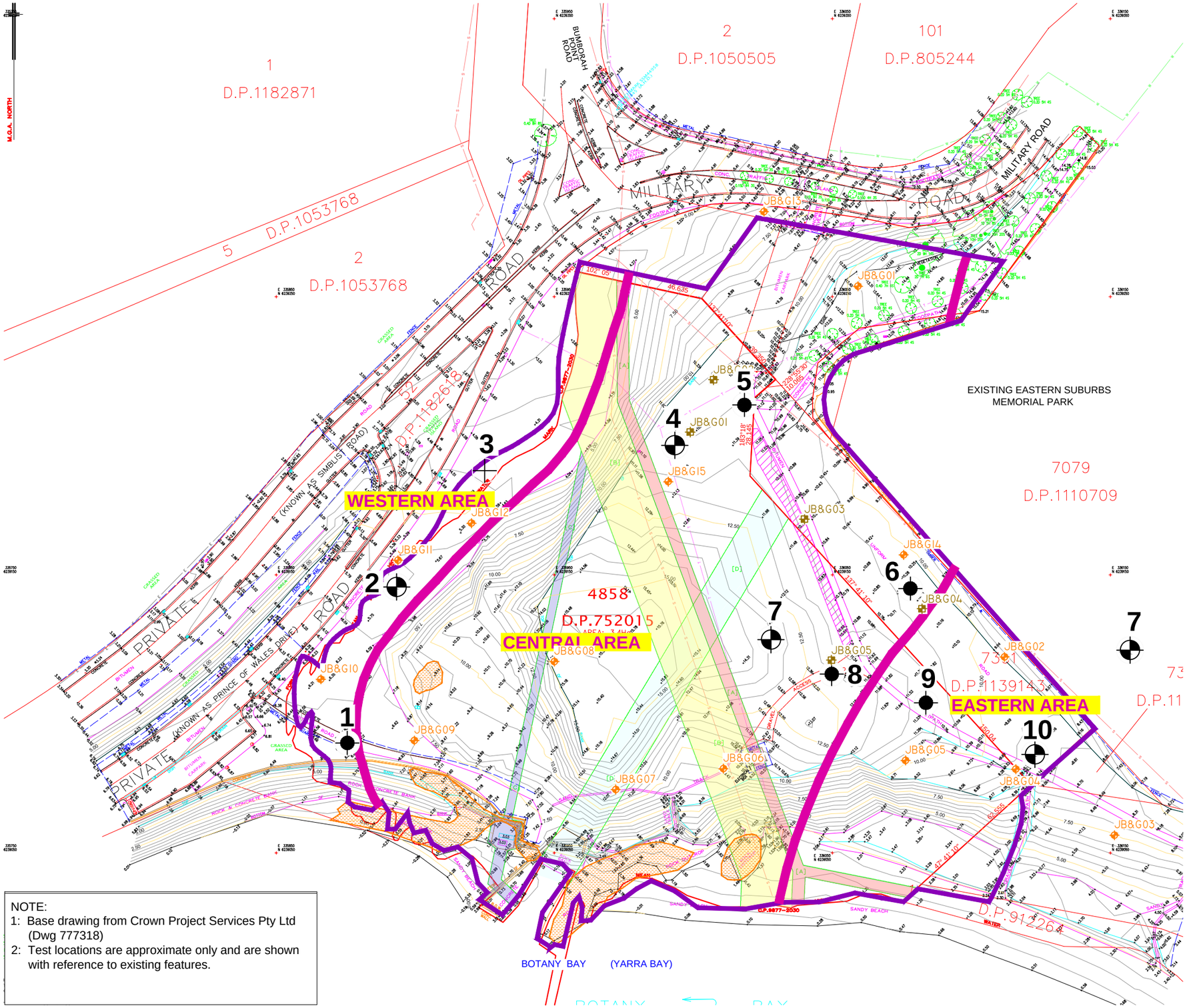
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later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

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



NOTE:
1: Base drawing from Crown Project Services Pty Ltd (Dwg 777318)
2: Test locations are approximate only and are shown with reference to existing features.

LEGEND

- Site Boundary
- Stockpile
- Sandstone outcrop
- Approximate model area boundary
- CPT location
- Shallow borehole location
- DPT location
- Envirnmental borehole (JBS&G) location
- Environmental test pit (JBS&G) location

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CLIENT: Southern Metrpolitan Cemeteries Trust		TITLE: **Test Location Plan**	PROJECT No: 86050.01
OFFICE: Sydney	DRAWN BY: PSCH	**Proposed Extension of Existing Cemetery**	DRAWING No: 1
SCALE: 1:1500 @ A3	DATE: 10.05.2018	**Prince of Wales Drive, MATRAVILLE**	REVISION: 0

Sampling

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

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

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil 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.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally 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 samples.

Continuous Spiral Flight Augers

The borehole 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 sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud 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 the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

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 increments and the 'N' value is taken as the number of blows for the last 300 mm. 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.

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

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726-1993, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Symbols & Abbreviations

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Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

- Asphalt
- Road base
- Concrete
- Filling

Soils

- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks

- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks

- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks

- Granite
- Dolerite, basalt, andesite
- Dacite, epidote
- Tuff, breccia
- Porphyry

BOREHOLE LOG

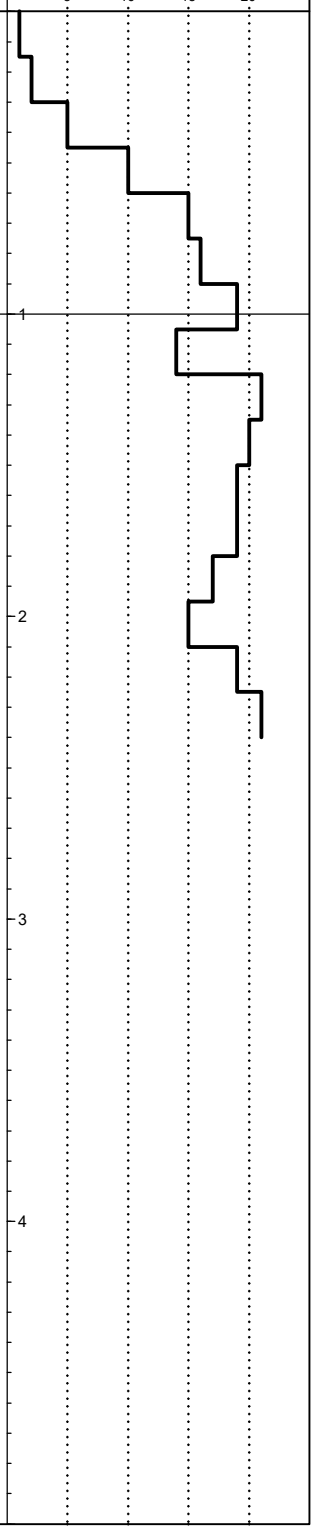
CLIENT: Southern Metropolitan Cemeteries Trust
PROJECT: Proposed Extension of Existing Cemetery
LOCATION: Prince of Wales Drive, Matraville

SURFACE LEVEL: 5.4 AHD
EASTING: 335893
NORTHING: 6239146
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 86050.01
DATE: 12/4/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILLING - light grey to light brown sub-rounded medium sand with trace shell fragments, humid		D	0.1			
				D	0.5		Water added	
	1.0	Bore discontinued at 1.0m		D	1.0		Water added	

Dynamic Penetrometer Test (blows per 150mm)



RIG: Hand tools **DRILLER:** RM **LOGGED:** RM **CASING:** None

TYPE OF BORING: Hand auger to 1.0m

WATER OBSERVATIONS: No free groundwater observed whils augering

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

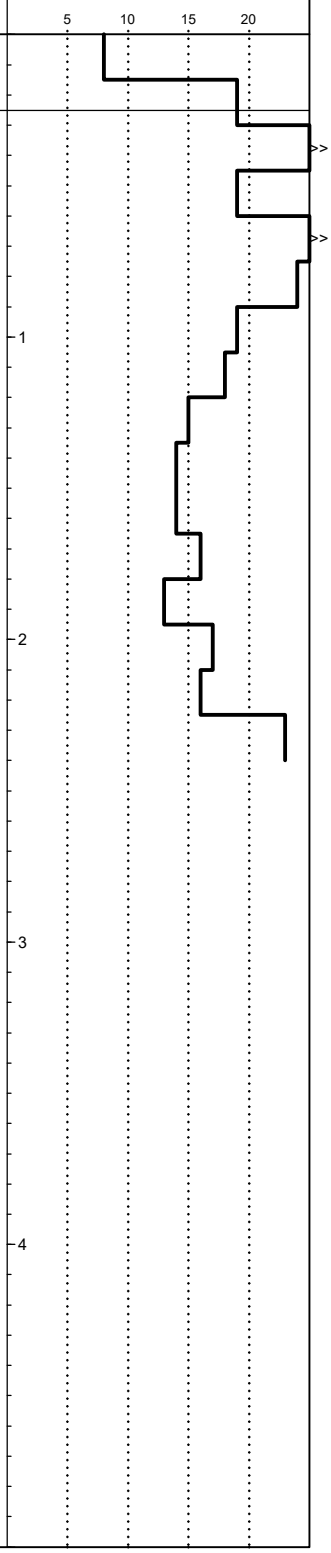
CLIENT: Southern Metropolitan Cemeteries Trust
PROJECT: Proposed Extension of Existing Cemetery
LOCATION: Prince of Wales Drive, Matraville

SURFACE LEVEL: 11.1 AHD
EASTING: 335993
NORTHING: 6239197
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 86050.01
DATE: 12/4/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
11		FILLING - brown and grey sub-rounded or sub-angular medium grained sand and fine gravel filling with some silt and traces of clay, humid. Gravel fractions comprises fine to coarse igneous and concrete gravel, typically angular or sub-angular.		D	0.1			
	0.25	Bore discontinued at 0.25m		D	0.25			
10	1							
9	2							
8	3							
7	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Hand tools **DRILLER:** RM **LOGGED:** RM **CASING:** None

TYPE OF BORING: Hand auger to 0.25m

WATER OBSERVATIONS: No free groundwater observed whils augering

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

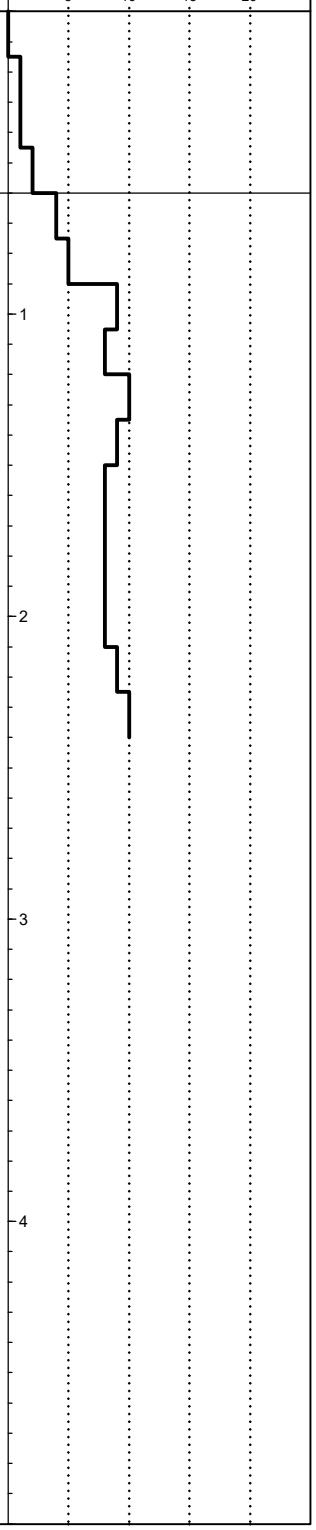
CLIENT: Southern Metropolitan Cemeteries Trust
PROJECT: Proposed Extension of Existing Cemetery
LOCATION: Prince of Wales Drive, Matraville

SURFACE LEVEL: 13.7 AHD
EASTING: 336028
NORTHING: 6269127
DIP/AZIMUTH: 90°/--

BORE No: 7
PROJECT No: 86050.01
DATE: 12/4/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		SAND - brown and grey sub-rounded or sub-angular medium sand with some roots and rootlets, humid. (possibly disturbed)		D	0.1			
				D	0.5		Water added	
	0.6	Bore discontinued at 0.6m						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Hand tools **DRILLER:** RM **LOGGED:** RM **CASING:** None

TYPE OF BORING: Hand auger to 0.6m

WATER OBSERVATIONS: No free groundwater observed whils augering

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Southern Metropolitan Cemeteries Trust
PROJECT: Proposed Extension of Existing Cemetery
LOCATION: Prince of Wales Drive, Matraville

SURFACE LEVEL: 9.5 AHD
EASTING: 336123
NORTHING: 6239085
DIP/AZIMUTH: 90°/--

BORE No: 10
PROJECT No: 86050.01
DATE: 12/4/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		FILLING - light grey to light brown fine to medium (sub-angular or sub-rounded) sand filling with traces of shell fragments and some rootlets, humid		D	0.1				
	0.2	FILLING - brown gravelly sub-rounded, fine to medium sand filling. Humid. Gravels typically fine with some coarse		D	0.3		Water added		
	0.4	Bore discontinued at 0.4m							
9									
	1								1
8									
	2								2
7									
	3								3
6									
	4								4
5									

RIG: Hand tools **DRILLER:** RM **LOGGED:** RM **CASING:** None

TYPE OF BORING: Hand auger to 0.6m

WATER OBSERVATIONS: No free groundwater observed whils augering

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Results of Dynamic Penetrometer Tests

Client	Southern Metropolitan Cemeteries Trust	**Project No.**	86050.01
Project	Proposed Extension of Existing Cemetery	**Date**	12.4.2018
Location	Prince of Wales Drive, Matraville	**Page No.**	1 of 1

Test Locations	2	3	4	7						
RL of Test (AHD)	5.4	4.4	11.1	13.7						
Depth (m)	**Penetration Resistance** Blows/150 mm									
0.00 – 0.15	1	0	8	0						
0.15 – 0.30	2	2	19	1						
0.30 – 0.45	5	6	38	1						
0.45 – 0.60	10	13	19	2						
0.60 – 0.75	15	14	26	4						
0.75 – 0.90	16	17	24	5						
0.90 – 1.05	19	19	19	9						
1.05 – 1.20	14	20	18	8						
1.20 – 1.35	21	27	15	10						
1.35 – 1.50	20	27	14	9						
1.50 – 1.65	19	25	14	8						
1.65 – 1.80	19	25	16	8						
1.80 – 1.95	17	22	13	8						
1.95 – 2.10	15	20	17	8						
2.10 – 2.25	19	20	16	9						
2.25 – 2.40	21	21	23	10						
2.40 – 2.55	D	D	D	D						
2.55 – 2.70										
2.70 – 2.85										
2.85 – 3.00										
3.00 – 3.15										
3.15 – 3.30										
3.30 – 3.45										
3.45 – 3.60										

Test Method AS 1289.6.3.2, Cone Penetrometer ☐
AS 1289.6.3.3, Sand Penetrometer ☑

Tested By RM
Checked By SCP

Remarks

Cone Penetration Tests

Douglas Partners

Introduction

The Cone Penetration Test (CPT) is a sophisticated soil profiling test carried out in-situ. A special cone shaped probe is used which is connected to a digital data acquisition system. The cone and adjoining sleeve section contain a series of strain gauges and other transducers which continuously monitor and record various soil parameters as the cone penetrates the soils.

The soil parameters measured depend on the type of cone being used, however they always include the following basic measurements

- Cone tip resistance q_c
- Sleeve friction f_s
- Inclination (from vertical) i
- Depth below ground z

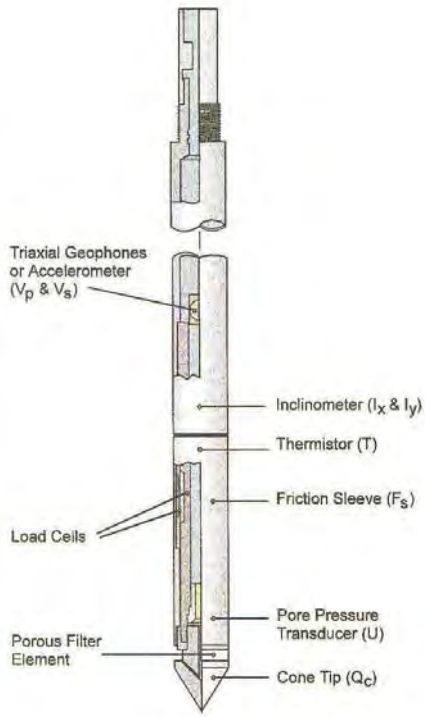


Figure 1: Cone Diagram

The inclinometer in the cone enables the verticality of the test to be confirmed and, if required, the vertical depth can be corrected.

The cone is thrust into the ground at a steady rate of about 20 mm/sec, usually using the hydraulic rams of a purpose built CPT rig, or a drilling rig. The testing is carried out in accordance with the Australian Standard AS1289 Test 6.5.1.

Figure 2: Purpose built CPT rig

The CPT can penetrate most soil types and is particularly suited to alluvial soils, being able to detect fine layering and strength variations. With sufficient thrust the cone can often penetrate a short distance into weathered rock. The cone will usually reach refusal in coarse filling, medium to coarse gravel and on very low strength or better rock. Tests have been successfully completed to more than 60 m.

Types of CPTs

Douglas Partners (and its subsidiary GroundTest) owns and operates the following types of CPT cones:

Type	Measures
Standard	Basic parameters (q_c, f_s, i & z)
Piezocone	Dynamic pore pressure (u) plus basic parameters. Dissipation tests estimate consolidation parameters
Conductivity	Bulk soil electrical conductivity (σ) plus basic parameters
Seismic	Shear wave velocity (V_s), compression wave velocity (V_p), plus basic parameters

Strata Interpretation

The CPT parameters can be used to infer the Soil Behaviour Type (SBT), based on normalised values of cone resistance (Qt) and friction ratio (Fr). These are used in conjunction with soil classification charts, such as the one below (after Robertson 1990)

Cone Penetration Tests

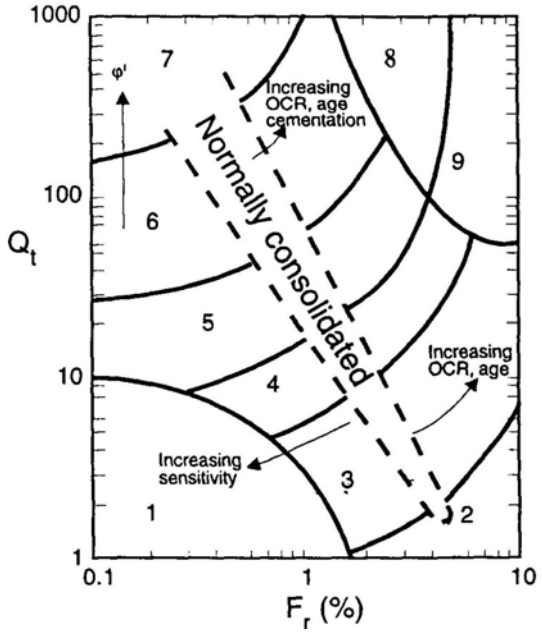


Figure 3: Soil Classification Chart

DP's in-house CPT software provides computer aided interpretation of soil strata, generating soil descriptions and strengths for each layer. The software can also produce plots of estimated soil parameters, including modulus, friction angle, relative density, shear strength and over consolidation ratio.

DP's CPT software helps our engineers quickly evaluate the critical soil layers and then focus on developing practical solutions for the client's project.

Engineering Applications

There are many uses for CPT data. The main applications are briefly introduced below:

Settlement

CPT provides a continuous profile of soil type and strength, providing an excellent basis for settlement analysis. Soil compressibility can be estimated from cone derived moduli, or known consolidation parameters for the critical layers (eg. from laboratory testing). Further, if pore pressure dissipation tests are undertaken using a piezocone, in-situ consolidation coefficients can be estimated to aid analysis.

Pile Capacity

The cone is, in effect, a small scale pile and, therefore, ideal for direct estimation of pile capacity. DP's in-house program ConePile can analyse most pile types and produces pile capacity versus depth plots. The analysis methods are based on proven static theory and empirical studies, taking account of scale effects, pile materials and method of installation. The results are expressed in limit state format, consistent with the Piling Code AS2159.

Dynamic or Earthquake Analysis

CPT and, in particular, Seismic CPT are suitable for dynamic foundation studies and earthquake response analyses, by profiling the low strain shear modulus G_0. Techniques have also been developed relating CPT results to the risk of soil liquefaction.

Other Applications

Other applications of CPT include ground improvement monitoring (testing before and after works), salinity and contaminant plume mapping (conductivity cone), preloading studies and verification of strength gain.

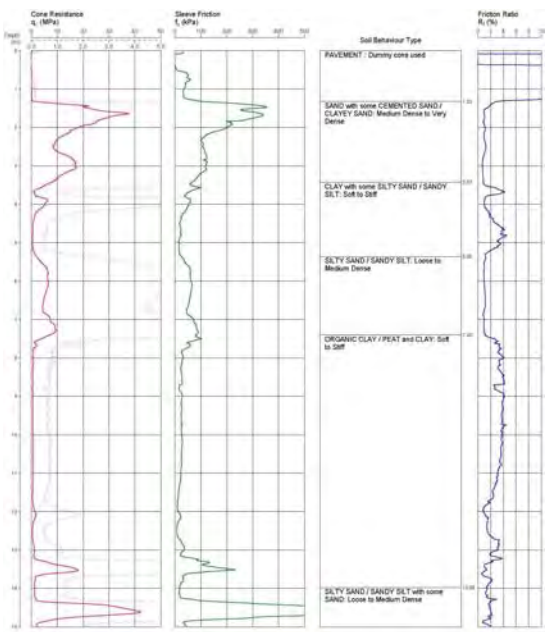


Figure 4: Sample Cone Plot

CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

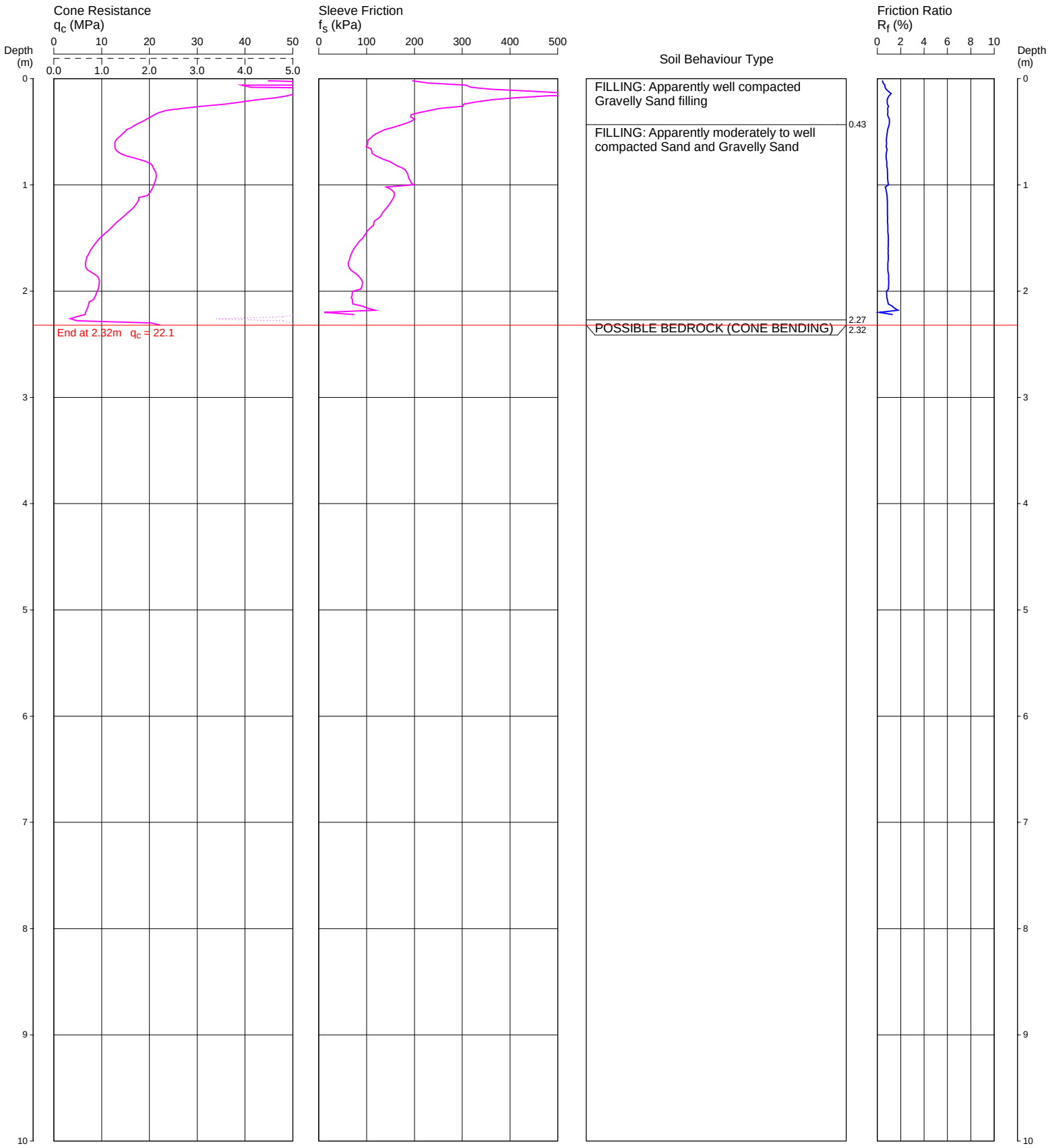
REDUCED LEVEL: 6.7

COORDINATES: 335876E 6239089N MGA

1

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED DUE TO SUDDEN BEND ON PROBABLE ROCK
HOLE COLLAPSED AT 1.9 m DEPTH AFTER WITHDRAWAL OF RODS

File: P:\86050.01 - MATRAVILLE, Prince of Wales Drive, Geote\4.0 Field Work\4.2 Testing\86050.01 - MATRAVILLE\1.CP5
Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

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Geotechnics / Environment / Groundwater

CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

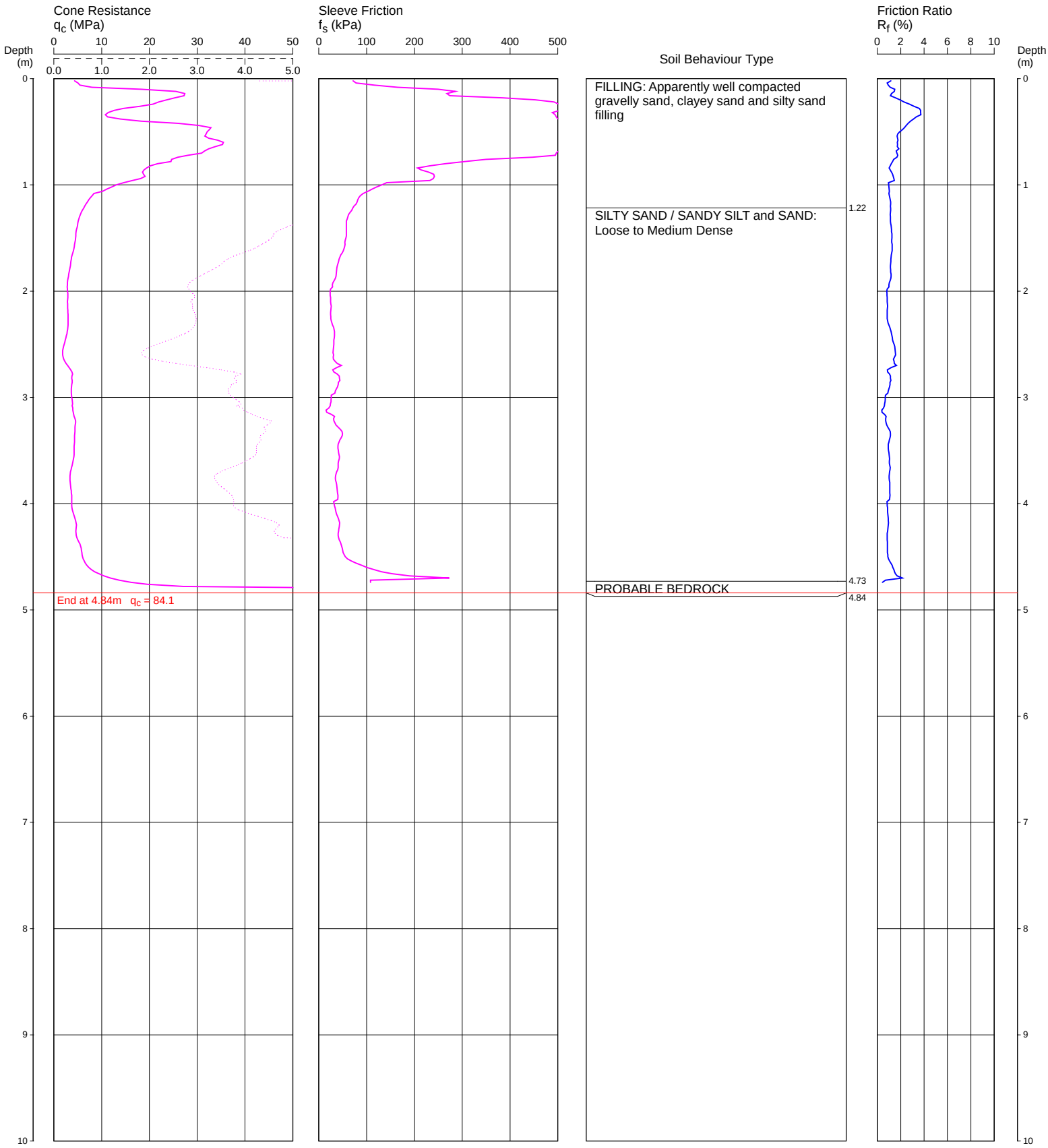
REDUCED LEVEL: 11.1

COORDINATES: 336019E 6239211N MGA

5

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED AT REFUSAL
HOLE COLLAPSED AT 0.3 m DEPTH AFTER WITHDRAWAL OF RODS

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Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

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CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

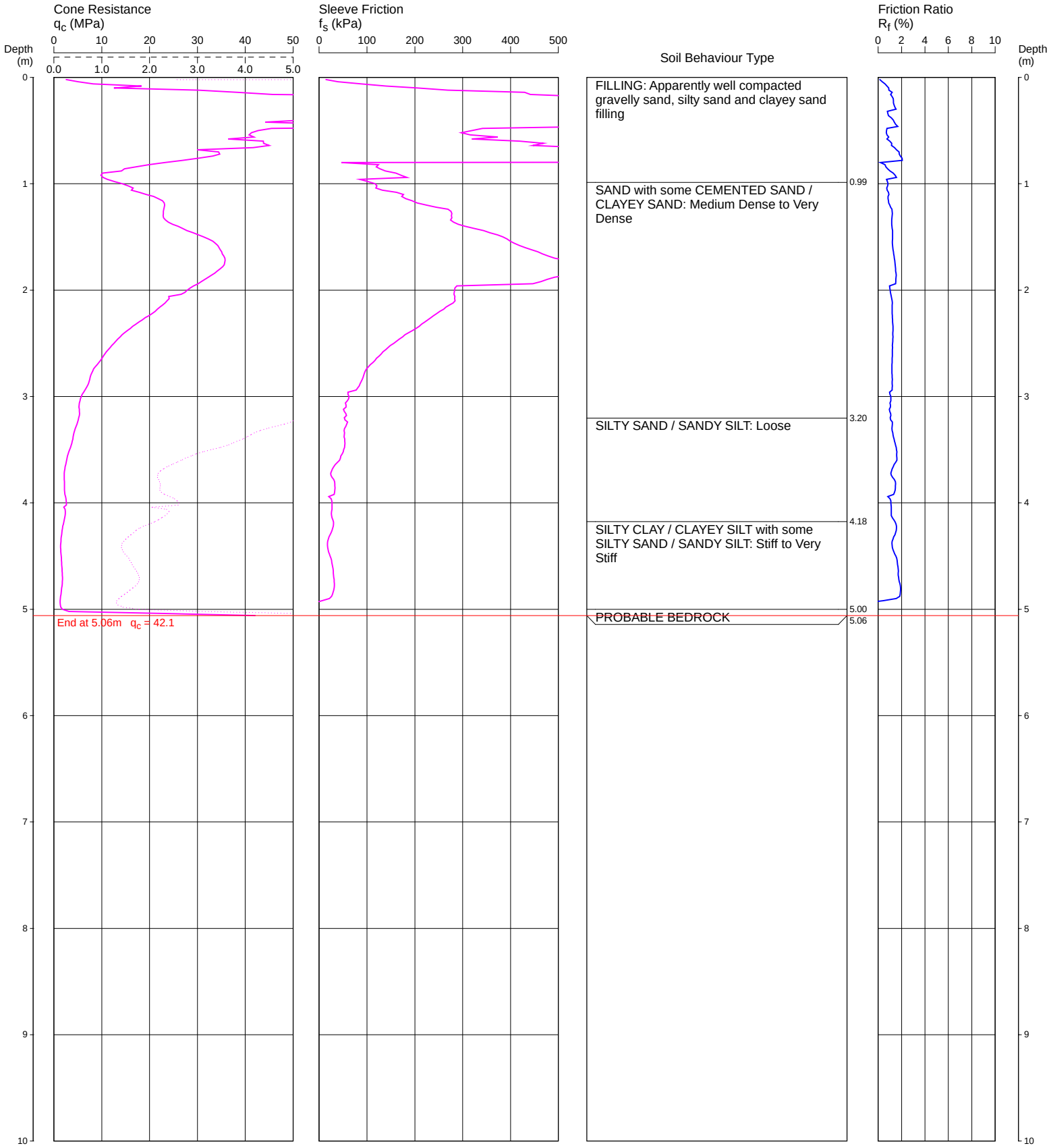
REDUCED LEVEL: 10.3

COORDINATES: 336078E 6239145N MGA

6

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED DUE TO SUDDEN BEND ON PROBABLE ROCK
HOLE COLLAPSED AT 4.9 m DEPTH AFTER WITHDRAWAL OF RODS

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Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

Douglas Partners
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CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

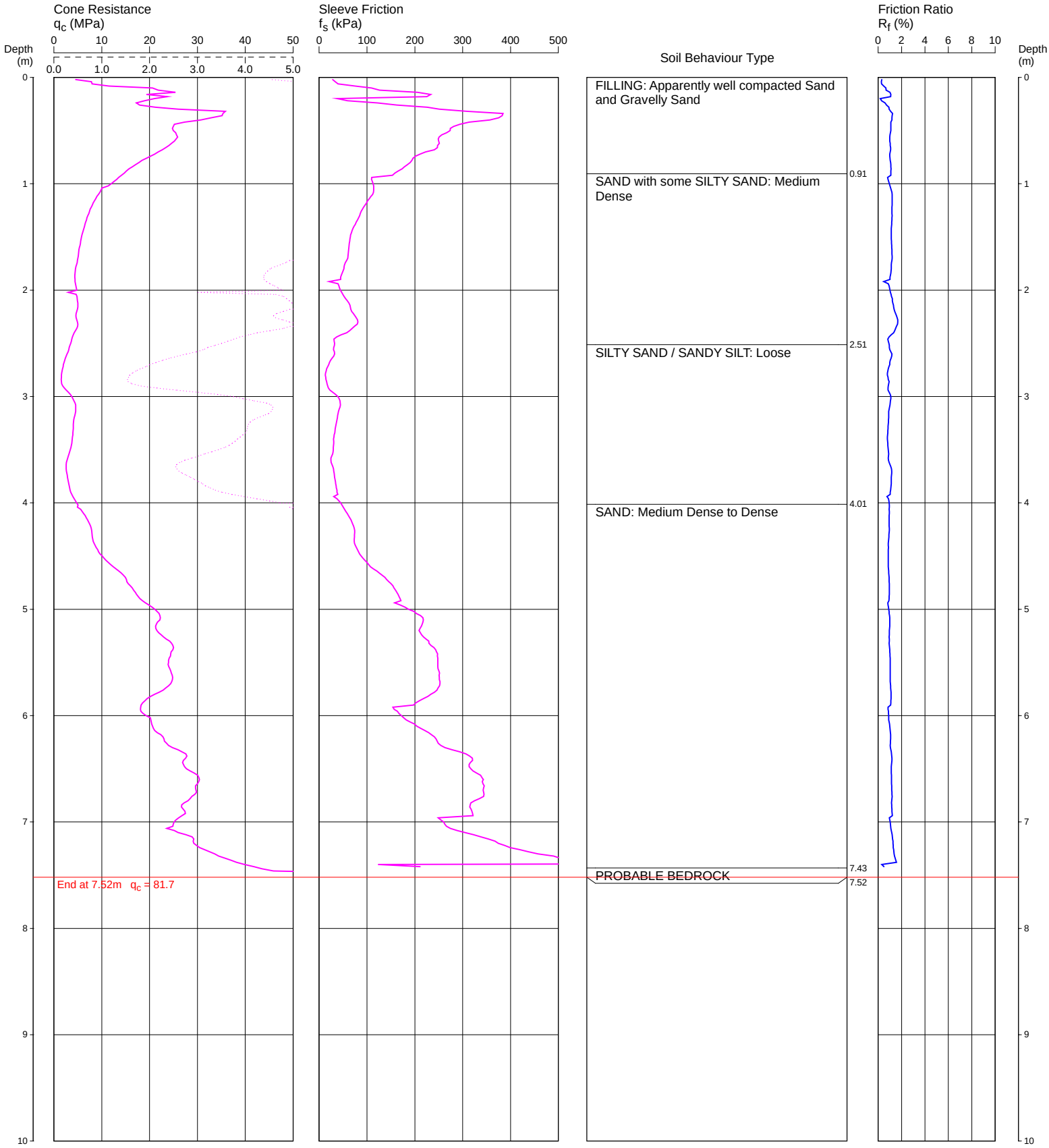
REDUCED LEVEL: 12.0

COORDINATES: 336050E 6239114N MGA

8

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED AT REFUSAL
HOLE COLLAPSED AT 4.9 m DEPTH AFTER WITHDRAWAL OF RODS

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Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

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Geotechnics / Environment / Groundwater

CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

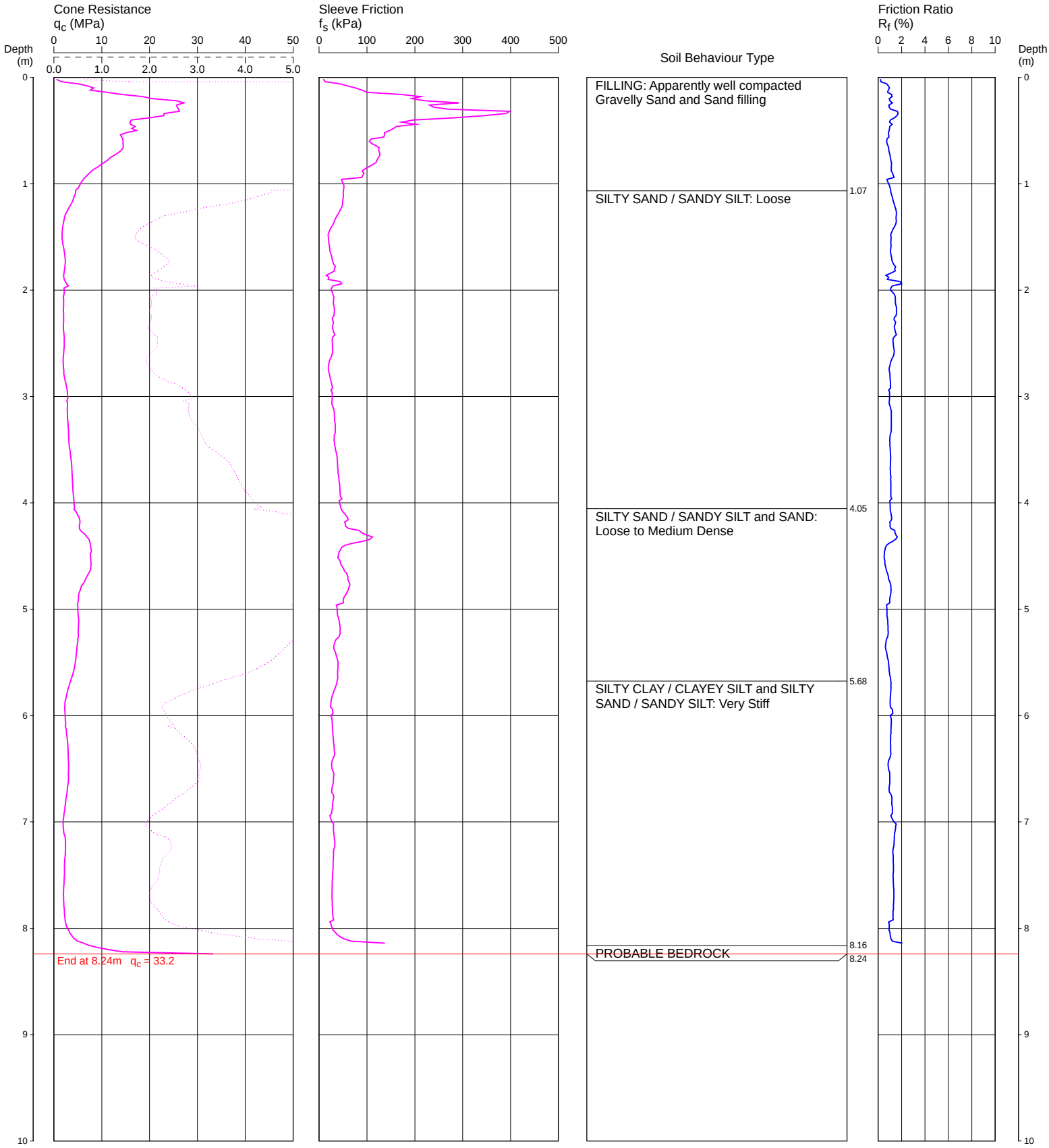
REDUCED LEVEL: 11.2

COORDINATES: 336084E 6239104N MGA

9

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED DUE TO SUDDEN BENDING ON PROBABLE ROCK
HOLE COLLAPSED AT 7.8 m DEPTH AFTER WITHDRAWAL OF RODS

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Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

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CONE PENETRATION TEST

CLIENT: SOUTHERN METROPOLITAN CEMETERIES TRUST

PROJECT: PROPOSED EXTENSION OF EXISTING CEMETERY

LOCATION: PRINCE OF WALES DRIVE, MATRAVILLE

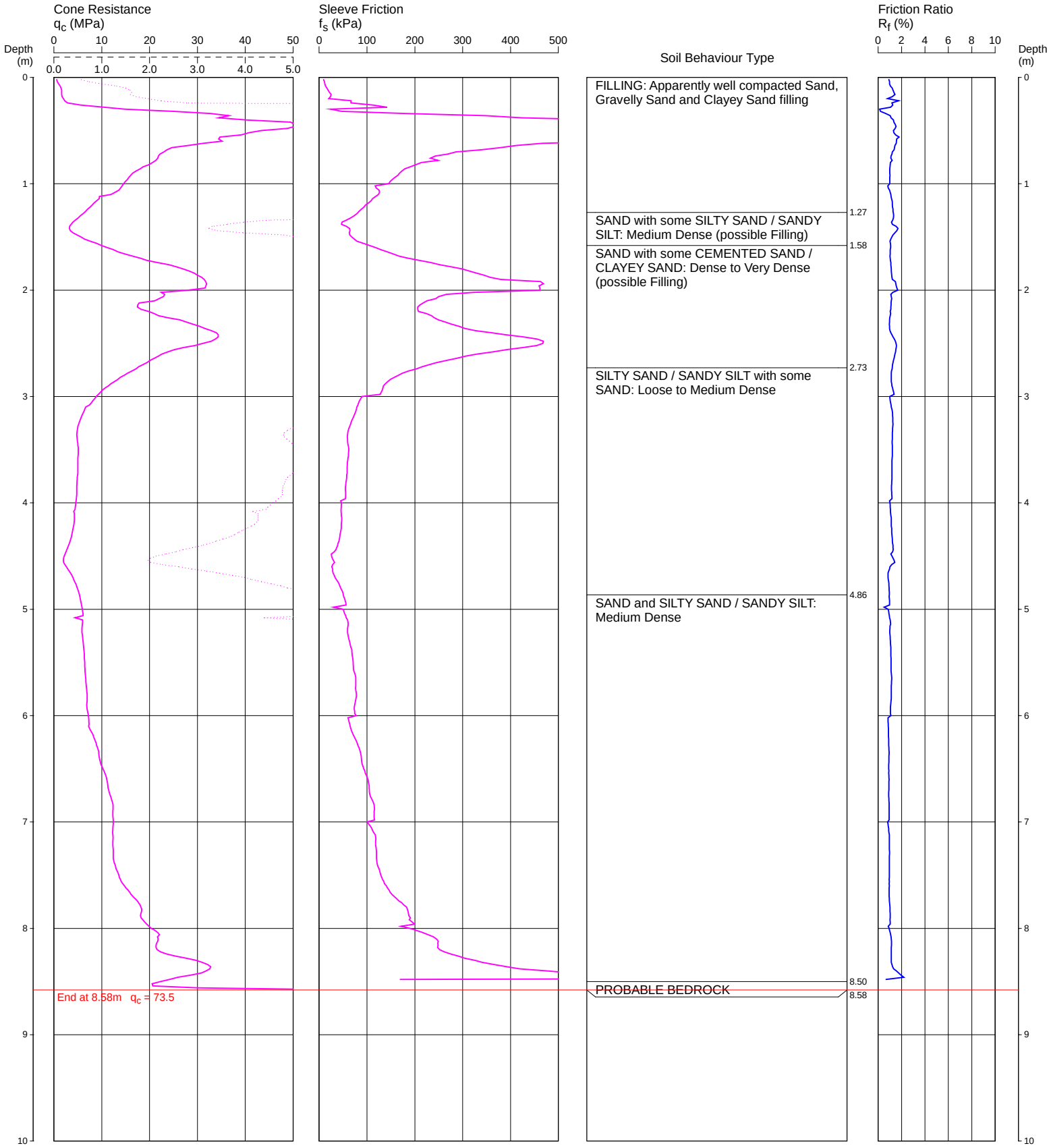
REDUCED LEVEL: 9.5

COORDINATES: 336123E 6239085N MGA

10

DATE 12/04/2018

PROJECT No: 86050.01



REMARKS: TEST DISCONTINUED DUE TO REFUSAL
HOLE COLLAPSED AT 7.1 m DEPTH AFTER WITHDRAWAL OF RODS

File: P:\86050.01 - MATRAVILLE, Prince of Wales Drive, Geote\4.0 Field Work\4.2 Testing\86050.01 - MATRAVILLE\10.CP5
Cone ID: 120630 **Type:** I-CFXY-10

ConePlot Version 5.9.2

Douglas Partners
Geotechnics / Environment / Groundwater

Material Test Report

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Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
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Email: lujia.wu@douglaspartners.com.au

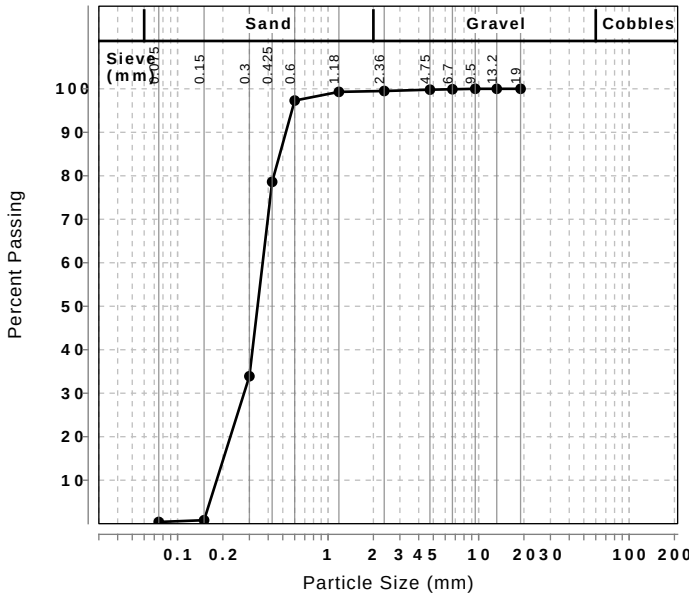
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Lujia Wu
dp-lujia.wu
NATA Accredited Laboratory Number: 828

Report Number: **86050.01-1**
Issue Number: 1
Date Issued: 30/04/2018
Client: Southern Metropolitan Cemeteries Trust
12 Military Road, Matraville NSW 2036
Contact: Tim Dowe
Project Number: 86050.01
Project Name: Proposed Extension of Existing Cemetery
Project Location: Prince of Wales Drive, Matraville
Work Request: 2906
Sample Number: 18-2906A
Date Sampled: 23/04/2018
Sample Location: **2 (1.0-1.0)**
Material: Brown sand

Particle Distribution (AS1289 3.6.1)			
Sieve	Passed %	Passing Limits	
19 mm	**100**		
13.2 mm	**100**		
9.5 mm	**100**		
6.7 mm	**100**		
4.75 mm	**100**		
2.36 mm	**100**		
1.18 mm	**99**		
0.6 mm	**97**		
0.425 mm	**79**		
0.3 mm	**34**		
0.15 mm	**1**		
0.075 mm	**0**		

Particle Size Distribution



Material Test Report

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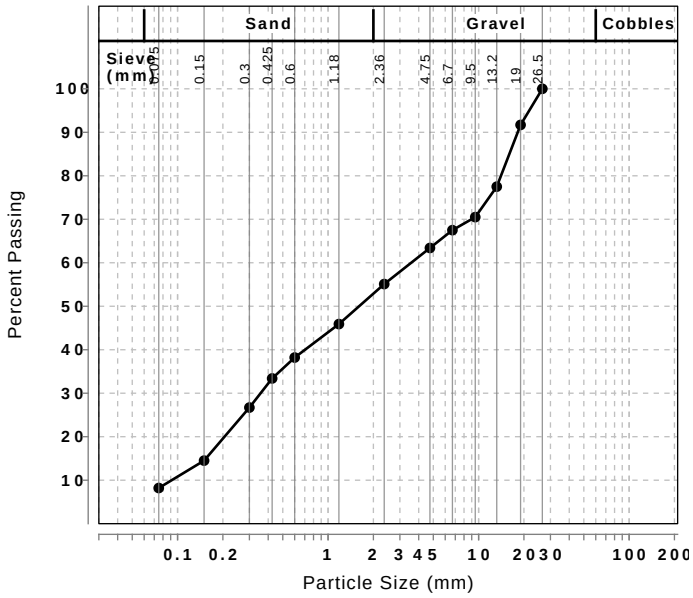
Approved Signatory: Lujia Wu
dp-lujia.wu
NATA Accredited Laboratory Number: 828

Report Number: **86050.01-1**
Issue Number: 1
Date Issued: 30/04/2018
Client: Southern Metropolitan Cemeteries Trust
12 Military Road, Matraville NSW 2036
Contact: Tim Dowe
Project Number: 86050.01
Project Name: Proposed Extension of Existing Cemetery
Project Location: Prince of Wales Drive, Matraville
Work Request: 2906
Sample Number: 18-2906B
Date Sampled: 23/04/2018
Sample Location: **4 (0.25-0.25)**
Material: Brown sand and gravel with some silt

Particle Distribution (AS1289 3.6.1)			
Sieve	Passed %	Passing Limits	
26.5 mm	**100**		
19 mm	**92**		
13.2 mm	**78**		
9.5 mm	**71**		
6.7 mm	**68**		
4.75 mm	**63**		
2.36 mm	**55**		
1.18 mm	**46**		
0.6 mm	**38**		
0.425 mm	**33**		
0.3 mm	**27**		
0.15 mm	**15**		
0.075 mm	**8**		

Particle Size Distribution



Material Test Report

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Accredited for compliance with ISO/IEC 17025 - Testing

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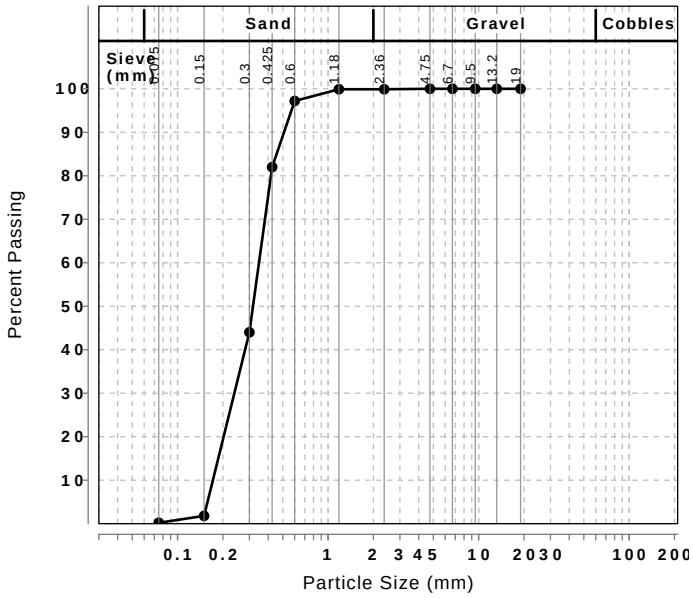
Report Number: **86050.01-1**
Issue Number: 1
Date Issued: 30/04/2018
Client: Southern Metropolitan Cemeteries Trust
12 Military Road, Matraville NSW 2036
Contact: Tim Dowe
Project Number: 86050.01
Project Name: Proposed Extension of Existing Cemetery
Project Location: Prince of Wales Drive, Matraville
Work Request: 2906
Sample Number: 18-2906C
Date Sampled: 23/04/2018
Sample Location: **7 (0.5-0.5)**
Material: Brown sand

Particle Distribution (AS1289 3.6.1)			
Sieve	Passed %	Passing Limits	
19 mm	**100**		
13.2 mm	**100**		
9.5 mm	**100**		
6.7 mm	**100**		
4.75 mm	**100**		
2.36 mm	**100**		
1.18 mm	**100**		
0.6 mm	**97**		
0.425 mm	**82**		
0.3 mm	**44**		
0.15 mm	**2**		
0.075 mm	**0**		

Particle Size Distribution



Material Test Report

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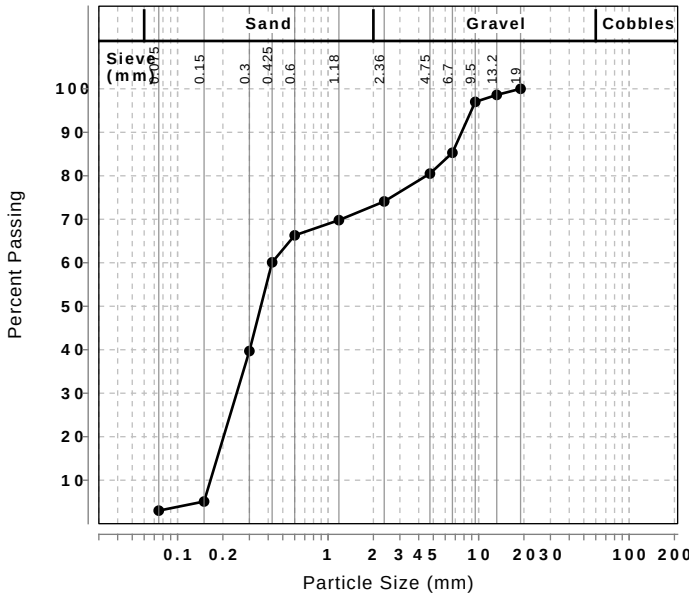
Client: Southern Metropolitan Cemeteries Trust
12 Military Road, Matraville NSW 2036
Contact: Tim Dowe
Project Number: 86050.01
Project Name: Proposed Extension of Existing Cemetery
Project Location: Prince of Wales Drive, Matraville
Work Request: 2906
Sample Number: 18-2906D
Date Sampled: 23/04/2018
Sample Location: **10 (0.3-0.3)**
Material: Brown gravelly sand with a trace of silt

Particle Distribution (AS1289 3.6.1)			
Sieve	Passed %	Passing Limits	
19 mm	**100**		
13.2 mm	**99**		
9.5 mm	**97**		
6.7 mm	**85**		
4.75 mm	**81**		
2.36 mm	**74**		
1.18 mm	**70**		
0.6 mm	**66**		
0.425 mm	**60**		
0.3 mm	**40**		
0.15 mm	**5**		
0.075 mm	**3**		

Particle Size Distribution



Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Desktop Assessment

Proposed Extension of Existing Cemetery
Prince of Wales Drive, Matraville

Prepared for
Southern Metropolitan Cemeteries Trust

Project 86050.00
January 2018

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

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Revision 1	1	0	Tim Dowe, Southern Metropolitan Cemeteries Trust Patrick Fishburn, Crown Project Services

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		22 January 2018
Reviewer		22 January 2018

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Douglas Partners
Geotechnics / Environment / Groundwater

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Report on Geotechnical Desktop Assessment
Proposed Extension of Existing Cemetery
Prince of Wales Drive, Matraville

1. Introduction

This report presents the results of a geotechnical desktop assessment undertaken by Douglas Partners Pty Ltd (DP) for a proposed extension of existing cemetery at Prince of Wales Drive, Matraville. The assessment was commissioned in an email dated 6 July 2017 by Mr Patrick Fishburn of Crown Project Services, on behalf of Southern Metropolitan Cemeteries Trust, and was undertaken in accordance with DP proposal SYD170399 dated 5 April 2017.

It is understood that the subject site is proposed to be used as an extension to the existing Eastern Suburbs Memorial Park, with the development to include lawn cemetery areas and ash internment walls. Proposed ground levels are yet to be determined, although re-contouring is anticipated and terraced landforms are expected as part of the final landform.

The aim of the study was to:

- Assess likely soil and groundwater conditions at the site; and,
- Provide geotechnical comments on:
  - Filling and excavation for bulk earthworks at the site, including excavation works, including excavation methods for expected subsurface materials and temporary and long-term batter slopes, proof roll and compaction procedures;
  - Potential foundation systems and areas favourable for foundations; and,
  - Suggested further geotechnical assessment for later project stages.
  - The geotechnical suitability of the site for use as a cemetery

The desktop study included a site walkover by an experienced geotechnical engineer over readily accessible areas, and a review of published geotechnical mapping and previous geotechnical investigation results from DP's database.

2. Site Description

The site is irregularly-shaped and located at Bumborah Point in Matraville, as shown in Drawing 1, in Appendix B. It is bounded by Military Road and Prince of Wales Drive to the north-west, by the existing Eastern Suburbs Memorial Park to the east and Botany Bay (Yarra Bay) to the south.

The site is understood to comprise two, adjoining, irregularly-shaped lots:

- Lot 4858 of DP 752015, the Bumborah Point site claimed by the La Perouse Local Aboriginal Land Council (LPLALC); and,

- Lot 7301 of DP 1139143, a Council road reserve.

The site is transected by multiple easements for services, as shown in Drawing 1. These services include easements for circulating water tunnels, manholes and inlets, high pressure pipelines, intakes and sewerage services.

Reference to the provided survey plans, together with current and 1943 aerial photography indicates that the site is located at a former headland, with land to the west of the site reclaimed since 1943 (see Figure 1), and a western site boundary defined by the historic mean high water mark. Given current ground levels of approximately RL 3.5 to RL 7 m along the boundary, this suggests that some metres of filling has occurred along that boundary.

Figure 1: Current (left hand side) and 1943 (right hand side) aerial photographs (ref: LPI and

Ground levels are highest centrally on the site, at approximately RL 16 m, falling gently towards the north-east at approximately 4°. From this gently sloping area, ground levels fall more steeply towards the south and west at approximately 10° to 30°, and down the near-vertical sandstone cliffs along parts of the waterfront.

2.1 Site Observations

A site walkover was performed by an experienced geotechnical engineer on 12 July 2017, and supplementary visit on 9 August 2017. Selected photographs from the site visit have been reproduced in Appendix C or are included within the text. The site observations have been subdivided into observations from the waterfront, of the elevated ground within the LPLALC site, and of the areas within the council reserve.

2.1.1 The Waterfront

At the time of the site walkover, sandstone cliffs and rock platforms were visible at the centre of the waterfront boundary and extending towards the west. Towards the western corner of the site, the

sandstone cliffs transitioned to concrete erosion protection measures founded on the rock platform as can be seen in Figure 1.

Figure 1: View of site from western corner

Towards the eastern side of the site, no sandstone cliffs nor rock platforms were visible, and site slopes were heavily vegetated (see Figure 2).

Figure 2: View of site from near eastern corner.

Some seepage was visible at the face of a sandstone cliff in the south-western part of the site, with associated vegetation growth (refer Photo 1 in Appendix C). Seepage was not observed from cliff faces towards the central waterfront area.

The sandstone cliffs were interrupted centrally along the waterfront, by an easement for water tunnels, with concrete sidewalls constructed along the waterfront and rockfill extended up the height of the retained slope (refer Photo 2 in Appendix C). The excavation pre-dates the 1943 aerial photographs, and appear to have included excavation into the rock platform. Based on the height of the rock fill, it appears that cutting and filling may have been used in the construction of these services.

Sand tracks led up into the site from the waterfront, with apparently natural sand and filling variously exposed in the slopes (refer Photo 3 and Photo 4, in Appendix C).

2.1.2 Elevated ground

The sand tracks lead up the slopes to areas vegetated by shrubs and trees. The vegetation was dense in some areas, but also opened up to small clearings. Inspection of areas towards the highest area of the site identified large concrete blocks and rubble at ground surface (refer Photos 5 and 6, in Appendix C).

Gravel tracks were present in some areas, likely for access to the easements. Numerous small stockpiles of filling (typically with building rubble including concrete, asphaltic concrete, tiles and pipe materials, but including glass and tyres at some locations) were present in the area, some partly overgrown (e.g. Photo 7). A larger, overgrown embankment was present west of the bitumen track that runs approximately along the northern boundary of the LPLALC land, with a height increasing to approximately 1.5 m towards its northern end. A photo of the embankment is included as Photo 8 in Appendix C, and location is shown in Drawing 1, in Appendix B.

Grass, low shrubs and some trees were present towards the western side of the LPLALC land, with vegetation generally becoming more dense with distance from Prince of Wales Drive, and slopes in this area generally densely vegetated. A sandstone outcrop was visible, though not readily accessible towards the south-western area of the site, in an area of sloping ground, as shown in Figure 3, below, and Drawing 1 in Appendix B.

Figure 3: Sandstone outcrop in south-western area

2.1.3 Council Reserve

The Council reserve area includes those parts of the site near Military Road, and extending around the western edge of the existing Eastern Suburbs Memorial Park, between the Park and the LPLALC land. The characteristics of this area vary significantly and include the following:

- The land between the existing Memorial Park and LPLALC land is generally grassed, with some trees (see Photo 10). Building rubble is present in these areas, particularly towards the Memorial Park boundary.
- Further north, between the Memorial Park and Military Road, the site is more extensively landscaped, with grassed areas and trees adjacent to and at similar, undulating levels to the Memorial Park (see Photo 11) then sloping down vegetated slopes to Military Road. Some rock boulders were visible in the landscapes ground surface, and additional filling was evident in the slopes along Military Road. Some fibrous cement fragments were observed at ground surface in this area.
- An existing, asphaltic concrete surface car park is present off Military Road. Some cracking and damage to the existing pavement is evident (see Photo 12 in Appendix C).
- West of the car park, the site is vegetated, although filling is evident at ground surface (see Photo 13, in Appendix C).

2.2 Regional Mapping

Reference to the 1:100,000 Sydney Geological Series Sheet indicates that the site is mapped as underlain by Hawkesbury Sandstone, near filling to the west of the site, and deep Quaternary Age soils at the south-eastern corner, and generally east of the site (refer Figure 4, below)

Figure 4: Geological Mapping (green is Hawkesbury Sandstone, grey is filling and yellow is Quaternary Age soils)

Reference to the 1:100 000 Soil Landscape Series indicates that the site is underlain by a central swathe of aeolian sand of the Newport Soil Landscape, and by disturbed terrain at the eastern and western sides of the site (see Figure 5, below).

Figure 5: Soil Landscape Mapping (grey is disturbed ground; yellow is Aeolian sand)

Reference to the 1:25,000 Acid Sulfate Soil Risk Mapping indicates that the site is variously located in areas of no, low and unknown probability of occurrence of acid sulfate soil. The areas affected are shown in Figure 6, below.

Figure 6: Acid Sulphate Soil Risk Mapping (grey is unknown; orange is low probability)

For the purpose of this assessment, these probabilities can be considered with respect to the ground conditions that influenced the mapping, which are considered to correspond to:

- Unknown probability of occurrence of acid sulphate soil - in reclaimed areas at the western side of the site – this is due to the known presence of filling in this area, and unknown origin of these materials, which may have included acid sulfate soils;
- Low probability of occurrence of acid sulphate soil – around the shoreline of the former headland. This corresponds to a risk of naturally occurring acid sulfate soils below approximately RL 5 m, and which may still be present in these areas; and,
- No risk of occurrence of acid sulphate soil – in the central and north-western parts of the site, where the site is expected to be underlain by sandstone above the level of coastal acid sulphate soil occurrence.

2.3 Groundwater Bores

Reference to the Office of Water groundwater database indicates that four bores are located approximately 500 m from the subject site, as shown in Figure 7, below.

Figure 6: Registered Groundwater Bores (Bore data from Department of Primary Industries, Office of Water, 2017)

Reference to the available data for the bores within 500 m provides the following information:

- GW114311 (east) – no relevant information
- GW114312 (east) – no relevant information
- GW028816 (east) – sand to 21.4m depth, no groundwater information
- GW110526 (north-east) - groundwater at 1.75 m within natural sand, slightly above rock level at 1.9 m.

2.4 Previous Investigation

Reference to previous investigation by Douglas Partners in the vicinity of the proposed extension indicates that at sites immediately north of the subject site, ground conditions from filling over deep sand (at the western side) to relatively shallow sandstone (to 0.5 m to 2.5 m depth, north of the central area of the site).

Previous investigation results west of the site suggest that the reclaimed land in the ports area generally comprises sand soils. North of the subject site, filling materials exhibit greater variability and include building rubble materials.

Groundwater levels immediately north of the site, measured west of the area of shallow sandstone, were below RL1 m AHD, with flow towards the west suggested by the limited groundwater measurements available.

3. Proposed Development

The proposed development of the site is for an extension to the existing cemetery, with a lawn and monumental cemetery, ash internment monuments and gardens, proposed.

For burial plots, it is likely that a modern burial system, a modular pre-installed concrete shoring system allowing for simple and safe access to burial plots, will be used. Estimated excavation depths of 2 m to 3 m are anticipated for the graves, potentially allowing for multiple internments.

Options for development include the possible return of an area of foreshore land to Council.

Road access into the cemetery will be required, together with car parking arrangements. Toilet facilities and shade structures are also expected to be required, and screening of the port facilities is being considered.

The intention is for the extended cemetery topography to blend in with the gently undulating ground of the existing cemetery. Earthworks are expected to be required to achieve the desired ground contours which are yet to be confirmed, and may be governed by the requirements of the services easements intersecting the site. Excavation, possible importation of validated suitable filling and/or the use of low retaining walls may be required to achieve these earthworks and landscaping requirements.

4. Comments

4.1 Geotechnical Model

The geotechnical model for the site is complicated by past disturbance of the site. Nonetheless, the following generalised geotechnical model is proposed, subdividing the site into three areas:

- Western Area of the site – the area towards the western site boundary, generally below approximately RL 5 to RL 7.0 m;
- Central Area of the site – the central part of the site from the southern waterfront boundary, to the northern boundary with Military Road; and,
- The Eastern Area of the site – the eastern part of the site

The approximate extent of these areas is shown in Drawing 2, in Appendix B.

It is noted that the geotechnical model is based on limited information, and further geotechnical investigation is appropriate to confirm the geotechnical model.

4.1.1 Western Area

The geotechnical model in this part of the site is dominated by the land reclamation undertaken for the Port expansion west of the site. In this area, ground conditions are expected to comprise:

- Shallow topsoil, say 0.05 m to 0.2 m of silty sand topsoil; underlain by,

- 2 m to 7 m of reclamation filling, typically sand; underlain by,
- Natural Aeolian sands in some areas, possibly with local alluvial sands; underlain by,
- Hawkesbury Sandstone, likely medium and high strength, generally below approximately RL 1, but potentially stepping up towards the Central Area as buried clifflines.

Permanent groundwater levels in this area are generally expected to be within the filling and alluvial sands, below approximately RL 2.0 m, and flowing towards Botany Bay at the south-west.

Acid sulphate soils may potentially be present within the reclamation filling. If present, such soils are expected to have been converted to actual acidic soils during the historic reclamation process. Acid sulphate soils may also potentially be present at greater depth within alluvial soils. Given the sand soils likely to be present, the risk of acid sulphate soils is nonetheless expected to be relatively low.

4.1.2 Central Area

The Central Area is characterised by the presence of relatively shallow Hawkesbury Sandstone, as visible in outcrops towards the southern end of the site, and determined from previous investigation north of the site. The actual depth of sandstone may vary across this area.

In this area, ground conditions are expected to comprise:

- Shallow topsoil, say 0.05 m to 0.2 m of silty sand topsoil; underlain by,
- Relatively shallow filling, including variable building rubble, and estimated as generally less than 0.5 m, though deeper in areas of stockpiled materials; underlain by,
- Aeolian sand soils, very loose to medium dense; underlain by,
- Hawkesbury Sandstone, estimated from a depth of up to 2 m, and generally medium and high strength, with some very low strength bands. An upper layer of extremely to very low strength rock may be present in some areas.

Historic excavation or similar operations for the existing services intersecting the site will potentially have influenced filling depths and rock levels, particularly at the south to north oriented water service. The deep rock fill visible at the waterfront of this easement suggests that open cut excavation was undertaken into the sandstone during construction of the service, and that deep filling may be present underlying this area.

Permanent groundwater within the Central Area is expected to be within the sandstone. Perched groundwater levels are expected to be present within the soil, above the top of bedrock. Such seepage is also likely to seep through bedding planes within the bedrock, as seen in the sandstone cliff face in Photo 1 in Appendix C.

4.1.3 Eastern Area

In the Eastern Area of the site, the geotechnical model is characterised by an increasing depth of soil. Ground conditions in this area are expected to comprise:

- Shallow topsoil, say 0.05 m to 0.2 m of silty sand topsoil; underlain by,

- Shallow filling, to depths of up to 0.5 m; underlain by,
- Natural sand soils, to depths of 2 m to 15 m, and possibly even greater depths. Likely to comprise loose soils near surface, improving to medium dense and dense with depth; underlain by,
- Hawkesbury Sandstone, generally medium and high strength. An upper layer of extremely to very low strength rock may be present in some areas.

Groundwater levels are expected to be generally below approximately RL 3 m and falling towards the south.

4.2 General Geotechnical Issues

At this site, the primary geotechnical issues relate to excavation conditions, earthworks, foundations and groundwater. Given the proposed burial plots at the site, it is expected that groundwater and seepage flow conditions will be important to the performance of the proposed cemetery.

These issues are likely to be readily manageable on the site, and are outlined in further detail below.

4.3 Excavation Conditions

The proposed depth of excavation will depend on the proposed site contours and location and depth of the proposed burial plots. The likely depth of excavation is therefore not clear at the present time.

Excavation at the site may potentially include excavation into filling, sand and sandstone. The sandstone is likely to be largely medium and high strength, but may include an upper weathered (extremely low to low strength sandstone) zone, and potentially weaker or stronger bands within the otherwise medium and high strength sandstone.

Excavation of soil and extremely low to very low strength rock should be achievable using conventional earthmoving equipment. Low strength sandstone may require light to medium ripping by a dozer.

Excavation of fractured, medium strength rock may require heavy or very heavy ripping with a large bulldozer. Ripping may be impractical, however, within slightly fractured to unbroken medium and high strength sandstone. Excavation of these rocks is likely to require a combination of hydraulic hammers and rock saw cuts, potentially in combination with milling heads. In practice, the excavation of medium and high strength rock is dependent upon rock mass characteristics, the equipment used and the skill of the operator.

During excavation of sandstone, it may be necessary to use appropriate methods and equipment to limit ground vibrations. The level of acceptable vibration is dependent on various factors, and acceptable vibration limits for existing services at the site should be assessed. Vibrations may also potentially cause settlement of very loose and loose sand and sand filling (potentially a concern within the site and at the neighbouring cemetery), and this should be considered to determine whether such settlement is acceptable or whether vibrations must be managed. The method and rate of excavation into sandstone may therefore be influenced by vibration issues.

All excavated material to be removed off site will need to be disposed of in accordance with the provisions of the current legislation and guidelines including the *Waste Classification Guidelines* (EPA, 2014). This includes filling and natural materials that may be removed from the site.

Where practical, it may be preferable to re-use the materials within the existing site. This may require segregation of, say, excavated filling from excavated natural soils, for

4.4 Groundwater

Permanent groundwater is generally expected to be below the likely depth of excavation for the proposed cemetery development. In areas of shallow bedrock, however (i.e. generally the Central Area), perched groundwater or seepage would be expected to occur within the soils above the top of rock, and through joints and bedding planes within the bedrock. This seepage may also pond in low points of the bedrock surface.

If burial plots are proposed in areas of shallow bedrock, then sufficient free-draining material should be present below the base of the burial excavation to permit natural seepage to pass below the excavation, and to allow for seepage to drain from within the grave. Depending on the ground contours desired, this may require over-excavation into the underlying sandstone, and placement of a specific drainage layer (e.g. clean sand – potentially site sourced, or gravel). Such measures may need to be combined with appropriate contouring of or excavation of drainage paths along the rock surface to ensure that the groundwater flow may continue beyond the area and depth of interest, rather than ponding at shallow depth in other areas of the site. Such seepage should also be directed across the site, and not towards the clifflines, to allow for natural attenuation of chemical and nutrient loading by percolation through the soils. In support of this, for burials it is suggested that a minimum 20 m setback be observed from the existing sandstone clifflines, based on research by Dent (2002).

4.5 Batters and Excavation Shoring

Excavations within the existing natural sand soils, and within the (likely sandy) filling are not expected to be stable if vertical. As for the existing cemetery, shoring will be required for burial plots excavated within these materials. The Modern Burial Solutions system is likely to be suitable for this purpose. Should imported, cohesive soil be introduced to the site for filling operations, shoring would still be recommended if people are to enter excavations deeper than 1.5 m (and possibly shallower excavations), for safety reasons. Other challenges may be associated with importing cohesive filling to the site, which would require further consideration.

Where acceptable, and where space permits, batters may be adopted around excavations. Suggested temporary and permanent maximum batter slopes are given in Table 1, below, for slopes up to the maximum slope height shown, where surcharges are set well back from the crest of the slope and no groundwater emerges from the slope.

Table 1: Recommended Temporary and Permanent Maximum Batter Slopes

Material	Maximum Total Slope Height (m)	Batter Slope Ratio (H:V)	
		Short-Term (temporary)	Long-term (Permanent)
Filling and natural soil	3	2:1	2:1
Extremely low to very low strength sandstone	3	1:1	2:1
Low strength sandstone	4	0.5:1	1:1
Medium and high strength sandstone	4	Vertical*	Vertical*

* Subject to assessment of jointing by a geotechnical engineer

In practice, the maximum batter slopes given above may need to be flattened, or additional stabilisation may be required due to adverse conditions such as adverse jointing in the rock mass or erodible surface conditions. The use of flatter batters of, say, 3H:1V or flatter may also be appropriate to allow for the long-term maintenance of vegetated slopes.

Where proposed slopes do not meet the characteristics outlined above (e.g. steeper slopes or surcharges proposed), then more detailed geotechnical assessment would be appropriate.

4.6 Excavation Support Selection and Design

Excavation support will be required for burial plots excavated into the existing site soils (e.g. shoring boxes). Retaining walls may also be required to produce stepped topography, if required by landscaping. Selection of an appropriate retaining wall type will depend on factors including the proposed wall height, location, purpose and construction conditions, which are not currently known.

For the preliminary design of simply supported retaining walls, the parameters given in Table 2, below are recommended.

Table 2: Preliminary Design Parameters for Shoring Systems and Retaining Walls

Material	Unit Weight (kN/m^3)	Earth Pressure Coefficient		
		Active (K_a)	At Rest (K_0)	Passive* (K_p)
Uncontrolled Filling and Loose Sand	20	0.35	0.5	3
Engineered Filling and Medium Dense Sand	20	0.3	0.45	3.5
Extremely low and very low strength sandstone	22	0.25	0.4	4.5

* Ultimate values, a factor of safety should be included in the design, and allowance made for accidental over-excavation.

The design of shoring and retaining walls should allow for all surcharge loads, including footings, inclined slopes behind the wall, traffic and construction-related activities.

Retaining walls should also be designed for full hydrostatic pressures, unless appropriate drainage is incorporated into the retaining wall design.

4.7 Earthworks

Earthworks are likely to be required at the site to produce the required site levels. Earthworks may also be required to provide a subgrade for the proposed car park and access roads.

In the absence of specific compaction records, the existing filling on the site must be considered uncontrolled. This includes filling below existing paths and car parking areas, together with the gravel paths, stockpiles and backfill material.

For the construction of permanent pavement areas subject to traffic, and for filling to support foundations, retaining walls and slopes, it would be usual to remove uncontrolled filling and replace it in a controlled manner, to provide confidence in the long-term behaviour of the filling. To achieve this, the following scope of works will generally be appropriate:

- Remove all existing filling and unsuitable materials (e.g. highly organic topsoil, oversized filling, oversized building rubble) from within the proposed fill area, exposing the natural subgrade surface. Where present, excavation or compaction of the natural very loose and loose sands may also be required to reduce the risk of future settlement and to improve site trafficability. Excavation should not be within 0.5 m of the groundwater table.
- During excavation, sort and stockpile the excavated materials into categories for removal from site, reuse in non-structural areas or reuse as controlled filling. From a geotechnical perspective, it is likely that the majority of material will be suitable for reuse as controlled filling. For the purpose of controlled filling, it is preferable that imported material is granular, free-draining material, compatible with the existing filling on the site. Should alternative filling be introduced (e.g. clay-type soils), then care should be taken to ensure that the interface between the materials is appropriate. This may involve assessment of relative grain sizes, use of geotextiles. The use of clay or other low permeability may also have other influences on the proposed design (e.g. groundwater, altered design parameters)
- Moisture condition the stripped surface by wetting or drying the natural subgrade, then proof roll in the presence of a geotechnical professional and improve the condition of the stripped surface where so directed. This may include the removal of any loose, soft or wet areas, if present. A smooth drum roller is suggested for proof rolling.
- For general purposes, after satisfactory compaction and proof rolling, place approved filling in uniform thickness layers not exceeding 300 mm loose thickness and compact each layer to a minimum density index of 65% (Standard dry density ratio of 97%), for settlement control. Below pavements, compaction should be increased to a minimum density index of 80% (100% Standard) within the upper 0.6 m below proposed pavements. For filling that will support footings, a minimum density index of 80% (100% Standard) would be suggested for the full depth of filling, as a preliminary recommendation.

The above comments are from geotechnical perspective, but it is noted that contamination of the soil, if present, may have an impact on material re-use and handling. This is outside of the scope of the

current assessment and it is understood that contaminations assessment is to be undertaken by others.

In the absence of specific CBR test results, it is suggested that a preliminary CBR value of 12% be adopted for pavement design over a natural sand subgrade.

4.8 Foundations

The following recommendations are given in relation to foundations:

- Structures founded on non-engineered filling are expected to be at an increased risk of elevated differential and total settlement. For some structures (e.g. shade structures) this risk may be managed by allowing for articulation of the structure, and accepting higher than usually accepted settlements.
- Where settlement is a concern (e.g. as likely for interment walls), then it is recommended that foundations for permanent structures be taken down below the depth of filling to bear on at least medium dense sand, or on sandstone bedrock.
- As very loose and loose soils are susceptible to vibration-induced settlement, it is not generally recommended that settlement-sensitive structures be founded on these materials.

Depending on the ground conditions and foundation requirements, a combination of shallow footings and pile foundations may be required on the site. Uncased bored piles through sand soils will be susceptible to collapse, and temporary pile casing is likely to be required for this pile type. Pile casing can be ineffective, however, if no penetration of casing into bedrock is achieved, particularly where perched groundwater flows occur along the rock interface. Continuous flight auger (CFA) piles may be considered to avoid this risk.

Additional investigation would be appropriate to confirm the consistency of the sand soils, and to assess the depth of sandstone. The investigation may indicate that deeper filling is relatively consistent, and may be associated with a reduced risk of excess settlement.

4.9 Proposed Investigation

The above geotechnical assessment is based on limited information, and further geotechnical investigation is appropriate to confirm the geotechnical model, as appropriate to the proposed development.

Such investigation may include additional boreholes, cone penetration test, test pits, groundwater wells and laboratory testing, depending on the development of the plans and designs for the proposed site, and constraints in relation to site access.

A useful next step, depending on the progress of the design, may be to undertake test pits in selected areas of the site to assess ground conditions, and to adjust the geotechnical model, if required. This could be combined with boreholes to provide information on the soil profile to greater depth.

4.10 Conclusions

The results of the desktop assessment indicate that, from a geotechnical perspective, the site may be made suitable for use as a cemetery.

Earthworks are expected to be required for the site for landscaping of the cemetery extension (landscaping details which are yet to be confirmed), for site preparation, and potentially to allow for pre-excavation of sandstone in areas of shallow sandstone.

The expected sandy filling and natural sand soils are not expected to be stable if vertical, and appropriate batters or support will be required for excavations and retaining walls, where required by site operations and the proposed landscaping

Groundwater and seepage flow conditions are expected to be important to the performance of the proposed cemetery, which, for burials over shallow sandstone, may require over-excavation into sandstone and contouring or provision of drainage paths along the underlying rock surface. A minimum burial setback of 20 m from the existing sandstone clifflines is suggested.

Further investigation is considered appropriate to confirm the geotechnical model developed within the geotechnical desktop assessment.

5. References

1. Dent, Boyd B. *The Hydrogeological Context of Cemetery Operations and Planning in Australia, Volume 1*, University of Technology, Sydney, December 2002.

6. Limitations

Douglas Partners (DP) has prepared this report for this project at Prince of Wales Drive, Matraville, in accordance with DP's proposal dated 5 April 2017, supplementary email dated 22 May 2017 and acceptance received from Crown Project Services on behalf of Southern Metropolitan Cemeteries dated 6 July 2017. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Southern Metropolitan Cemeteries for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

DP's advice is based upon the conditions encountered during the site walkover and from desk top assessment. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations, and by variations over time. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

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

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

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements 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.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

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

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

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

Information for Contractual Purposes

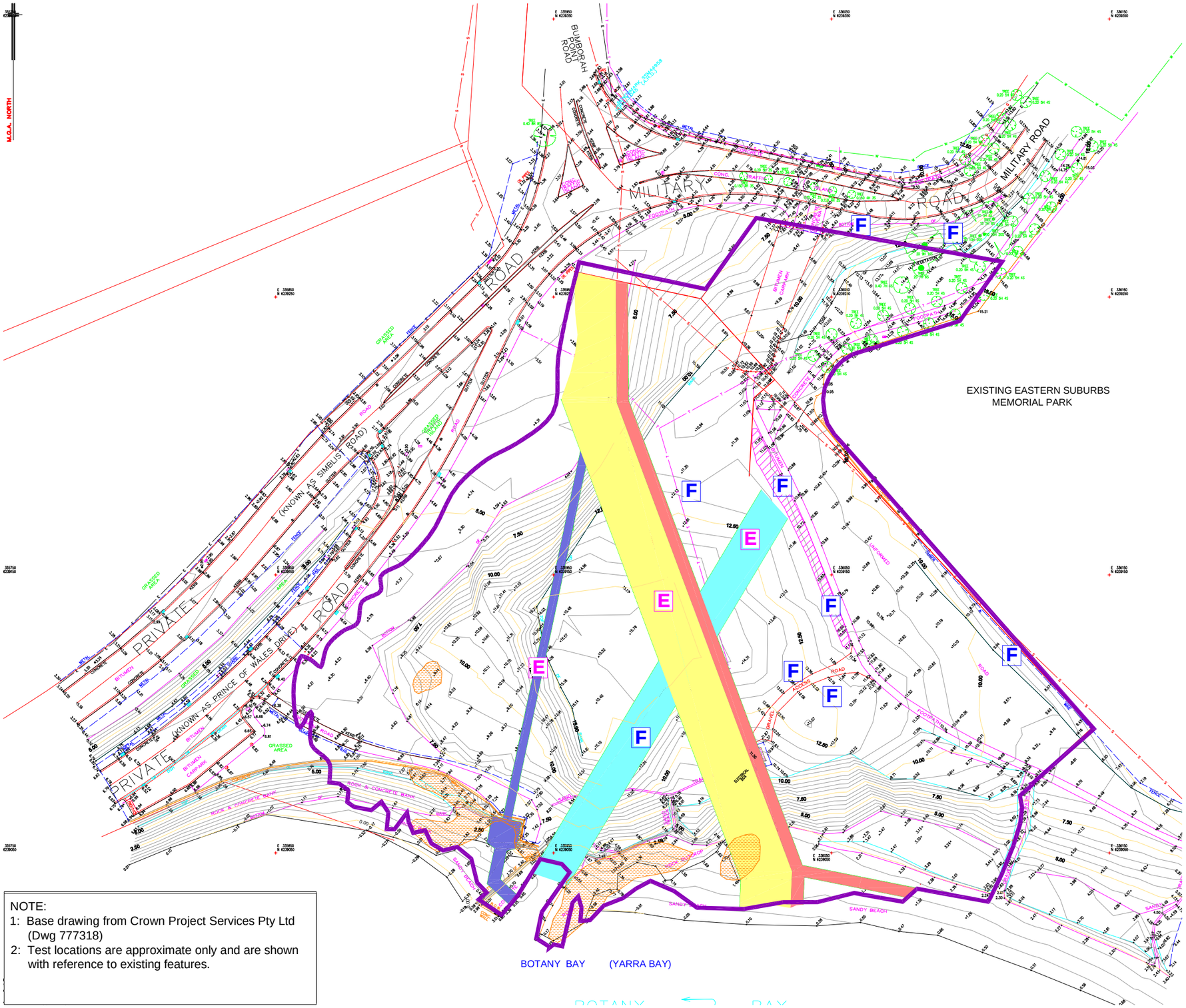
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

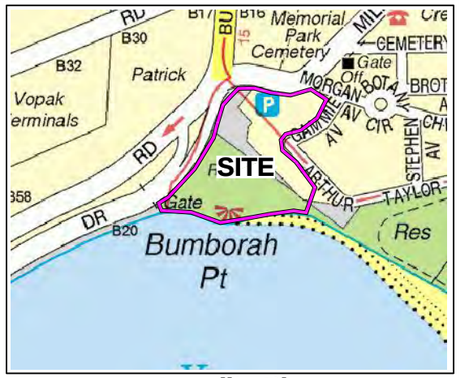
Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawings





Locality Plan

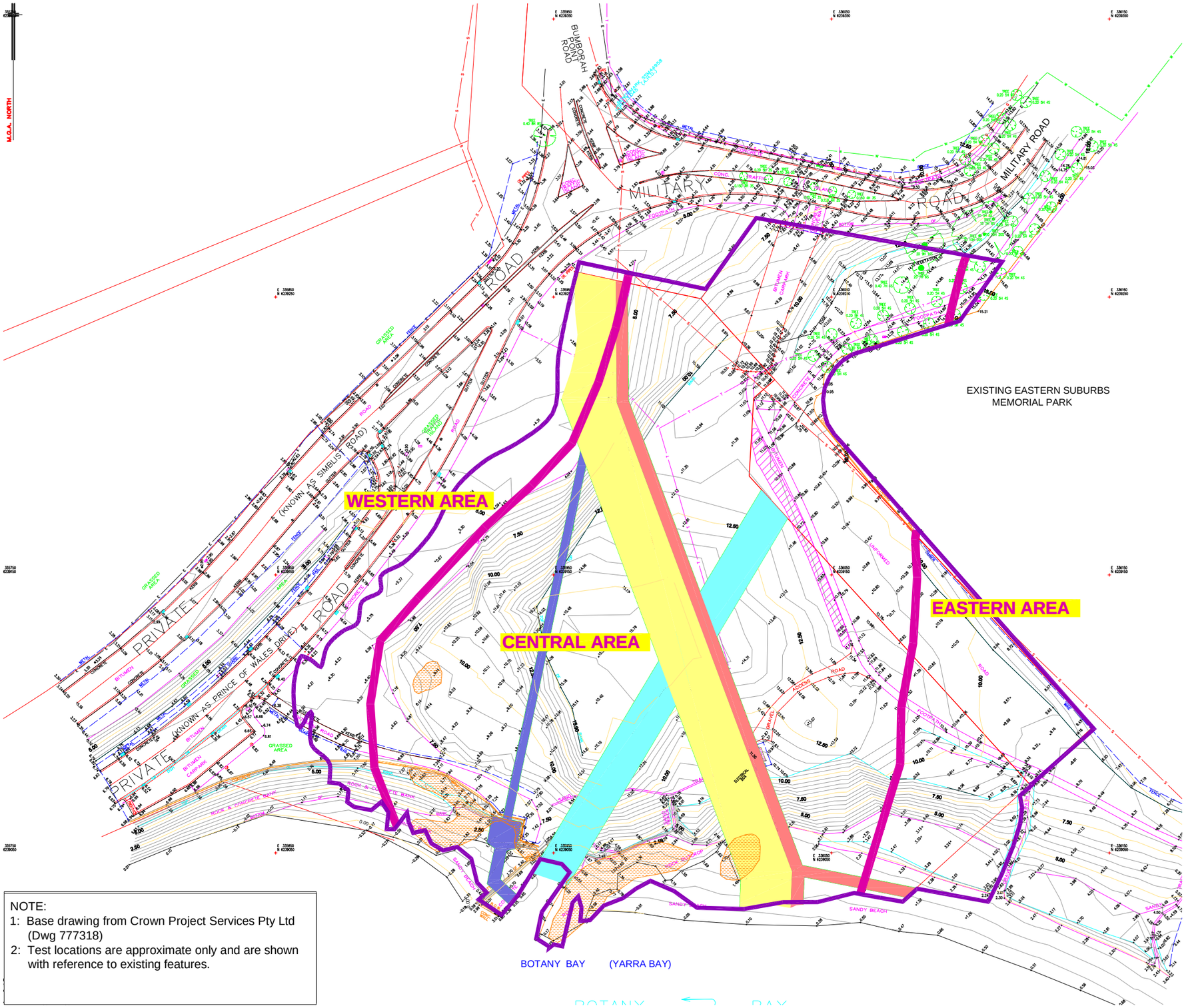
NOTE:
1: Base drawing from Crown Project Services Pty Ltd (Dwg 777318)
2: Test locations are approximate only and are shown with reference to existing features.

LEGEND

- Site Boundary
- Stockpile
- F Areas with visible building rubble
- E Easements
- Sandstone outcrop

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: Southern Metrpolitan Cemeteries Trust		TITLE: **Site Features**	PROJECT No: 86050.00
OFFICE: Sydney	DRAWN BY: PSCH	**Proposed Extension of Existing Cemetery**	DRAWING No: 1
SCALE: 1:1500 @ A3	DATE: 17.01.2018	**Prince of Wales Drive, MATRAVILLE**	REVISION: 1



NOTE:
1: Base drawing from Crown Project Services Pty Ltd (Dwg 777318)
2: Test locations are approximate only and are shown with reference to existing features.

LEGEND

- Site Boundary
- Stockpile
- Sandstone outcrop
- Approximate model area boundary

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Southern Metrpolitan Cemeteries Trust	TITLE: **Geotechnical Model Areas**	PROJECT No: 86050.00
	OFFICE: Sydney / DRAWN BY: PSCH	**Proposed Extension of Existing Cemetery**	DRAWING No: 2
	SCALE: 1:1500 @ A3 / DATE: 17.01.2018	**Prince of Wales Drive, MATRAVILLE**	REVISION: 1

Appendix C

Site Photographs

Photo 1 – Seepage from bedding plane in sandstone rock face, at waterfront.

Photo 2 – Concrete sidewalls and rock fill at the water easement on the waterfront

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs**	PROJECT:	86050.00
	Proposed Extension of Existing Cemetery	PLATE No:	1
	Prince of Wales Dr, Matraville	REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 3 – Sand track towards southern side of site.

Photo 4 – Eroded slope in filling, with coir socks to limit erosion (limited effectiveness)

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs** **Proposed Extension of Existing Cemetery** **Prince of Wales Dr, Matraville**	PROJECT:	86050.00
		PLATE No:	1
		REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 5 – Concrete blocks on elevated ground

Photo 6 – Concrete blocks on elevated ground

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs**	PROJECT:	86050.00
	Proposed Extension of Existing Cemetery	PLATE No:	1
	Prince of Wales Dr, Matraville	REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 7 – Gravel access track on elevated ground.

Photo 8 – Embankment on western side of bitumen track

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs** **Proposed Extension of Existing Cemetery** **Prince of Wales Dr, Matraville**	PROJECT:	86050.00
		PLATE No:	1
		REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 9 – Typical vegetation at western side of site.

Photo 10 – Grassed areas between the Memorial Park (at right) and LPLALC.

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs**	PROJECT:	86050.00
	Proposed Extension of Existing Cemetery	PLATE No:	1
	Prince of Wales Dr, Matraville	REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 11 – Landscaped area between Military Road and the Eastern Suburbs Memorial Park

Photo 12 – Existing Car Park – note damage to existing pavement

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs**	PROJECT:	86050.00
	Proposed Extension of Existing Cemetery	PLATE No:	1
	Prince of Wales Dr, Matraville	REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17

Photo 13 – Filling slope towards Military Road, west of car park.

Douglas Partners Geotechnics ! Environment ! Groundwater	**Site Photographs** **Proposed Extension of Existing Cemetery** **Prince of Wales Dr, Matraville**	PROJECT:	86050.00
		PLATE No:	1
		REV:	0
	CLIENT: Southern Metropolitan Cemeteries Trust	DATE:	12-Jul-17