Douglas Partners
Geotechnics | Environment | Groundwater

Report on
Preliminary Stability Assessment

Proposed Memorial Park
167 – 177 St Andrews Road, Varroville

Prepared for
Catholic Metropolitan Cemeteries Trust

Project 73732.01
March 2017

Integrated Practical Solutions

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

Document details

Project No.	73732.01	Document No.	R.001
Document title	Report on Preliminary Stability Assessment Proposed Memorial Park		
Site address	167 – 177 St Andrews Road, Varroville		
Report prepared for	Catholic Metropolitan Cemeteries Trust		
File name	73732.01.R.001.Rev0		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	R Machiani	A Castrissios	27 March 2017

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	0	Catholic Metropolitan Cemeteries Trust

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		27 March 2017
Reviewer	for AC	27 March 2017

ISO 9001 Quality Management

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Report on Preliminary Stability Assessment
Proposed Memorial Park
167 – 177 St Andrews Road, Varroville

1. Introduction

This report presents the results of a preliminary stability assessment undertaken for a proposed memorial park at 167 – 177 St Andrews Road, Varroville (‘the site’). The assessment was commissioned in an email dated 12 December 2016 by Mr John Richardson of Catholic Metropolitan Cemeteries Trust and was undertaken in accordance with Douglas Partners' (DP) proposal MAC1600290 dated 30 September 2016.

It is understood that consideration is being given to development of the site as a memorial park and cemetery that will include the construction of associated buildings and roadways. Geotechnical assessment is required to provide preliminary comments with regard to the slope stability to assist in the conceptual planning and design of the development.

The assessment comprised desktop study, field mapping by a senior geotechnical engineer and test pit excavation followed by laboratory testing of selected samples, engineering analysis and reporting.

Details of the work undertaken and the results obtained are given within this report, together with comments relating to design and construction practice. Preliminary concept layouts plans and a site contour plan were provided by the client for the investigation.

2. Site Description

The site which includes three lots (Lot B on DP 370979, Lot 22 on DP 564065 & Lot 1 on DP 218016) is an irregular shaped area of approximately 113 ha located 10 km north of Campbelltown. Maximum north-south and east-west dimensions are approximately 2100 m and 800 m respectively. The site is bounded by St Andrews Road to the west and rural land to the north, east and south directions. The majority of the site was vacant at the time of the field work, with only one existing structure noted within the central portion. This building is understood to be heritage listed property and will be kept as a part of the proposed development.

The site is currently used for the purpose of cattle grazing and onsite vegetation noted as sparse grass and scattered trees with communities of medium size trees (<10 m) noted across flat areas of the site. The south-facing slope of Bunbury Curran Hill (in the north of the site) is covered by dense medium size and large trees.

The site encompasses ridgelines and areas of undulating terrains. The ridgelines border the northern and north-eastern ends of the site and slope steeply (15 – 30%) toward south and east. The ground slope then decreases in grade becoming undulating terrains sloping gently (less than 10%) and relatively level to the central and southern portions of the site. The areas of moderate to steep land with slopes greater than 10%, occupies approximately 25 – 30% of the site.

The site has an overall relief of approximately 85 m from the highest point, knowns as Bunbury Curran Hill (approximately RL 150 relative to Australian Height Datum – AHD) to the lowest part within the manmade ponds close the western boundary of the site (approximately RL 65).

3. Regional Geology

Reference to the Wollongong – Port Hacking and Penrith Sheets (Refs. 1 and 2) 1:100 000 Geological Series Sheet indicates that the site is underlain by Bringelly Shale (mapping unit Rwb) of the Wianamatta Group of Triassic age. This formation typically comprises shale, carbonaceous claystone, laminite and fine to medium grained, lithic sandstone members. The results of the field investigation were consistent with the broad-scale geological mapping with sandstone, siltstone or shale encountered in 12 of the 17 test pits.

4. Field Work Methods

The field investigation comprised a walkover assessment by a senior geotechnical engineer to assess the slope stability across the site, identify any signs of previous instability and areas which could be susceptible to potential slope instability. The assessment was followed by an intrusive investigation comprising the excavation of 17 test pits (Pits 1 – 17) to depths of 0.8 – 3.7 m with a JCB 4CX backhoe fitted with a 450 mm wide bucket. The investigation was undertaken in the presence of a geotechnical engineer who collected disturbed samples to assist in strata identification and for laboratory testing. Dynamic cone penetrometer (DCP) tests (AS1289 6.3.2) were undertaken at the test pit locations to assess the in-situ strength of the upper 0.5 – 1.2 m of the subsurface profile. Following logging and sampling, each test pit was backfilled and the ground surface was reinstated to its previous level.

The test pits locations were nominated by DP and located on site prior to the investigation using a differential GPS unit for which an accuracy of ± 20 mm is typical. The location of test pits are shown on Drawing 1 (Appendix A). The surface levels were obtained using the differential GPS unit.

All field measurements and mapping for this project were carried our using the Geodetic Datum of Australia 1994 (GDA94) and the Map Grid of Australia 1994 (MGA94). All reduced levels are given in relation to Australian Height Datum (AHD).

5. Field Work Results

The test pits logs are included in Appendix B which should be read in conjunction with the accompanying standard notes that define classification methods and descriptive terms. Relatively uniform conditions were encountered in the test pits, with the general succession of strata broadly summarised as follows:

- TOPSOIL – brown/grey silty clay with trace rootlets and gravel to depths 0.1 – 0.3 m (but generally 0.3 m) in all test pits;

- COLLUVIUM –brown silty clay with some gravel and cobble size particles to depths of 1.4 m (Pits 4) and 3 m (Pit 8) and to the termination depths of 3.7 m (Pit 7) and 3 m (Pit 7);
- CLAY – red brown and orange brown silty clay with seams of extremely weathered shale to depths of 0.5 – 1.7 m in Pits 1 – 3, 5, 9 – 15 &17 and to the termination depths of 2.0 – 2.7 m in Pits 4, 8 & 16; and
- BEDROCK – extremely low strength to medium strength sandstone, shale and siltstone generally at depths within the range 0.5 m to 2.3 m Pits 1 – 3, 5, 9 – 15 &17 and continuing to the termination depth of 0.8 – 2.5 m;

No free groundwater was observed in the test pits during excavation and for the short time that they were left open. It is noted, however, that the test pits were immediately backfilled following logging and sampling which precluded longer term monitoring of any groundwater levels that might be present. Groundwater levels are affected by factors such as weather conditions and will vary with time.

6. Laboratory Testing

Selected samples from the test pits were tested in the laboratory for measurement of field moisture content, Atterberg limits and linear shrinkage. The detailed laboratory test report sheets are given in Appendix C, with the results summarised in Table 1.

Table 1: Results of Atterberg Limits and Linear Shrinkage Testing

Pit No.	Depth (m)	W_F (%)	W_L (%)	W_P (%)	PI (%)	LS (%)	Material
2	0.3 – 0.5	13.1	45	18	27	13.5	Silty Clay
4	0.3 – 0.5	13.1	43	17	26	11.0	Colluvium
5	0.3 – 0.5	15.6	65	29	36	11.5	Silty Clay
6	1.8 – 2.0	14.0	41	16	25	9.5	Colluvium
8	0.9 – 1.0	15.0	62	17	45	15.0	Colluvium
15	0.3 – 0.6	12.4	47	17	30	9.0	Silty Clay

Where W_F = Field moisture content
W_L = Liquid limit
LS = Linear shrinkage
W_P = Plastic limit
PI = Plasticity Index

The results indicate that the tested clays are of intermediate to high plasticity and as such, would be expected to be susceptible to shrinkage and swelling movements due to change in moisture content.

7. Proposed Development

The construction of a memorial park and cemetery within the site is proposed. As part of the development, several roadways will be constructed as well as associated facilities comprising buildings, monuments and carparks. The final earthworks plans and detailed design of structures were not finalised prior to the field work. However, minimal cutting and filling are anticipated to be required for the development.

8. Comments

8.1 General

The following comments are based on findings of desktop study, observations of walkover inspection and subsurface profiles encountered in the test pits.

The main objective of this investigation was undertake a stability assessment of the sloping areas of the site to assist in the earthworks design of the proposed new roadways and buildings. Further detailed geotechnical investigation is required to provide subsurface information and foundation design parameters at the footprint of each individual structure.

As detailed design of the proposed development has not been undertaken, the comments given must also be considered as being preliminary in nature. Once details are available, they must be forwarded to DP for review to determine if comments given within this report are appropriate or require revision.

8.2 Desktop Study

The desktop study comprised a review of published geological maps and aerial photographs of the area together with the Macarthur Memorial Park Masterplan prepared by Florence Jaquet Architects.

The latter provided the site contour map (Figure 1) and the location of proposed structures within the site. The site contour map suggests the natural batter grade across the majority of the site is relatively flat or gently inclined with slopes between 10 – 12%. The Masterplan, indicates the general topographical features of the site (eg. existing ground slopes, dams, vegetation, etc) will be kept during the site development.

A review of aerial photographs of the area indicated signs of previous landslips on the northern side of the site along the south-facing slopes of Bunbury Curran Hill. The change of colour in the vegetation cover on this section of the site can be considered as an indicative of ongoing soil creep. Taking into account the findings of background search, the inferred extent of colluvium is shown on Drawing 1 (Appendix A).

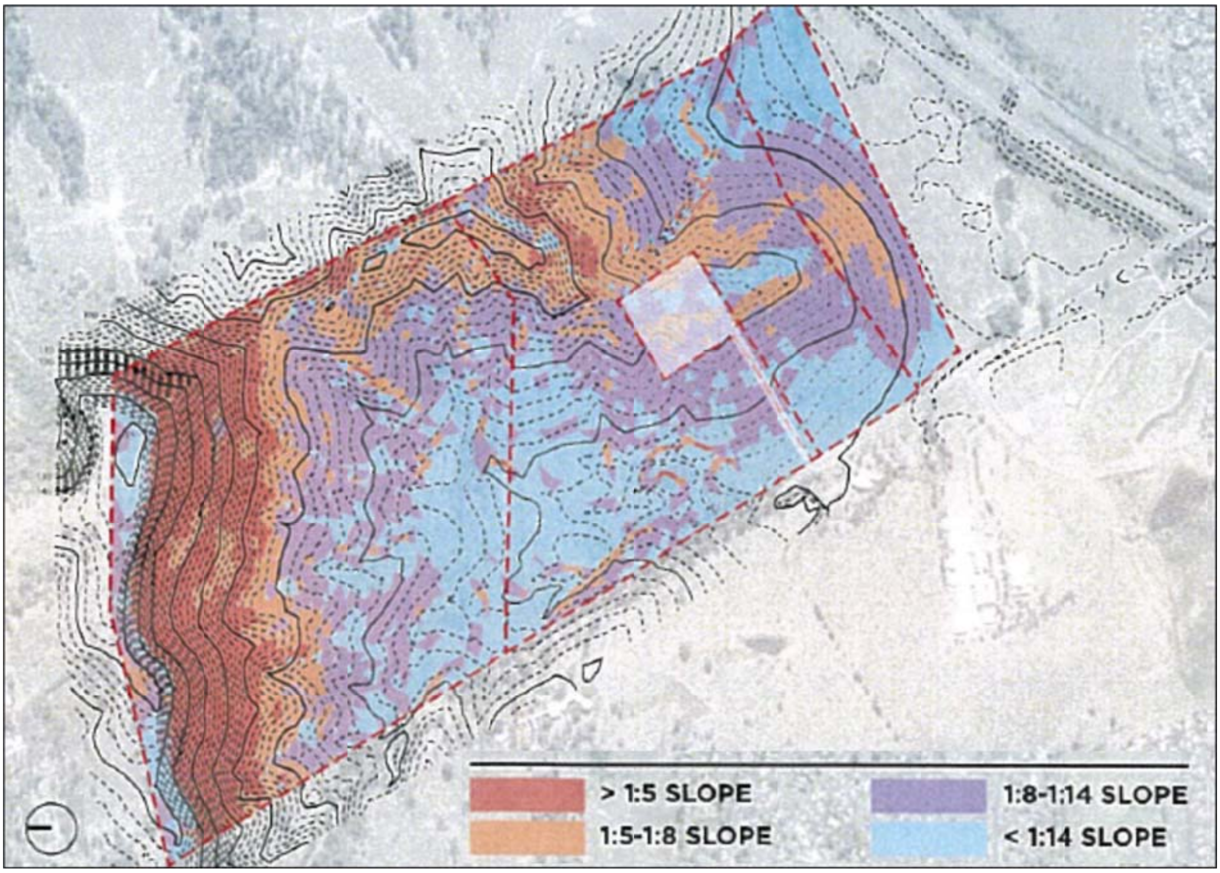

Figure 1 – Site contours (extract from Macarthur Memorial Park Masterplan)

8.3 Site Observations

The field observations during walkover inspection confirmed the findings of desktop study. Signs of previous slope movements in the form of local surface irregularities were observed along the gently inclined south-facing slopes of Bunbury Curran Hill. The typical site condition at the surface of the colluvial areas is shown in Figure 2.

During walkover inspection, the extent of the colluvial area could not be accurately determined due to sloping site and presence of medium size trees within this area. As such, the test pits were excavated to provide subsurface information at targeted locations. The hummocky areas were generally void of trees. However, upright tree growth patterns of the medium size trees on the upper slopes of the hill did not show significant signs of ongoing slope movement.

The available concept designs indicate the footprint of the Chapels & Condolence Rooms, one of the main buildings of the development, falls within the identified affected area.

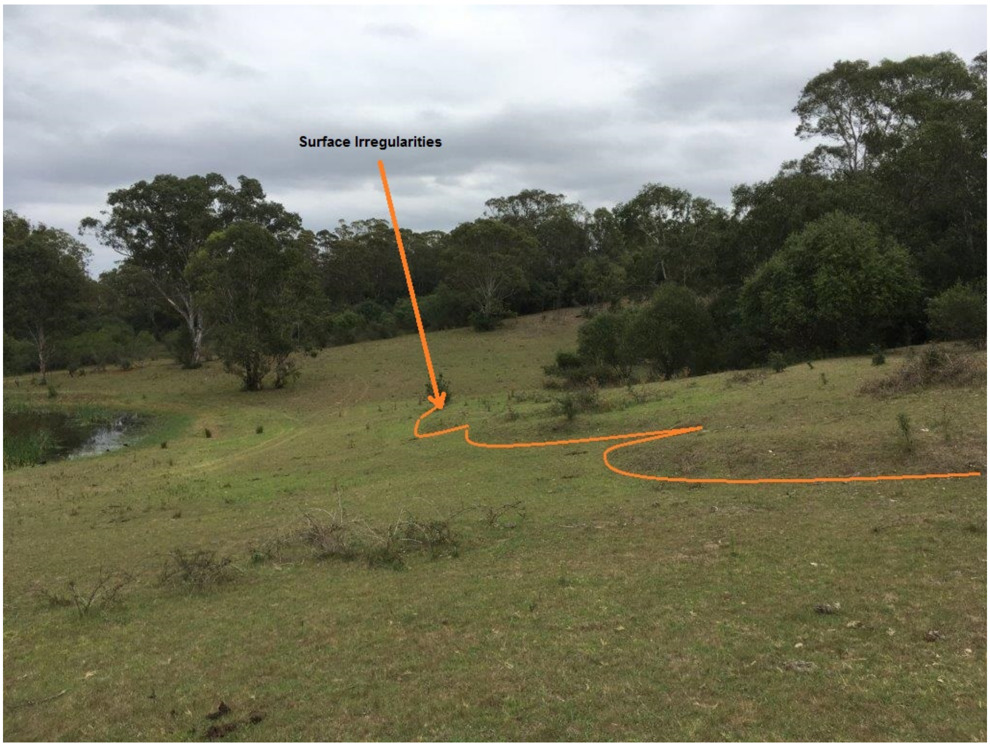

Figure 2 – Local surface irregularities in the vicinity of Pit 3 (looking west)

Based on the site observations, stormwater run-off appears to be one of the major issues concerning the site development. There are signs of severe soil erosion resulting from surface run-off particularly across the sloping areas in which the loss of protective cover is evident. Signs of erosion and rilling were observed towards the eastern boundary along an existing track in the vicinity of eastern boundary (Figures 3 & 4). The presence of clayey soils of low permeability at the surface of moderately sloping ground underlain by weathered rock has exacerbated the impact of surface run-off across these areas. The signs of tunnel erosion beneath the access track were observed in two locations (Figure 5). The loss of surface grass could be resulted from both human activities (site preparation for agricultural purposes, road construction, etc) and stormwater run-off.

There was a drainage depression immediately to the south of the eroded areas running towards an existing dam at the central portion of the property (Figure 6).

Figure 3 – The effect of stormwater run-off

Figure 4 – The effect of stormwater run-off

Figure 5 – The effect of stormwater run-off (tunnel erosion)

Figure 6 – Drainage Depression (looking north)

8.4 Subsurface Conditions

The results of the investigation have indicated that subsurface conditions underlying the site generally comprise topsoil to depths 0.1 – 0.3 m overlying stiff to hard silty clay and gravelly clay. In Pits 4, 6, 7 and 8, the topsoil was underlain by colluvium to depths within the range 1.4 – 3.7 m. The thickness of colluvium within Pits 6 and 7 could not be identified as it continued beyond the termination depth of both test pits. Bedrock generally comprising weathered shale and siltstone was found in 12 of the 17 test pits at depths within the range 0.5 – 2.3 m.

8.5 Stability Risk Assessment

The site has been divided into three general risk of instability zones (low, moderate and high risk of instability) as summarised below. The approximate interpreted zone boundaries are shown on Drawing 2 (Appendix A).

8.5.1 Low Risk

This zone is characterised by gently sloping footslopes and the broader crests of undulating areas with slopes generally less than 10°.

Instability should not generally be expected within the zone unless major changes to site conditions occur. Minor instability may locally occur where concentrated seepage and erosion occurs in areas of deep soil profiles. The provision of subsurface drainage may be locally required in zones of seepage.

8.5.2 Moderate Risk

This zone is characterised by moderate slopes generally in the range 10° to 15° identified across the northern and eastern sections of the site. Taking into account the surface slope and the presence of colluvium within the range 1.4 m to excess of 3.4 m, it is considered that a moderate risk classification should be adopted for these areas. The most likely failure mechanism is considered soil creep within the colluvium with anticipated thickness of approximately 3 – 4 m. The other potential hazards which are less likely could include deep seated slope failures and earthflows.

In areas of gentler slope, but with possible colluvium, a low to moderate or moderate risk has been included. Similarly, moderate to high risk zoning has also been included to indicate transition zones of increased assessed risk, generally associated with moderate slope angle and deeper soil profiles potentially affected by previous slope movements and periodic seepage lines.

Instability in the zone can be expected if development does not have regard to site conditions, with the most likely areas of instability being in areas of colluvium particularly when affected by earthworks and seepage.

8.5.3 High Risk

This zone is generally characterised by the steep lands (slopes greater than 15%) across the upper slopes of Bunbury Curran Hill. It is considered that localised instability may occur during and after extreme rainfall events. Any development requires detailed planning and care in construction, particularly related to presence of colluvium, cutting and filling of slopes and the control of surface run-off and groundwater seepage. It is noted however, that the high risk zoning would preclude construction of any structures.

8.6 Site Preparation and Earthworks

Although, only minor earthworks are planned for the proposed development, due to presence of colluvium on site, cut-fill may be required to prepare building envelopes or regrade the site by replacing unsuitable material with suitable filling.

Excessive filling over the sloping areas of the site may cause instability and creep, and should be avoided. It is recommended that excavation into the sloping areas should be minimized. Excavations will need to be supported by engineer-designed retaining structures that take into account the slope behind the excavation.

To prepare the site for the construction of new structures, the following procedures are suggested.

- Strip any topsoils, root affected soils and other deleterious material. Organic topsoil may be stockpiled for future use for landscaping purposes or disposal to spoil;
- Inspect and test roll the exposed surface under the direction of a geotechnical engineer and treat any weak subgrade areas revealed by excessive movement by over-excavation and replacement or, in pavement areas, by placement of a coarse granular bridging layer;
- Suitably bench the stripped area, to facilitate near-horizontal fill placement;
- Where filling is required to attain site levels, place approved materials in near-horizontal layers of maximum 250 mm loose thickness;
- Compaction of new filling to a dry density ratio (DDR) of 98 – 102% relative to standard compaction, with moisture contents maintained within 2% of the optimum moisture content (OMC) for laboratory standard compaction.
- Care should be taken to avoid the drying out of natural clays or engineered filling during construction. A protective layer or membrane should be used in conjunction with regular site watering, if appropriate.
- It is recommended that all filling be placed and compacted in accordance with Level 1 requirements (AS3798 – 2007). Filling should not contain vegetation or other organic matter.
- In order to minimise the effects of erosion and to prevent drying of the site soils, the site will need to be revegetated immediately after completing filling/regrading; this should include a minimum of 100 mm of topsoil.

8.7 Batter Slopes

While cut slopes within the clays may often stand vertically and unsupported (provided no nearby structures are present) for short periods of time, they will rapidly lose strength upon exposure to weather. A maximum batter slope of 2(H):1(V) is recommended for permanent slopes in stiff clays, provided that the slopes are no more than 4 m in height and they are protected against surface erosion and local slumping. Where the slopes are to be vegetated to prevent erosion, a maximum batter slope of 3(H):1(V) is recommended.

If batters greater than 4 m in height are required, the inclusion of an intermediate bench every 5 m in height, approximately 3 m wide, is recommended to reduce the effects of scour and erosion.

Where filling batters are proposed, filling should be limited to no greater than 1 m and fill platforms should be battered to no steeper than 3(H):1(V) or supported by an engineered retaining wall founded into the bedrock to an adequate depth. It is recommended that whilst the slope is being formed the batters should be over-filled in near-horizontal lifts and cut back to form the design grades.

Earthworks operations within slope movement affected areas and construction of roads or buildings may cause further instability. The factor of safety and stability of the final batters, are governed by the material type, groundwater condition, surcharge loads and the time of construction. The maximum unprotected safe batter slope in steeper topography should be limited to less than 1.5 m above or below the existing ground surface.

In order to maintain the global stability and enhance the factor of safety against slope instability after construction of the roadways and other structures, remedial works may be required for the landslip affected areas of the site. Remedial options could be either in the form of a piled retaining wall or removal of the colluvium and regrading the areas or a combination of both options. The need and extent of such work, is best determined as part of specific geotechnical investigations undertaken at the appropriate time as planning and design progresses.

The project considers minimal changes to the ground slopes. As such, removal of colluvium and regrading the landslip affected areas may be limited to the flatter slopes within the footprint of proposed Chapel Building. Given that the extent of the colluvium along the slope could not be determined accurately as the majority of the areas are covered by medium size trees, a piled retaining structure may be required at the upper limit of the regarding profile. All excavations in colluvium are recommended to be supported by suitably designed retaining walls.

To avoid saturation of soils at the upper parts of slope which subsequently could lead to instability, a suitably designed and constructed drainage system is required to collect stormwater at the crest of Bunbury Hill and the sloping ground along the eastern boundary and discharge beyond a point at least 5 m from the slope crest.

Colluvium generally has slight or no shear resistance when saturated and the factor of safety of the excavated batters will be reduced significantly in undrained conditions.

8.8 Retaining Walls

Where engineer-designed retaining walls are proposed, the following measures should be incorporated into the design:

- Backfilling of the void between the wall and the slope using imported, free draining granular material connected into a drainage pipe at the base of the wall;
- Capping of the backfill (where exposed) with compacted clay or concrete to prevent surface runoff entering the backfill;
- Provision of an open drain to collect and divert surface runoff from ponding above the wall;
- For horizontal backfill or retained soils, design based on an average bulk unit weight for retained material of 20 kN/m^3 and on a triangular earth pressure distribution based on an active earth pressure coefficient of (K_a) 0.3 for compacted filling and natural clay where no movement sensitive structures are located within a horizontal distance of 2H (where H is the vertical height of the retained zone) of the rear of the wall;
- Where there are movement sensitive structures located within the abovementioned critical zone, an at rest pressure coefficient (K_0) of 0.6 should be adopted;
- If hydrostatic pressures are allowed, soil densities could be reduced to the buoyant values.

If a drainage medium is not provided behind the retaining wall, then hydrostatic pressures must be incorporated within the design. Similarly, surcharge loads and the slope behind the wall need to be considered in the determination of active earth pressure coefficient, as those given above are for horizontal backfill only.

8.9 Footings

The principal recommendation fo footings in hillside areas is for the provision of a uniform bearing stratum below the zone fo potential soil creep. In this regard, preliminary design should allow for footings to be found and socket within weathered rock.

Design of footings for the structures can only be undertaken once the final design loads and finished levels have been determined. The design parameters and allowable bearing capacity of each structure should be provided by investigation at the footprint of each individual building. As a guide however and based on the results of the subsurface investigation and the range of soils encountered, preliminary footing design could be based on the parameters presented in Table 4.

Table 4: Preliminary Footing Design Parameters

Material	Allowable Base Bearing Pressures (kPa)
Colluvium	-
Stiff clay or controlled filling	150
Very stiff clays or stronger	250
Weathered rock	500

8.10 Site Maintenance and Drainage

The developed site should be maintained in accordance with the CSIRO publication "Guide to Home Owners on Foundation Maintenance and Footing Performance", a copy of which is included in Appendix D. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits.

Surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system. The possible need for subsurface drainage installation as part of individual building and roadway construction (particularly within the moderate risk zone) is noted, the extent of which is best determined once site-specific development details are determined.

9. Summary

The assessment included a desktop study, followed by walkover inspection and excavation of 17 test pits within the targeted areas of the site.

The test pits have indicated that subsurface conditions underlying the site generally comprise topsoil to a depth of 0.1 m, overlying stiff to hard silty clay. Colluvium was encountered in Pits 4, 6, 7 & 8 and continued beyond the termination depth of test pits at Pits 6 and 7. Bedrock generally comprising weathered shale and siltstone was found in all test pits with the exception of Pits 4, 6 – 8 & 16 at depths within the range 0.5 – 2.3 m.

The site has been divided into three general risk of instability zones (low, moderate and high risk of instability) as discussed in Section 8.5. The gently sloping areas of the site are considered stable with regards to instability in the current state. Taking into account the surface slope and the presence of colluvium, it is considered that the areas moderate slopes generally in the range 10° to 15° have the potential of large scale slope instability and recommendation of this report should be considered to reduce the risk of instability to a tolerable level. Any development in areas with slopes greater than 15° requires detailed planning and care in construction.

Safe batter slopes and remedial options to reduce the risk of instability are discussed in Section 8.7.

The site preparation and earthworks are to be undertaken in accordance with Section 8.6. The preliminary bearing capacity parameters for the design of footing are given in Table 4.

Consideration must be given to the preliminary nature of the investigation and potential for variability in the subsurface condition across the site. Should onsite materials differ from what has been encountered in test pits, it may be necessary to re-assess the recommendations of this report.

10. References

1. Geology of 1:100 000 Wollongong – Port Hacking Geological Series Sheet No 9029 – 9129, Dept of Mines, (1985).

2. Geology of Penrith 1:100 000 Geological Series Sheet No 9030, NSW Geological Survey, (1991).
3. Australian Standard AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.
4. Australian Geomechanics Society (AGS), Practice Note Guidelines for Landslide Risk Management.

11. Limitations

Douglas Partners (DP) has prepared this report (or services) for this project at 167 – 177 St Andrews Road, Varroville NSW in accordance with DP's proposal dated 30 September 2016 and acceptance received from Mr John Richardson dated 12 December 2016. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Catholic Metropolitan Cemeteries Trust for this project only and for the purposes as described in the report. It should not be used for other projects or 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.

Douglas Partners Pty Ltd

Appendix A

About This Report
Drawings 1 and 2

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.

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This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

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.

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.

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

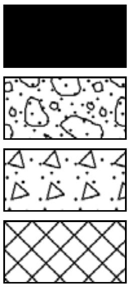
Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

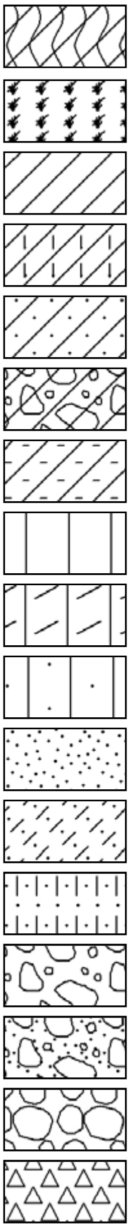
Graphic Symbols for Soil and Rock

General



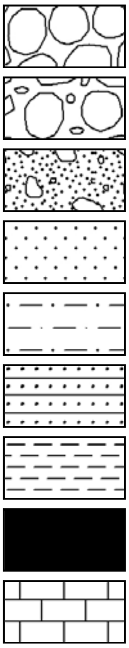
Asphalt
Road base
Concrete
Filling

Soils



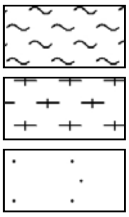
Topsoil
Peat
Clay
Silty clay
Sandy clay
Gravelly clay
Shaly clay
Silt
Clayey silt
Sandy silt
Sand
Clayey sand
Silty sand
Gravel
Sandy gravel
Cobbles, boulders
Talus

Sedimentary Rocks



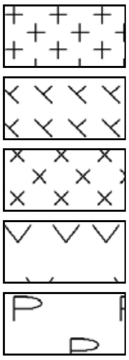
Boulder conglomerate
Conglomerate
Conglomeratic sandstone
Sandstone
Siltstone
Laminite
Mudstone, claystone, shale
Coal
Limestone

Metamorphic Rocks



Slate, phyllite, schist
Gneiss
Quartzite

Igneous Rocks



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

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, 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.

Rock Descriptions

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approx Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Core lengths mostly > 1000 mm

Rock Descriptions

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100\text{ mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

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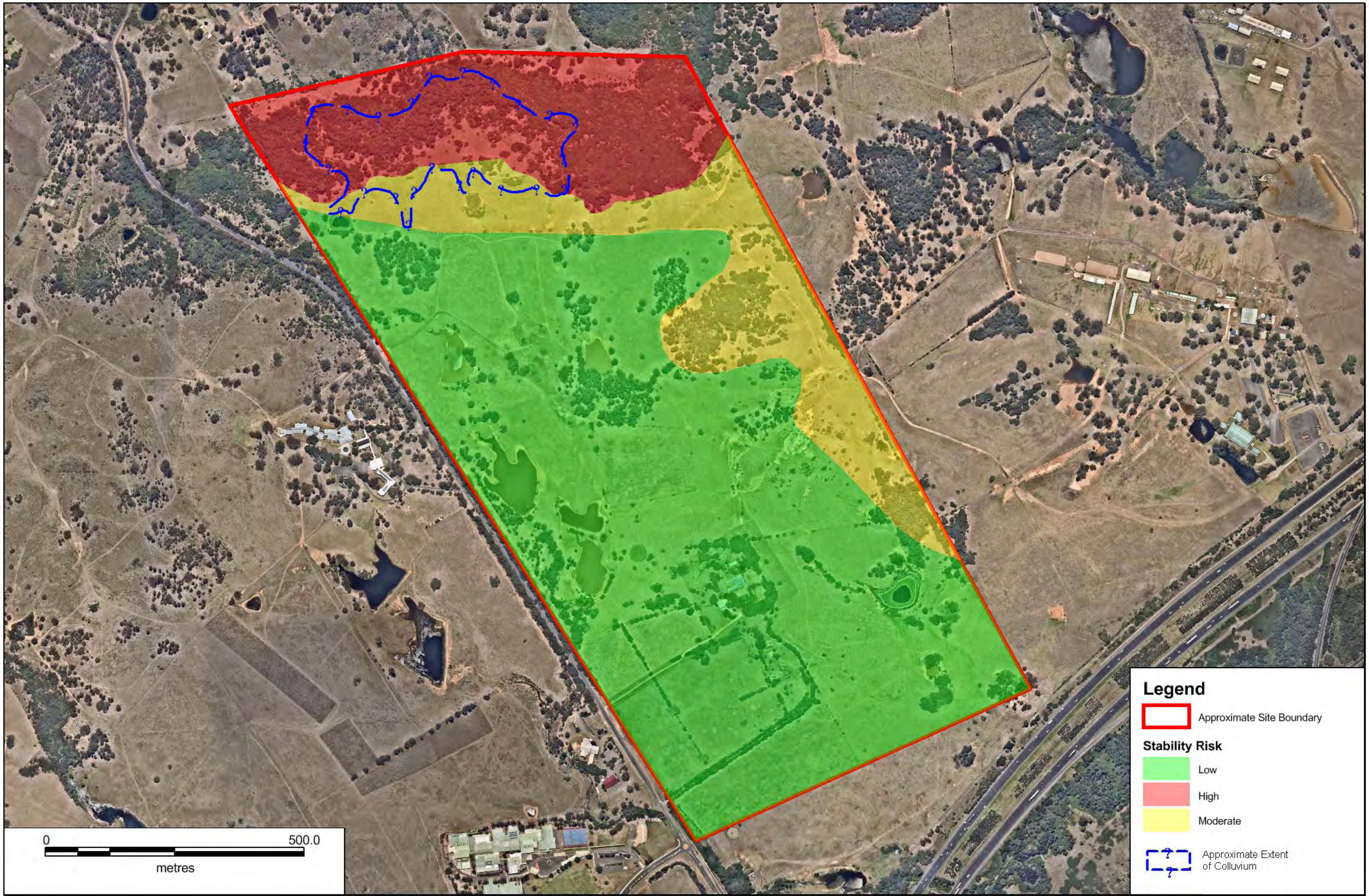
CLIENT: Catholic Metropolitan Cemeteries Trust
OFFICE: Macarthur
DRAWN BY: IKA
SCALE: As shown
DATE: 6.03.2017

TITLE: **Approximate Test Pit Locations**
Proposed Memorial Park
167 - 177 St Andrews Road, Varroville, NSW

N
MGA

PROJECT No: 73732.01
DRAWING No: 1
REVISION: 0



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CLIENT: Catholic Metropoloitan Cemeteries Trust
OFFICE: Macarthur
DRAWN BY: IKA
SCALE: As shown
DATE: 27.03.2017

TITLE: Stability Assessment
Proposed Memorial Park
167 - 177 St Andrews Road, Varroville, NSW

MGA N

PROJECT No: 73732.01
DRAWING No: 2
REVISION: 0

Appendix B

Test Pit Logs (Pits 1 – 17)

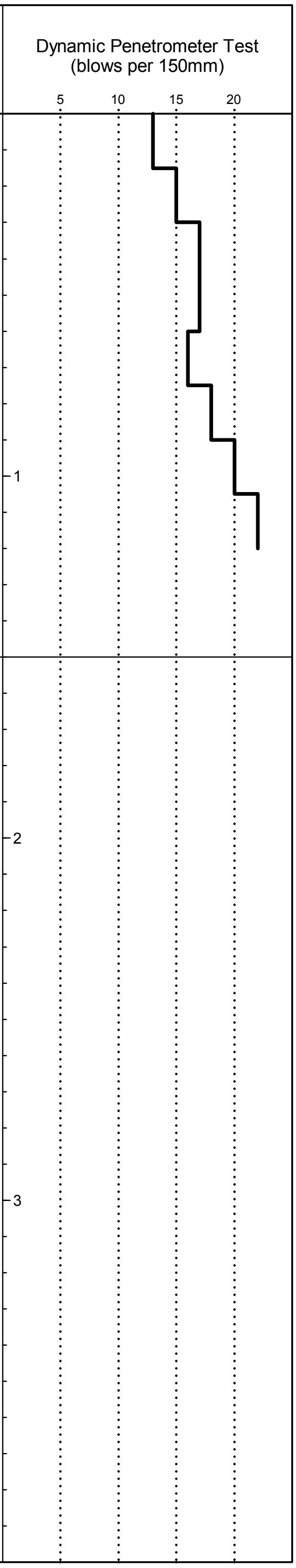
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 74.0 mAHD
EASTING: 298642
NORTHING: 6235880

PIT No: 1
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Sampling & In Situ Testing Depth	Sampling & In Situ Testing Sample	Sampling & In Situ Testing Results & Comments	Water
74		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.3	SILTY CLAY - hard, red to orange mottled grey silty clay, MC~PL (RESIDUAL)		D	0.5		pp >600	
73	1 1.0	SHALE - extremely low strength, extremely weathered, light grey interbedded siltstone and sandstone - becoming very low to low strength, highly weathered below 1.3m		D	1.0			
	1.5	Pit discontinued at 1.5m - limit of investigation						
72	2							
71	3							



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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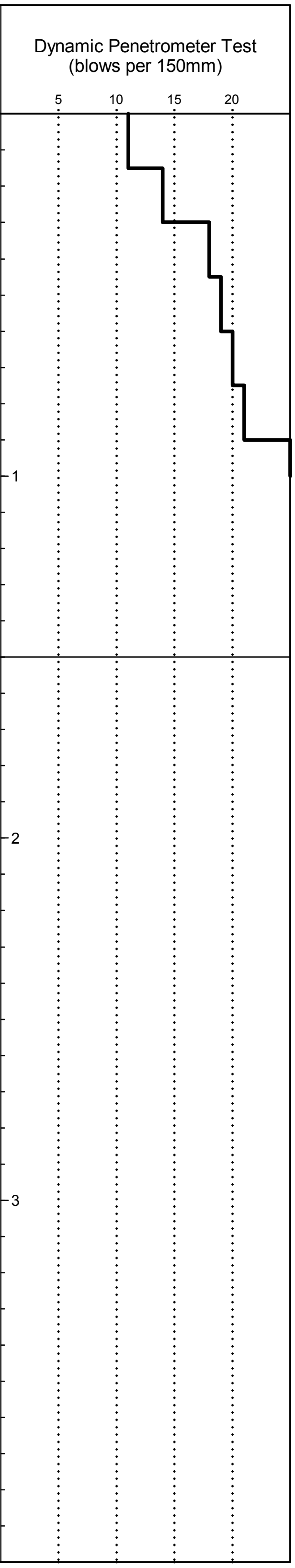
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 86.0 mAHD
EASTING: 298388
NORTHING: 6235986

PIT No: 2
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
86		TOPSOIL - brown clayey silt with a trace of rootlets, moist					
	0.3	SILTY CLAY - hard, brown mottled orange silty clay, fissured, MC<PL (RESIDUAL)	D	0.5		pp >600	
	0.9	SILTSTONE - extremely low strength, extremely weathered, grey to brown siltstone					
85	1		D	1.0			
		- becoming very low to low strength, highly weathered below 1.3m					
	1.5	Pit discontinued at 1.5m - limit of investigation	D	1.5			
84	2						
83	3						



RIG: JCB 4CX backhoe - 450mm wide bucket

LOGGED: ECR

SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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TEST PIT LOG

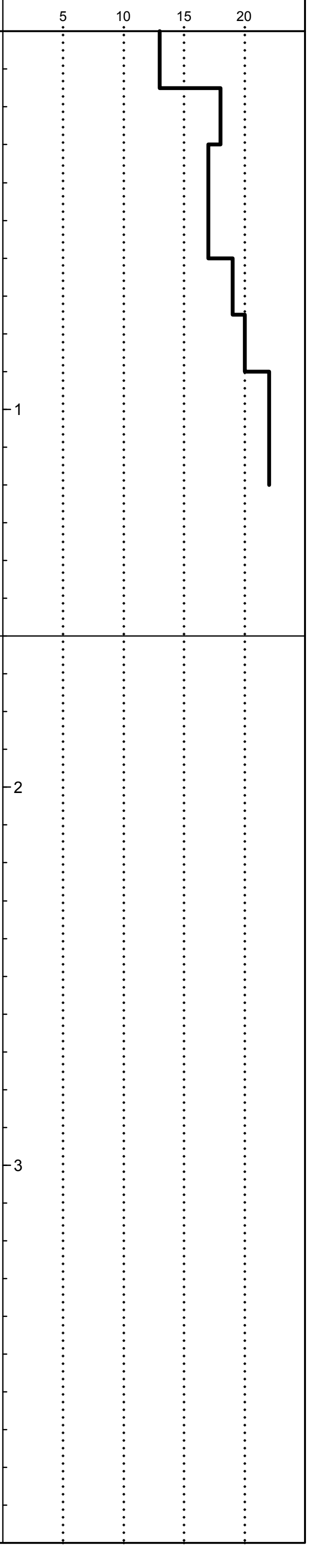
CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 87.0 mAHD
EASTING: 298456
NORTHING: 6236023

PIT No: 3
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
87	0.0	TOPSOIL - brown silty clay with a trace of rootlets, moist					
	0.3	SILTY CLAY - hard, orange brown silty clay, MC<PL (RESIDUAL)	D	0.5		pp >600	
		- with low strength siltstone bands below 0.8m					
86	1						
	1.3	SILTSTONE - low strength, highly weathered, brown siltstone					
	1.6	Pit discontinued at 1.6m - limit of investigation					
85	2						
84	3						

Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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TEST PIT LOG

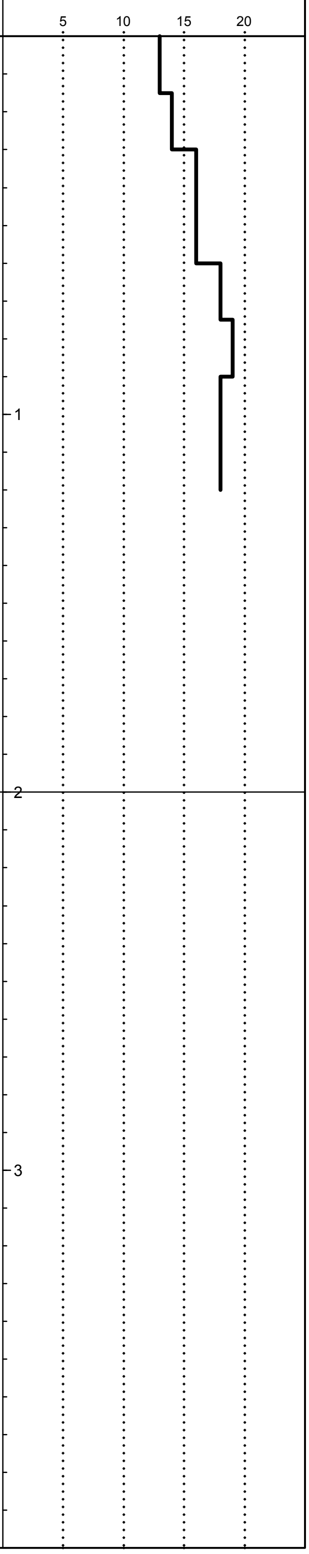
CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 80.0 mAHD
EASTING: 298580
NORTHING: 6235986

PIT No: 4
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
80		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.3	SILTY CLAY - hard, brown silty clay with a trace of sandstone and siltstone gravel, MC<PL (COLLUVIUM)						
				D	0.5		pp >600	
		- with some sandstone cobbles below 0.8m						
79	1			D	1.0		pp >600	1
		- sandstone boulder at 1.3m						
	1.4	SILTY CLAY - hard, dark brown silty clay, MC<PL (RESIDUAL)						
				D	1.5		pp >600	
78	2 2.0	Pit discontinued at 2.0m - limit of investigation		D	2.0		pp >600	2
77	3							3

Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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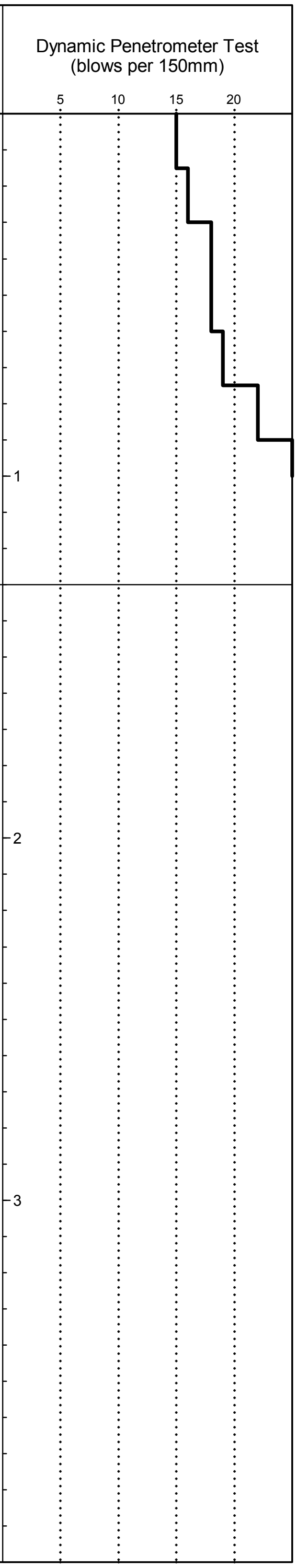
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 87.0 mAHD
EASTING: 298667
NORTHING: 6236024

PIT No: 5
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
87		TOPSOIL - brown silt and clay with a trace of rootlets, moist					
	0.3	SILTY CLAY - hard, orange brown silty clay, MC<PL (RESIDUAL)	D	0.5		pp >600	
86	0.8	SILTSTONE - very low to low strength, highly weathered, brown and grey siltstone	D	1.0			
	1.3	Pit discontinued at 1.3m - limit of investigation					
85	2						
84	3						



RIG: JCB 4CX backhoe - 450mm wide bucket

LOGGED: ECR

SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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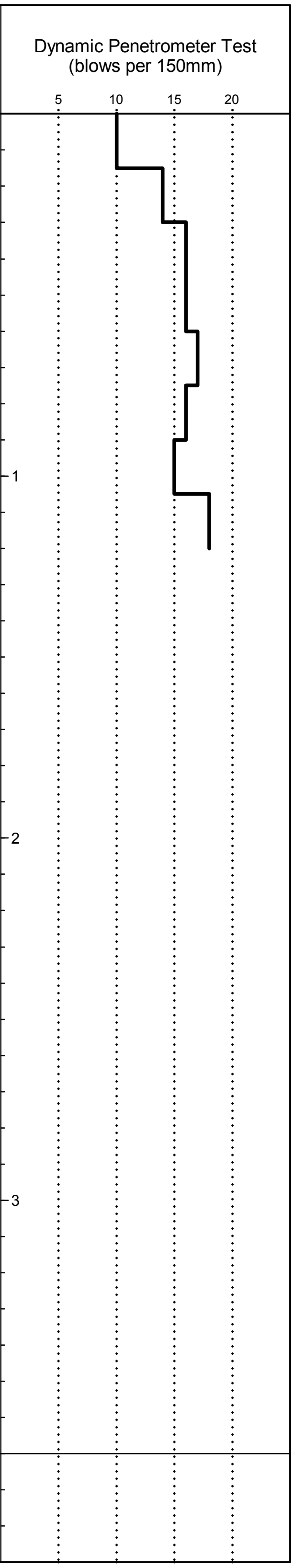
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 92.5 mAHD
EASTING: 298690
NORTHING: 6236146

PIT No: 6
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - brown clayey silt with a trace of rootlets, friable, moist						
	0.3	SILTY CLAY - hard, brown silty clay with a trace of sandstone gravel and cobbles, MC<PL (COLLUVIUM)						
92				D	0.5		pp >600	
	1			D	1.0		pp >600	
91				D	1.5		pp >600	
		- becoming dark brown, moist below 1.8m						
	2			D	2.0		pp >600	
90				D	2.5		pp >600	
	3	- becoming brown and grey below 3.0m		D	3.0		pp >600	
89		- possible slip plane at 3.5m		D	3.5		pp >600	
	3.7	Pit discontinued at 3.7m - limit of investigation						



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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TEST PIT LOG

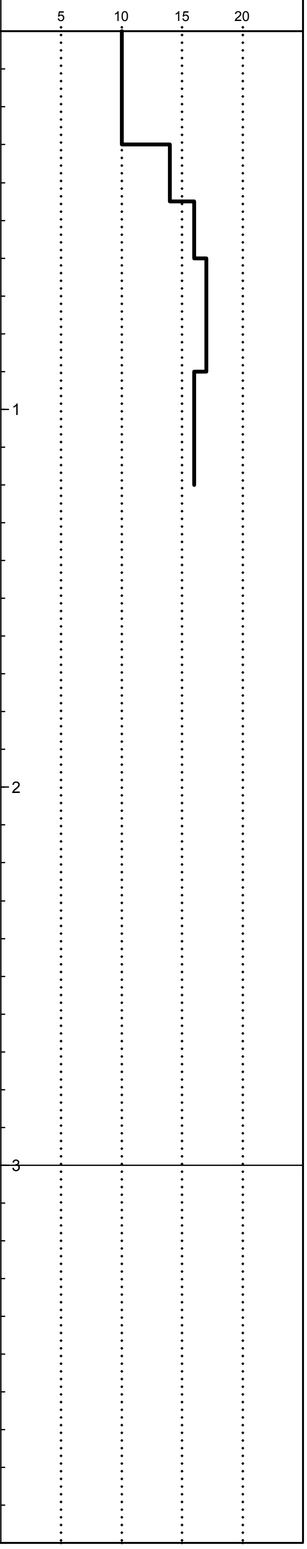
CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 105.0 mAHD
EASTING: 298788
NORTHING: 6236048

PIT No: 7
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
105		TOPSOIL - brown clayey silt with a trace of rootlets, friable, moist					
	0.3	SILTY CLAY - hard, light brown silty clay with a trace of sandstone cobbles, MC<PL (COLLUVIUM)					
			D	0.5		pp >600	
104	1		D	1.0		pp >600	
			D	1.5		pp >600	
103	2	- becoming very stiff, brown and grey below 2.0m	D	2.0		pp = 250-32	
		- becoming very stiff to hard below 2.5m	D	2.5		pp = 350-400	
102	3 3.0	Pit discontinued at 3.0m - limit of investigation	D	3.0		pp = 350-450	

Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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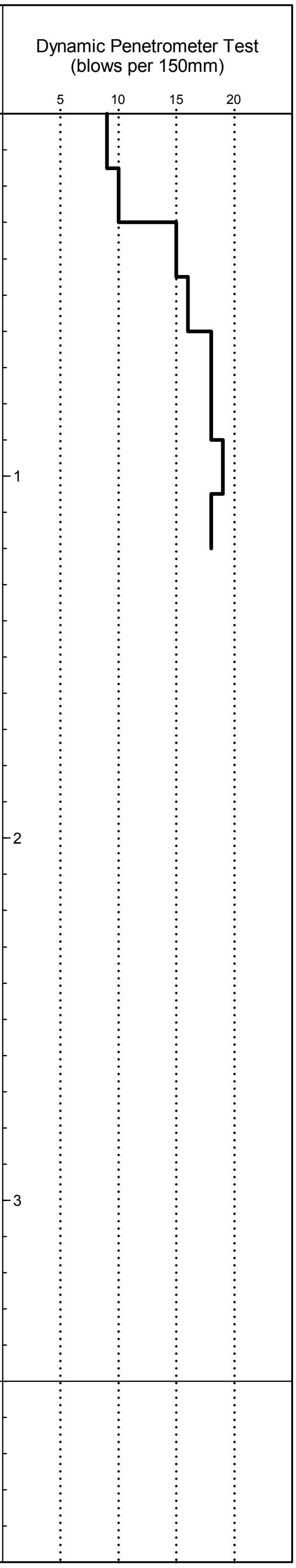
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 88.5 mAHD
EASTING: 298839
NORTHING: 6236040

PIT No: 8
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - brown silty clay with a trace of rootlets, moist					
	0.3	SILTY CLAY - hard, brown silty clay with some sandstone gravel and cobbles, MC<PL (COLLUVIUM)					
88			D	0.5		pp >600	
	1	- becoming light brown below 0.9m	D	1.0		pp >600	
87		- becoming brown mottled grey below 1.5m	D	1.5		pp >600	
	2		D	2.0		pp >600	
86			D	2.5		pp >600	
	3.0	SILTY CLAY - hard, red to orange mottled grey silty clay, MC<PL (RESIDUAL)	D	3.0		pp >600	
85	3.5	Pit discontinued at 3.5m - limit of investigation	D	3.5		pp >600	



RIG: JCB 4CX backhoe - 450mm wide bucket

LOGGED: ECR

SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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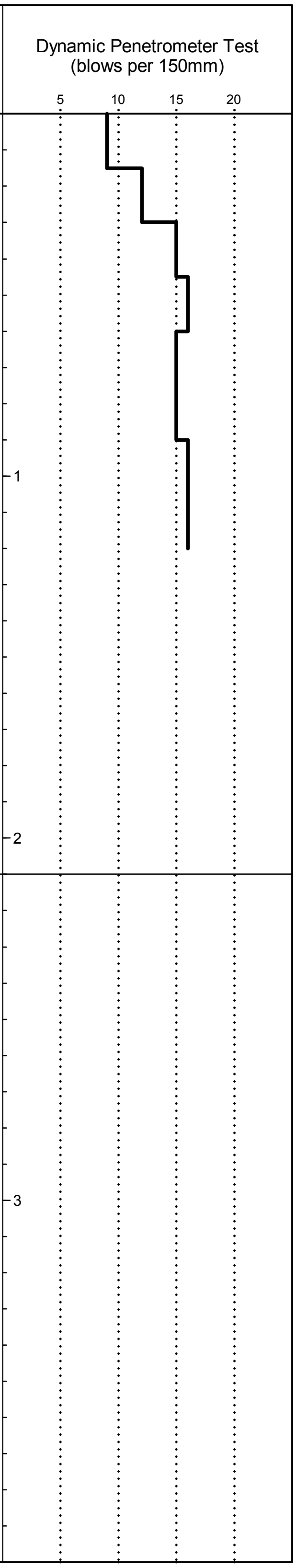
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 86.5 mAHD
EASTING: 299045
NORTHING: 6236001

PIT No: 9
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.2	SILTY CLAY - hard, red brown mottled grey silty clay, MC<PL (RESIDUAL)						
86				D	0.5		pp >600	
	1			D	1.0		pp = 550	
85				D	1.5		pp >600	
	1.7	SHALE - extremely low to very low strength, extremely to highly weathered, grey and red brown shale						
	2			D	2.0			
	2.1	Pit discontinued at 2.1m - limit of investigation						
84								
	3							
83								



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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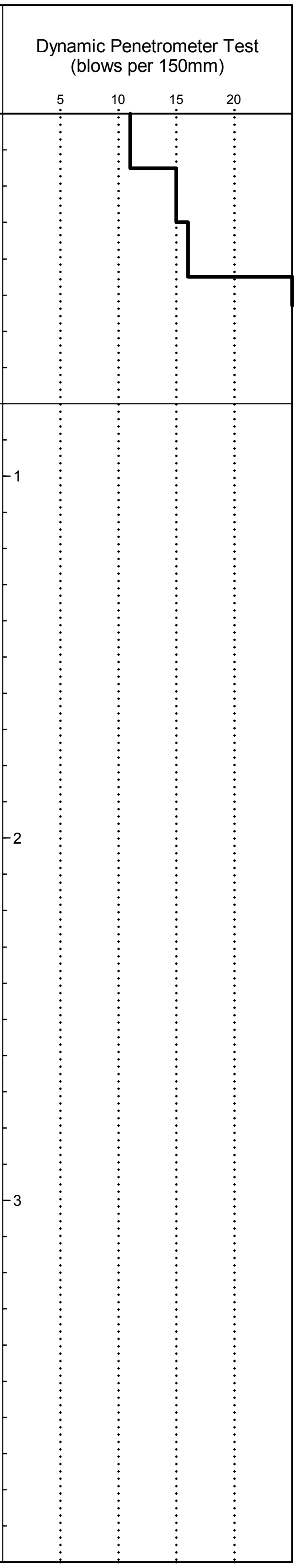
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 89.0 mAHD
EASTING: 299156
NORTHING: 6236024

PIT No: 10
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
89		TOPSOIL - brown silty clay with a trace of rootlets, moist					
	0.1	SILTY CLAY - hard, red to orange brown silty clay, MC<PL (RESIDUAL)					
	0.5	SILTSTONE - very low to low strength, highly weathered, grey and brown siltstone	D	0.5			
	0.8	Pit discontinued at 0.8m - limit of investigation					
88	1						
87	2						
86	3						



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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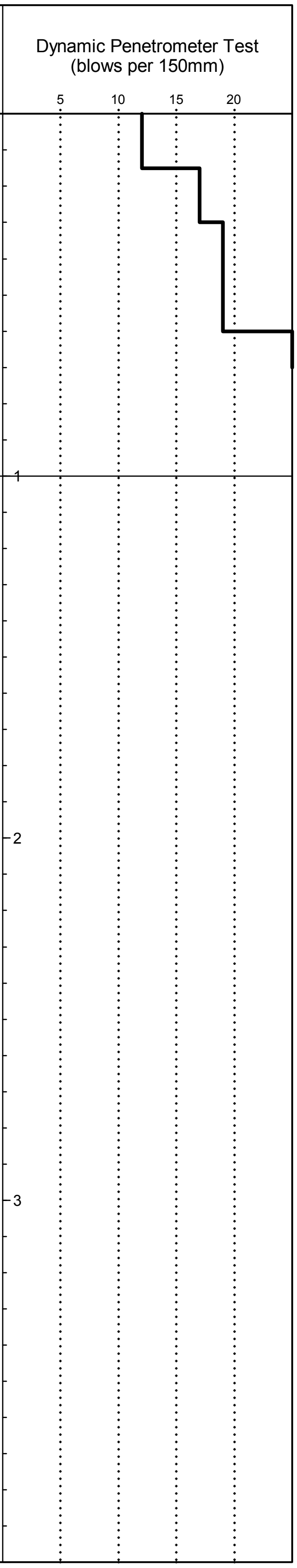
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 81.5 mAHD
EASTING: 299156
NORTHING: 6235873

PIT No: 11
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL - brown silty clay with a trace of rootlets, moist					
81	0.7	SILTY CLAY - hard, red to orange brown silty clay, MC<PL (RESIDUAL)	D	0.5		pp >600	
	1.0	SILTSTONE - very low to low strength, highly weathered, grey and brown siltstone					
		Pit discontinued at 1.0m - limit of investigation					



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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TEST PIT LOG

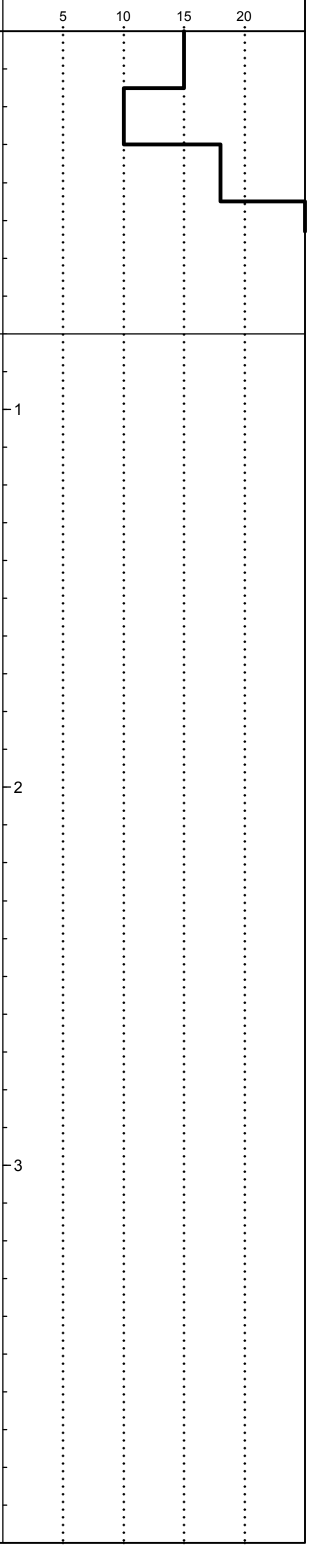
CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 72.0 mAHD
EASTING: 299062
NORTHING: 6235807

PIT No: 12
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
72		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.2	SILTY CLAY - hard, red brown silty clay, MC<PL (RESIDUAL)						
	0.5	SANDSTONE - low to medium strength, highly weathered, brown fine to medium grained lithic sandstone		D	0.5			
	0.8	Pit discontinued at 0.8m - limit of investigation						
71	1							
70	2							
69	3							

Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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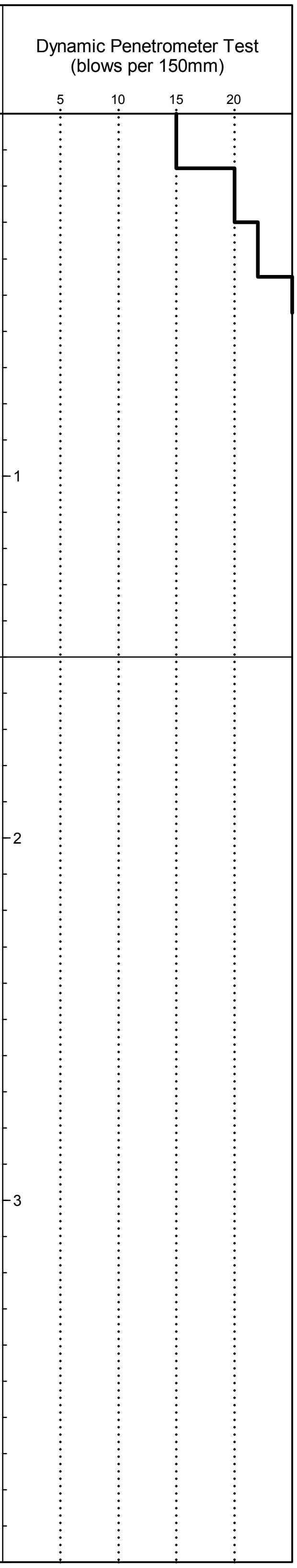
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 76.5 mAHD
EASTING: 299227
NORTHING: 6235741

PIT No: 13
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.3	SILTY CLAY - hard, orange brown silty clay, MC<PL (RESIDUAL)						
76				D	0.5		pp >600	
	1			D	1.0		pp >600	
	1.3	SHALE - low to medium strength, highly weathered, grey and brown iron-indurated shale						
75	1.5	Pit discontinued at 1.5m - limit of investigation		D	1.5			
	2							
74								
	3							
73								



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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Geotechnics / Environment / Groundwater

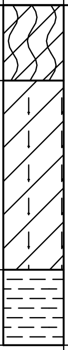
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

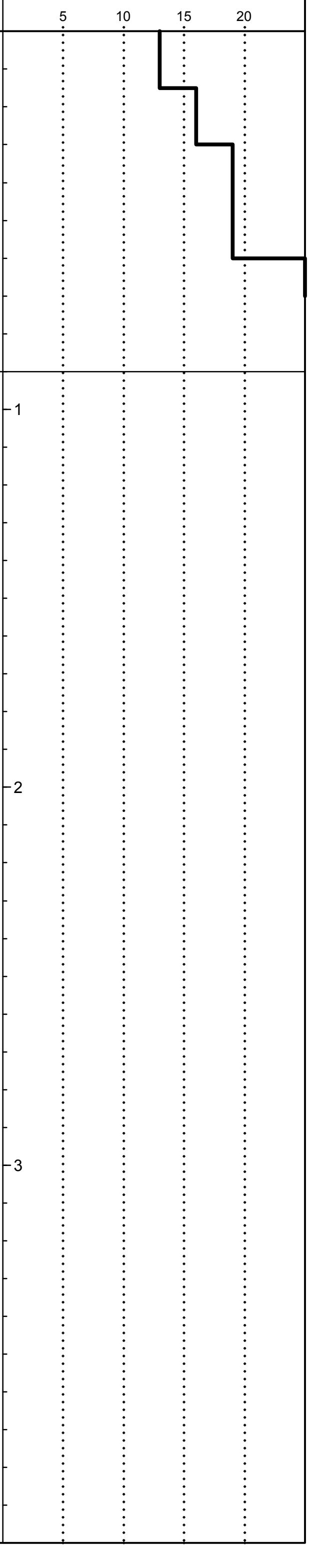
SURFACE LEVEL: 91.0 mAHD
EASTING: 299301
NORTHING: 6235811

PIT No: 14
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
91		TOPSOIL - brown silty clay with a trace of rootlets, moist						
	0.2	SILTY CLAY - hard, brown silty clay with some ironstone gravel and cobbles, fissured, MC<PL (RESIDUAL)		D	0.5			
	0.7	SHALE - medium strength, moderately weathered, grey shale						
	0.9	Pit discontinued at 0.9m - limit of investigation						
90	1							
89	2							
88	3							



Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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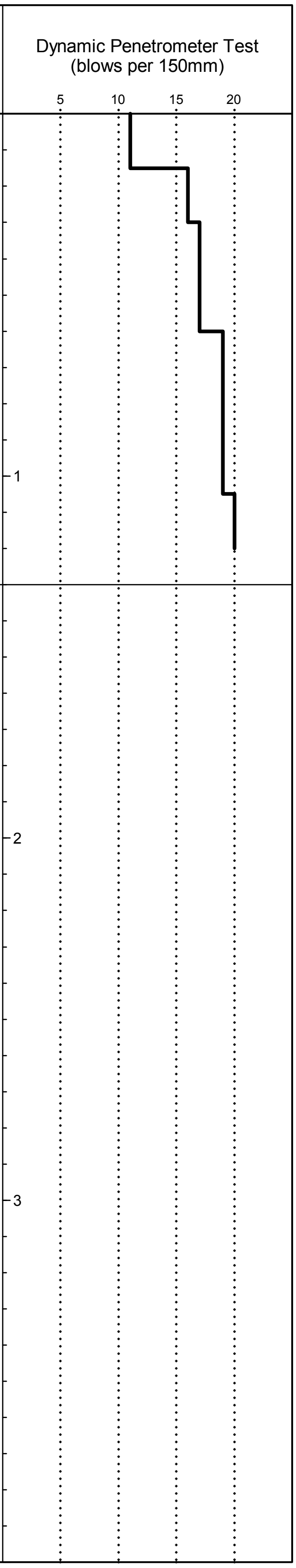
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 86.0 mAHD
EASTING: 299277
NORTHING: 6235879

PIT No: 15
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
86		TOPSOIL - brown silty clay with a trace of rootlets, moist					
	0.2	SILTY CLAY - hard, red to orange brown silty clay, MC<PL (RESIDUAL)	D	0.5		pp >600	
85	0.9	SHALE - extremely low to very low strength, extremely to highly weathered, dark grey shale	D	1.0			
	1.3	Pit discontinued at 1.3m - limit of investigation					
84	2						
83	3						



RIG: JCB 4CX backhoe - 450mm wide bucket

LOGGED: ECR

SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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TEST PIT LOG

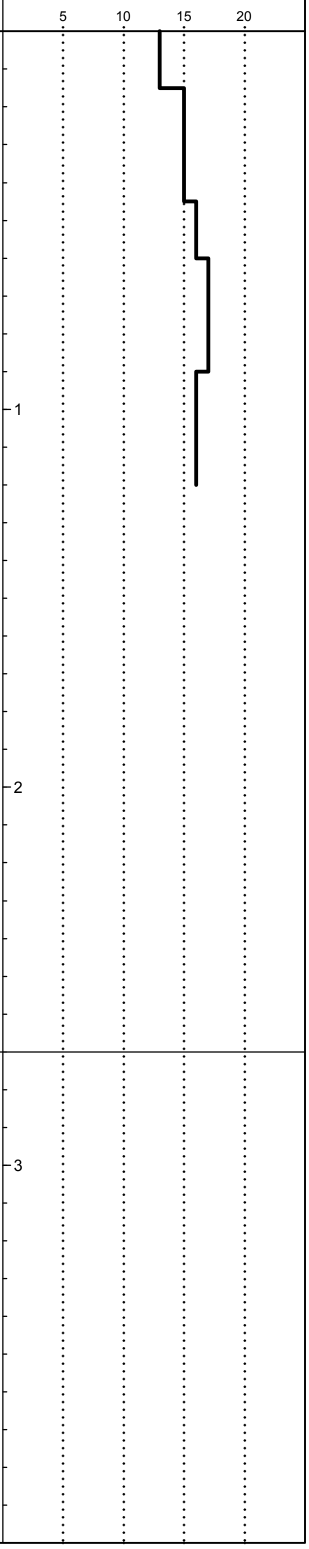
CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 73.0 mAHD
EASTING: 298825
NORTHING: 6235850

PIT No: 16
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
73		TOPSOIL - brown clayey silt with a trace of rootlets, moist					
	0.3	SILTY CLAY - hard, red to orange brown silty clay, MC<PL (RESIDUAL)					
			D	0.5		pp >600	
72	1		D	1.0		pp >600	
			D	1.5		pp >600	
71	2	- becoming red mottled grey below 2.0m	D	2.0		pp >600	
		- with low strength shale bands below 2.3m					
			D	2.5		pp >600	
	2.7	Pit discontinued at 2.7m - limit of investigation					
70	3						

Dynamic Penetrometer Test (blows per 150mm)



RIG: JCB 4CX backhoe - 450mm wide bucket
LOGGED: ECR
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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

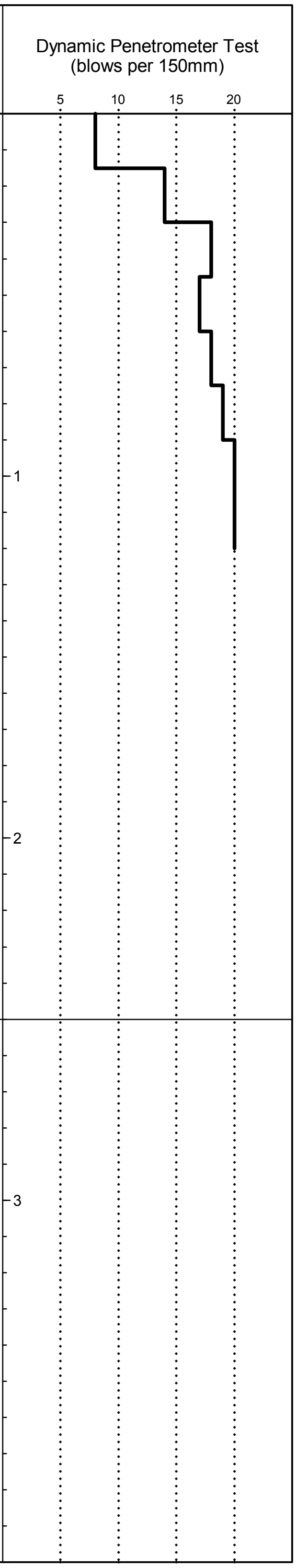
TEST PIT LOG

CLIENT: Catholic Metropolitan Cemeteries Trust
PROJECT: Proposed Memorial Park
LOCATION: 167 - 177 St Andrews Road, Varroville, NSW

SURFACE LEVEL: 65.5 mAHD
EASTING: 298621
NORTHING: 6235704

PIT No: 17
PROJECT No: 73732.01
DATE: 22/2/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.0	TOPSOIL - brown silty clay with a trace of rootlets, moist					
	0.2	SILTY CLAY - hard, orange brown silty clay, MC<PL					
65			D	0.5		pp >600	
	1		D	1.0		pp >600	
		- becoming orange brown mottled grey below 1.3m					
64			D	1.5		pp >600	
	2		D	2.0		pp = 450-500	
	2.3	SHALE - extremely low strength, extremely weathered, grey and brown shale with low to medium strength bands					
63	2.5	Pit discontinued at 2.5m - limit of investigation	D	2.5			



RIG: JCB 4CX backhoe - 450mm wide bucket **LOGGED:** ECR **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

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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Appendix C

Laboratory Test Results

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Macarthur Laboratory
18 Waler Crescent Smeaton Grange NSW 2567
Phone: (02) 4647 0075
Fax: (02) 4646 1886
Email: anthony.sweetland@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Anthony Sweetland
Nata Accredited Laboratory Number: 828

Report Number:	**73732.01-1**
Issue Number:	1
Date Issued:	23/03/2017
Client:	Catholic Metropolitan Cemeteries Trust PO Box 10, LIDCOMBE NSW 2141
Contact:	John Richardson
Project Number:	73732.01
Project Name:	Proposed Memorial Park
Project Location:	167 - 177 St Andrews Road, Varroville
Work Request:	125
Sample Number:	17-125A
Date Sampled:	02/03/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP2 (0.3 - 0.5m)**
Material:	SILTY CLAY - Brown mottled red brown

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	45		
Plastic Limit (%)	18		
Plasticity Index (%)	**27**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	None		

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Issue Number: 1
Date Issued: 23/03/2017
Client: Catholic Metropolitan Cemeteries Trust
PO Box 10, LIDCOMBE NSW 2141
Contact: John Richardson
Project Number: 73732.01
Project Name: Proposed Memorial Park
Project Location: 167 - 177 St Andrews Road, Varroville
Work Request: 125
Sample Number: 17-125B
Date Sampled: 02/03/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP4 (0.3 - 0.5m)**
Material: SILTY CLAY - Brown gravelly

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	43		
Plastic Limit (%)	17		
Plasticity Index (%)	**26**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.0		
Cracking Crumbling Curling	Curling		

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Issue Number: 1
Date Issued: 23/03/2017
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PO Box 10, LIDCOMBE NSW 2141
Contact: John Richardson
Project Number: 73732.01
Project Name: Proposed Memorial Park
Project Location: 167 - 177 St Andrews Road, Varroville
Work Request: 125
Sample Number: 17-125C
Date Sampled: 02/03/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP5 (0.3 - 0.5m)**
Material: SILTY CLAY - Red brown

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Natural		
Liquid Limit (%)	65		
Plastic Limit (%)	29		
Plasticity Index (%)	**36**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.5		
Cracking Crumbling Curling	Curling		

Material Test Report

Report Number: **73732.01-1**
Issue Number: 1
Date Issued: 23/03/2017
Client: Catholic Metropolitan Cemeteries Trust
PO Box 10, LIDCOMBE NSW 2141
Contact: John Richardson
Project Number: 73732.01
Project Name: Proposed Memorial Park
Project Location: 167 - 177 St Andrews Road, Varroville
Work Request: 125
Sample Number: 17-125D
Date Sampled: 02/03/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP6 (1.8 - 2.0m)**
Material: SILTY CLAY - Dark brown

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	41		
Plastic Limit (%)	16		
Plasticity Index (%)	**25**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	9.5		
Cracking Crumbling Curling	Curling		

Material Test Report

Report Number: **73732.01-1**
Issue Number: 1
Date Issued: 23/03/2017
Client: Catholic Metropolitan Cemeteries Trust
PO Box 10, LIDCOMBE NSW 2141
Contact: John Richardson
Project Number: 73732.01
Project Name: Proposed Memorial Park
Project Location: 167 - 177 St Andrews Road, Varroville
Work Request: 125
Sample Number: 17-125E
Date Sampled: 02/03/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP8 (0.9 - 1.0m)**
Material: SILTY CLAY - Orange brown

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Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	62		
Plastic Limit (%)	17		
Plasticity Index (%)	**45**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	15.0		
Cracking Crumbling Curling	Curling		

Material Test Report

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Report Number:	**73732.01-1**
Issue Number:	1
Date Issued:	23/03/2017
Client:	Catholic Metropolitan Cemeteries Trust PO Box 10, LIDCOMBE NSW 2141
Contact:	John Richardson
Project Number:	73732.01
Project Name:	Proposed Memorial Park
Project Location:	167 - 177 St Andrews Road, Varroville
Work Request:	125
Sample Number:	17-125F
Date Sampled:	02/03/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP15 (0.3 - 0.6m)**
Material:	SILTY CLAY - Red brown

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	47		
Plastic Limit (%)	17		
Plasticity Index (%)	**30**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	9.0		
Cracking Crumbling Curling	Curling		

Material Test Report

Report Number: **73732.01-1**
Issue Number: 1
Date Issued: 23/03/2017
Client: Catholic Metropolitan Cemeteries Trust
PO Box 10, LIDCOMBE NSW 2141
Contact: John Richardson
Project Number: 73732.01
Project Name: Proposed Memorial Park
Project Location: 167 - 177 St Andrews Road, Varroville
Work Request: 125

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Nata Accredited Laboratory Number: 828

Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content	Material
17-125A	TP2 (0.3 - 0.5m)	13.1 %	SILTY CLAY - Brown mottled red brown
17-125B	TP4 (0.3 - 0.5m)	13.1 %	SILTY CLAY - Brown gravelly
17-125C	TP5 (0.3 - 0.5m)	15.6 %	SILTY CLAY - Red brown
17-125D	TP6 (1.8 - 2.0m)	14.0 %	SILTY CLAY - Dark brown
17-125E	TP8 (0.9 - 1.0m)	15.0 %	SILTY CLAY - Orange brown
17-125F	TP15 (0.3 - 0.6m)	12.4 %	SILTY CLAY - Red brown

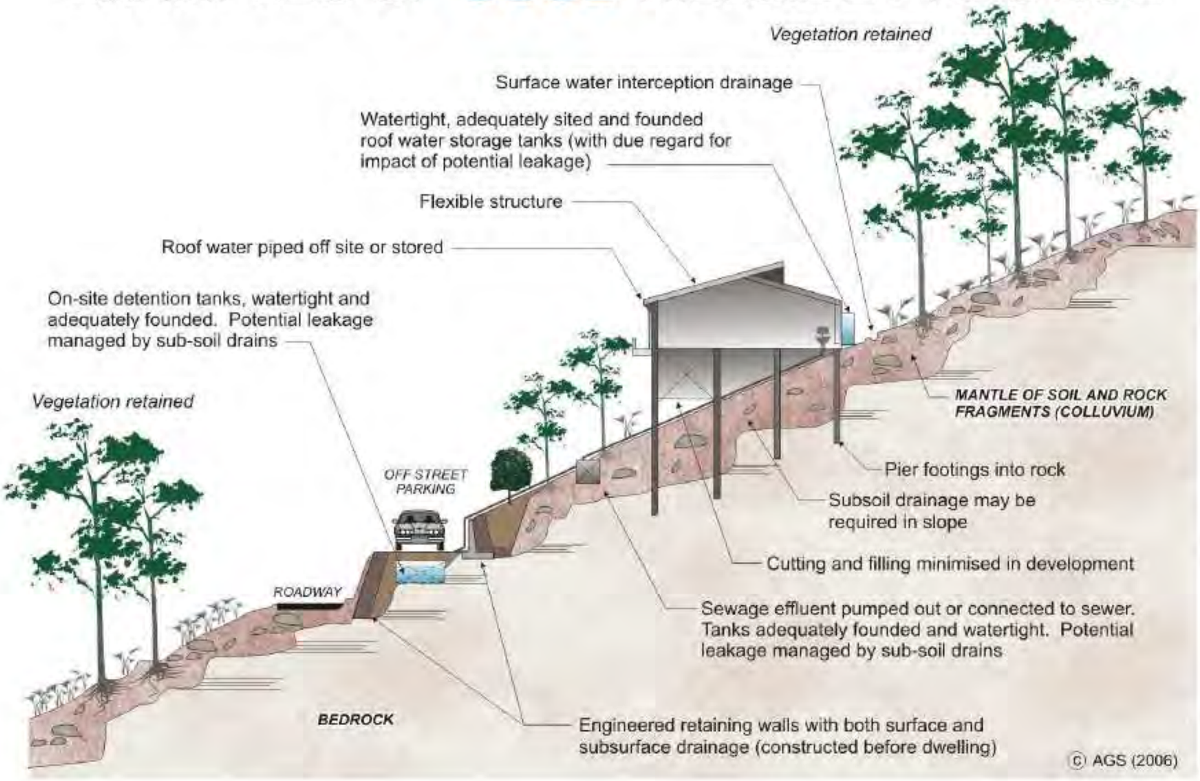
Appendix D

AGS Extracts: Guidelines on Hillside Developments
CSIRO Publication

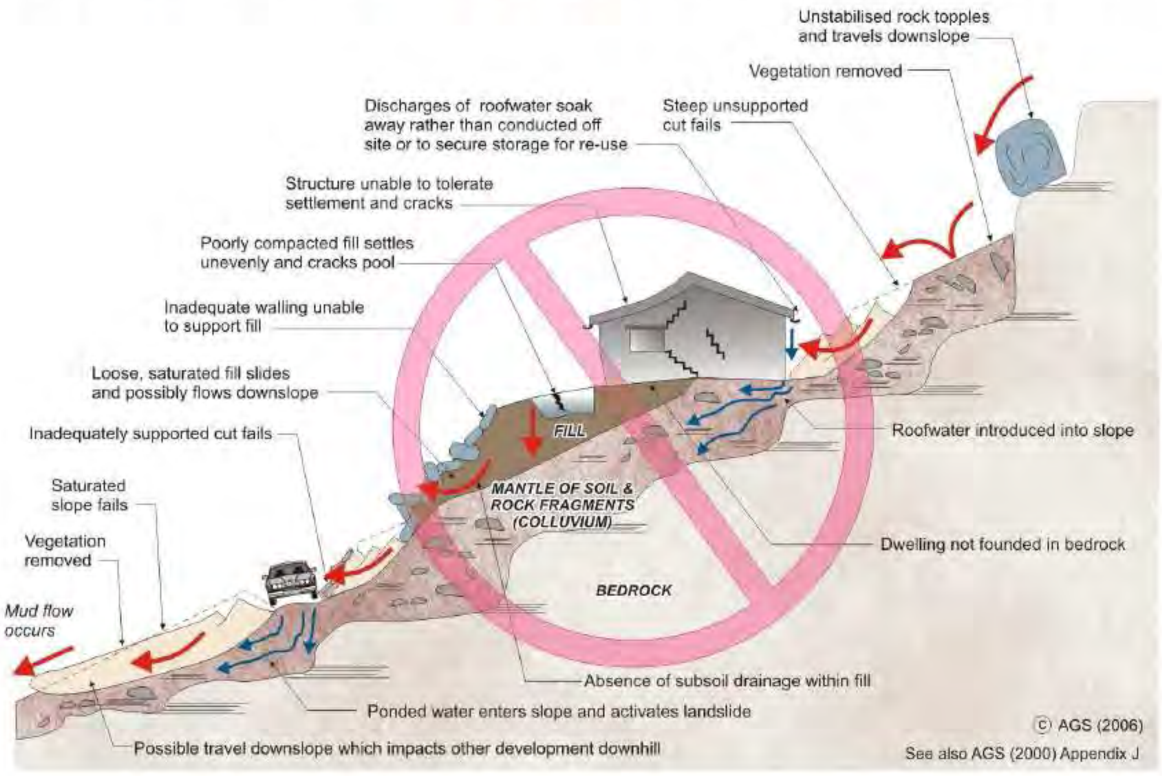
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



Foundation Maintenance and Footing Performance:

A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

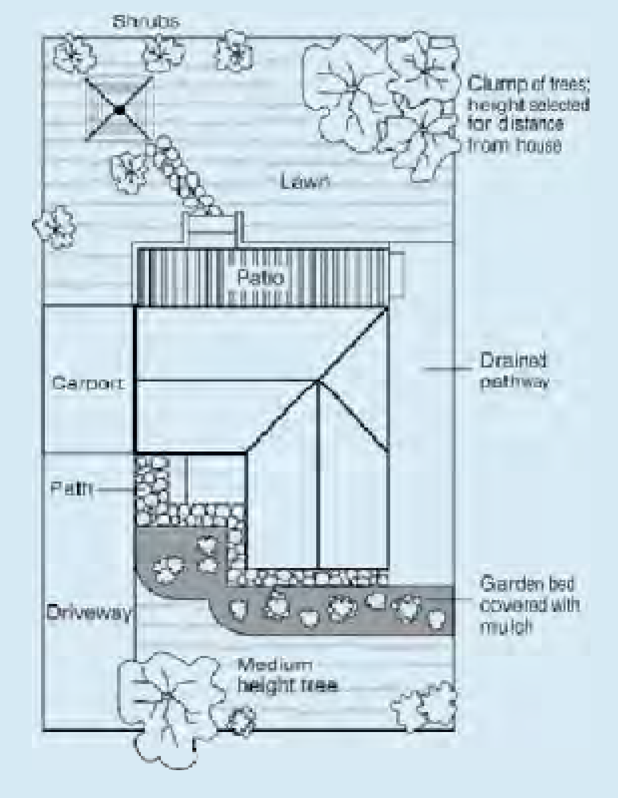
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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Distributed by
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