Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on Geotechnical Investigation

Proposed Townhouse Development
54 Terry Road, Rouse Hill

Prepared for
Prisma Rouse Hill Development Pty Ltd

Project 94508.00
August 2018

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Report on Geotechnical Investigation
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1. Introduction

This report presents the results of a geotechnical investigation carried out by Douglas Partners Pty Ltd (DP) for a proposed townhouse development at 54 Terry Road, Rouse Hill. The investigation was commissioned in an email dated 27 May 2018 by Celesteem Rouse Hill Development Pty Ltd and was undertaken in accordance with DPs proposal NWS180021.P.001.Rev0 dated 16 May 2018.

It is understood that the development will include the construction of 43 townhouses together with associated pavements. DP understands that the development will be positioned over the eastern two-thirds of the site to avoid the flood affected zone (western side). Preliminary site levels are expected to involve up to about 1.5 m of cut and fill on-site.

Geotechnical investigation was carried out to provide information on subsurface conditions for the planning and design of earthworks, foundations and pavements.

The investigation included the drilling of three boreholes, the excavation of nine test pits, nine Dynamic Cone Penetration (DCP) tests and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations for design and construction.

2. Site Description

The site of the proposed development is located at 54 Terry Road, Rouse Hill. It is an irregular shaped area of approximately 2 hectares. It is bounded by Terry Road to the east, a residential subdivision to the north, the Sydney Metro Northwest railway corridor to the south and a residential property to the west. Second Ponds Creek dissects the site from the south-east corner to the north, extending to about 50 m east of the western boundary.

At the time of the field work the site predominantly comprised farm paddocks with a grass covering, scattered small to large sized trees, a dilapidated residential building, metal sheds, and fencing mainly located in the central portion of the site. A dam was located towards the centre of the site and was estimated to be approximately 600 m^2 in size using a spatial function in Nearmap.

The topography of the site generally falls gently from the east side of the site (Terry Road) at RL 49 m AHD down towards to the west at RL 44 m AHD. A portion of the northern boundary has been filled up to 1.5 m high, for a width of approximately 3 - 4 m, to form a relatively level platform with the adjacent residential subdivision to the north. The adjacent subdivision has a road pavement on this boundary and it is understood that the road will be widened to service this subdivision.

A location plan showing the site area is presented in Figure 1.

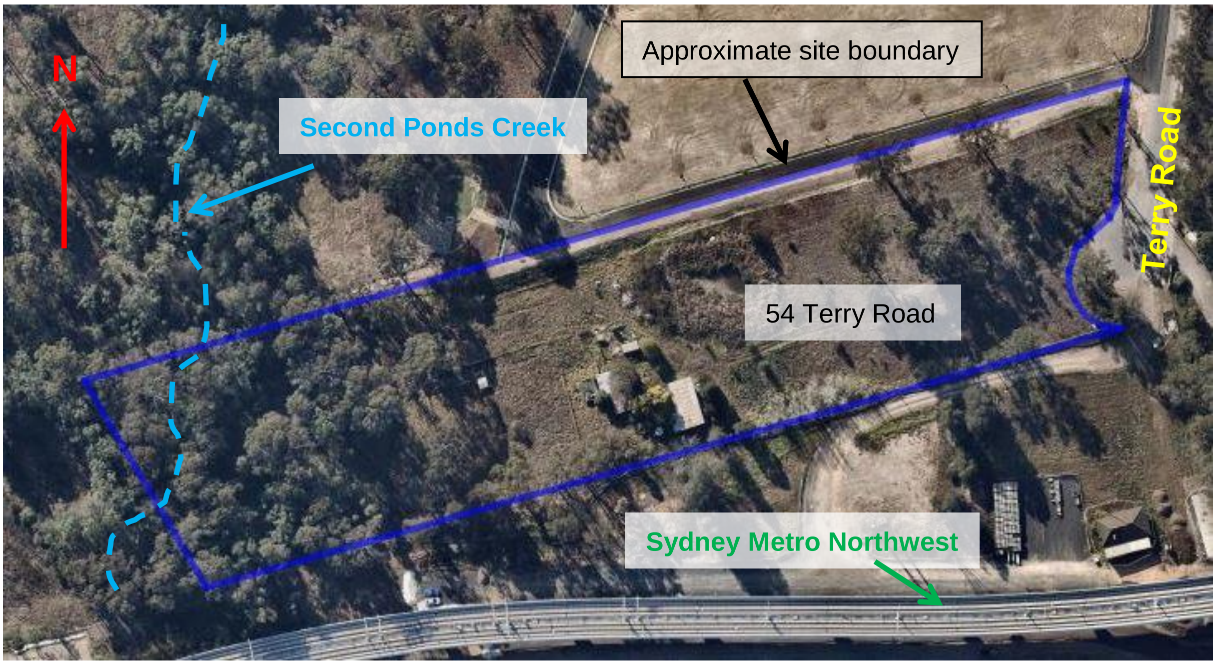

Figure 1: Site Location Plan (Source: Nearmap)

3. Geological Mapping

3.1 Geology

Reference to the Penrith 1:100 000 scale Geological Series Sheet indicates that the site is predominantly underlain by Ashfield Shale of the Wianamatta Group of Triassic age. Ashfield Shale typically comprises dark grey to black shale, siltstone and laminate which weathers to a residual clay profile of medium to high plasticity. Alluvial sediments may be present due to the floodplain associated with Second Ponds Creek traversing the western part of the site.

3.2 Soil Landscape

Reference to the Penrith 1: 100 000 scale Soil Landscape Series Sheet indicates that the site is located within the Blacktown soil landscape group. The Blacktown Group is characterised by moderately reactive, highly plastic subsoil with poor drainage.

3.3 Acid Sulphate Soils

Reference to the Acid Sulphate Soil (ASS) mapping for the area indicates that the site is in an area of no known occurrence.

The NSW Acid Sulphate Soils Manual 1998 published by the Acid Sulphate Soils Advisory Committee (ASSMAC) indicates that ASS (and Potential Acid Sulphate Soils – PASS) normally occur in alluvial or estuarine soils below RL 5 m AHD although occasionally are encountered up to RL 12 m AHD. Considering the ASS mapping and given that the site soils are at site elevations are above RL 44 m AHD it is considered unlikely that ASS is present on-site.

3.4 Salinity

The Department of Infrastructure, Planning and Natural Resources (DIPNR) "Map of Salinity Potential in Western Sydney 2002" map suggests that the site is in an area of "moderate salinity potential" with a higher potential in the lower elevation areas in close proximity to the Second Ponds Creek system. Salinity investigation and testing was outside the agreed scope of this investigation.

4. Field Work Methods

The field work was undertaken between 15 June 2018 and 3 July 2018 and involved the following:

- Nine test pits (TP 1 – 9) excavated using a 3.5 tonne mini excavator fitted with a 300 mm wide bucket attachment. The test pits were excavated to depths ranging between 1.1 – 2.5 m.
- Three boreholes (BH10 – BH12) drilled using a truck mounted rig with 110 mm diameter augers. The boreholes were drilled to depths of 5 m.
- DCP testing adjacent to each of the nine test pit locations to depths of between 0.75 m and 1.2 m.

Undisturbed and disturbed samples were collected from the test pits and boreholes to assist with logging and for laboratory testing. Bulk samples were taken in some of the test pits to enable testing to be undertaken for compaction properties and California Bearing Ratio (CBR).

Each borehole was converted to a groundwater monitoring well at the completion of drilling. The wells involved inserting Class 18 uPVC screen and casing to the required depths, backfilling the screened length with clean gravel, plugging the top of the gravel with bentonite pellets and backfilling the casing with drilling spoil. Approximately 1.0 – 1.2 m of casing was left extending above the ground surface and a VC cap was placed on the end to enable groundwater monitoring of the well. Following installation, the wells were purged of groundwater and measurement of the groundwater level occurred on three subsequent occasions (21 June 2018, 3 July 2018 and 18 July 2018).

The AHD ground surface levels at the test pit and borehole locations were determined by using a High Precision Differential GPS (HPDGPS) which is accurate to approximately 0.2 m. The locations of the tests are shown on Drawing 1 in Appendix B.

5. Field Work Results

The detailed test pit and borehole logs are provided in Appendix C. Notes defining classification methods and terms used to describe the soils and rocks are provided in Appendix C. The subsurface conditions encountered on the site can be described as:

- **TOPSOIL** - typically silty clay with some vegetation and rootlets to depths of up to 0.3 m in all boreholes and test pits except TP1;
- **FILLING:** - silty clay, clayey silt or gravelly clay filling with inclusions of bricks, plastic and concrete to depths ranging between 0.3 m and 2.4 m in TP1, TP7 and TP8. Silty clay or clayey silt filling was encountered below the topsoil in TP3 and TP4 to depths of 0.5 m and 0.6 m, respectively. The filling ranges from poorly compacted to moderately well compacted;
- **NATURAL SOILS** - typically very stiff silty clay in all boreholes and test pits except TP7 to depths ranging between 1.1 m and 2.7 m;
- **WEATHERED ROCK** - generally extremely low strength shale at depths of 1.1 m to 2.8 m in all pits and bores except TP6, TP7, TP8 and TP9. Some very low and low strength shale was encountered below depths of 1.8 m and 2.8 m in TP2 and BH10, respectively. Low to medium strength or low and medium strength shale was encountered in BH10, BH11 and BH12 below depths of between 3.5 m and 4.0 m.

No free groundwater was encountered during the drilling of the boreholes or during excavation of the test pits. Backfilling of the test pits at the completion of testing precluded long-term monitoring of groundwater levels in test pits.

Groundwater levels were measured by an experienced geotechnical engineer in the monitoring wells on three subsequent occasions. A summary of the groundwater levels measured to date are provided in Table 1 below.

Table 1: Results of Groundwater Measurements

Bore No.	Surface RL (m AHD)	Standpipe Measurements – Water Level					
		21 June 2018		3 July 2018		18 July 2018	
		Depth (m)	RL (m AHD)	Depth (m)	RL (m AHD)	Depth (m)	RL (m AHD)
10	47.5	4.3	43.2	3.6	43.9	4.2	43.3
11	47.7	Dry	Dry	Dry	Dry	Dry	Dry
12	46.1	4.4	41.7	4.3	41.8	4.4	41.7

Note: RL = Reduced Levels relative to Australian Height Datum (AHD)

6. Laboratory Testing

Selected samples collected from the test pits and boreholes were tested for aggressivity (pH, sulphate and chloride), compaction properties and CBR, Atterberg limits, moisture content, shrink-swell and Emerson testing. The detailed results are given in Appendix D and are summarised in Tables 2 and 3 below.

Table 2: Results of Geotechnical Laboratory Testing

Sample Location	Material	Depth (m)	FMC (%)	SOMC (%)	MDD (t/m³)	CBR (%)	W_L (%)	W_P (%)	PI (%)	LS (%)	I_{ss} (%)	ECN
TP1	Silty Clay	0.5 – 1.0	19.7	20.5	1.8	2	61	19	42	17	-	4
TP4	Silty Clay	1.0 – 1.4	-	-	-	-	-	-	-	-	0.9	-
TP5	Silty Clay	0.5 – 1.0	19.5	22.5	1.67	2.5	-	-	-	-	-	-
TP8	Filling	0.5 – 1.0	14.3	18.5	1.71	9	37	19	18	7.5	-	4
BH10	Silty Clay	1.0 – 1.27	-	-	-	-	45	18	27	12.5	-	-
BH11	Silty Clay	1.0 – 1.4	-	-	-	-	-	-	-	-	1.1	-
BH12	Silty Clay	1.0 – 1.4	-	-	-	-	-	-	-	-	2.2	-

Notes: FMC= Field Moisture Content; SOMC = Standard Optimum Moisture Content
MDD = Maximum Dry Density; CBR = California Bearing Ratio
W_L = Liquid Limit; W_P = Plastic Limit
PI = Plasticity Index; LS = Linear Shrinkage
I_{SS} = Shrink Swell Index; ECN = Emerson Class No.

Table 3: Results of Chemical Testing

Sample Location	Material	Sample Depth (m)	pH	Chloride Ion (mg/kg)	Sulphate Ion (mg/kg)
TP2	Shale	1.5 – 1.6	5.5	730	77
TP5	Silty Clay	0.9 – 1.0	5.0	830	120

Note: All samples mixed at a ratio of 1 (soil):5 (water) prior to testing

The results of laboratory testing indicate the following;

- The Atterberg Limits results indicate that the samples were generally of medium to high plasticity.
- The shrink-swell results indicated site clays are moderately susceptible to shrink and swell movements due to changes in soil moisture content.
- The Emerson Class No. results indicate the clays are generally moderately dispersive.
- The CBR values ranged from 2 % to 9% for the clay and sandy clayey silt filling samples tested. The samples were between 0.8% and 4.2% dry of Standard Optimum Moisture Content (SOMC).
- The results of the pH, chloride and sulphate concentration testing indicate that the soils are mildly aggressive to subsurface concrete elements and non-aggressive to steel elements when

assessed relative to the exposure classifications outlined in AS2159 – 2009: “Piling - Design and Installation”.

7. Proposed Development

It is understood that the proposed development will involve the construction of 43 two-storey townhouses with associated landscaping and pavements. Based on information provided, it is expected that the townhouses will be located over the eastern two – thirds of the site to avoid the existing flood affected zone (western side).

Based on observations on site during field work, the construction of the adjacent subdivision to the north has raised the levels of the north western corner of the proposed development by up to about 1.5 m. Records of the placement of this filling have not been available for review.

Preliminary floor levels provided have indicated that site levels are likely to increase by up to 1.5 m at the western end of the development and up to about 0.5 m of cut will be required at the eastern end. It is understood that batter slopes are proposed for the edge of fill platforms.

8. Comments

8.1 Geotechnical Model

The site is underlain by variable amounts of uncontrolled filling overlying residual or alluvial clays. Weathered shale is generally encountered at depths of 1 – 1.5 m on the eastern side of the site and up to 2.8 m on the western side of the site. Rock strengths progressively increase with depth.

The filling material on-site appears uncontrolled and of variable compaction.

Groundwater is generally expected to be at depths ranging from 3.6 m to 4.4 m below existing surface levels. Groundwater levels are expected to vary with climatic changes and given the proximity to a flood zone could be at relatively shallow depths (i.e. less than 0.5 m) following wet weather.

8.2 Site Preparation and Earthworks

8.2.1 General

The extent of site earthworks will depend on the foundation system that is to be adopted. The existing ‘uncontrolled’ filling is considered unsuitable to support buildings loads and will need to be removed and replaced.

Fill placed on the western batter of the fill platform should have a low permeability and low erosion potential for a distance of at least 5 m. The fill platform batter will need to be protected from erosion and moisture infiltration through placement of vegetation and/or geotextiles.

8.2.2 Excavation Conditions

It is expected that there will be some form of excavation works on site due to the sloping nature of the site. Excavation to depths of up to say 0.5 m is generally expected to be within fill soils and natural clay which should be achievable using conventional earthmoving equipment.

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

8.2.3 Subgrade Preparation

Where buildings are intended to be supported by controlled engineered fill, the following site preparation measures are recommended:

- remove any deleterious, soft, wet or highly compressible material or material rich in organics or root matter;
- test roll the exposed surface with at least six passes of a minimum 12 tonne deadweight smooth drum roller, with a final test roll pass accompanied by careful visual inspection to ensure that any deleterious materials such as soft, wet or highly compressible soil and any organics are identified and removed;
- place approved filling, where required, in layers not exceeding 300 mm loose thickness, with each layer compacted to a dry density ratio between 95 % and 102 % relative to Standard compaction and within 2% of optimum moisture content (OMC); new filling should be free of oversize particles (>75 mm) and deleterious material;
- moisture conditioning of clay soils may be required if soils are saturated. Moisture conditioning would involve drying in ‘sunny and windy’ weather, blending with other drier materials or lime stabilisation;
- promptly cover any exposed clay at subgrade level with a minimum 150 mm of select granular fill (minimum CBR 15%) to reduce potential wetting and drying and trafficability problems; and
- new filling required to achieve design levels for support of any on-ground slabs and/or structural loads will need to be carried out under Level 1 testing conditions as defined in AS 3798–2007 “Guidelines on Earthworks for Commercial and Residential Developments”. Level 2 testing is recommended for filling materials beneath pavements, recreational and landscaping areas.

The above procedures will require geotechnical inspection and testing services to be employed during construction.

For areas where pavements are proposed, subgrade preparation should adopt the above methodology, albeit, the existing filling could remain in place without needing to be fully removed provided that it performs adequately during proof roll testing. The presence of building rubble in this filling, however, suggests that there could be localised unsuitable areas requiring removal and replacement (as described above).

8.3 Excavation Support

Excavation of a maximum of 0.5 m for the proposed buildings and pavement areas are assumed to be within filling, residual clays and possibly some extremely low to low strength rock in service trenches.

The soils exposed in cut will not be able to stand vertically without support in the longer term. Where space permits, it will be possible to batter the sides of the excavation and in these conditions, it is suggested to allow for temporary side slopes of 1H:1V in the clays.

A maximum batter slope of 2H:1V is recommended for permanent slopes in the clays, provided that the slopes are protected against surface erosion and local slumping. Where the slopes are to be vegetated to prevent erosion, a maximum batter slope of 6H:1V is recommended. The batter slopes recommended above are appropriate provided there are no surcharge loads from buildings or structures near the top of the batters.

Retaining walls could be designed to support fill or cut slopes in accordance with engineering principles.

8.4 Foundations

8.4.1 Preliminary Lot Classification

The results of field work indicate that the site includes existing uncontrolled filling (to about 1.2 m depth), overlying natural soils. The laboratory testing indicates that the clays at the site are of medium to high plasticity and therefore likely to be moderately to highly susceptible to shrink-swell movements in response to seasonal variations in soil moisture content. Based on the soil depth, and the results of laboratory testing, it is considered that the natural soil profile would generally be consistent with either a Class “M” or Class “H1” site as per AS 2870 – 2011: “Residential Slabs and Footings”. The presence of greater than 0.4 m depth of uncontrolled filling together with the presence of mature trees within (or near) the building footprints, however, will necessitate a “P” classification for the site in accordance with the “uncontrolled fill” and “abnormal moisture condition” provisions of AS2870.

If fill materials are to be removed and replaced under controlled conditions (refer to Section 8.2.3) then it is considered feasible that such areas could be reclassified. Options for the various site classifications, including anticipated reclassifications, are outlined in Table 4 (following page).

Table 4: Site Classification Options

Option	Description	Site Classification[1]
1	Retain existing uncontrolled filling	P[2]
2	Areas of cut where rock is less than 1.4 m below the proposed surface level.	M
2	Rework existing uncontrolled filling and place and compact under controlled conditions.[3]	H1
3	Remove existing uncontrolled filling and replace with at least 1 m of imported non-reactive or very low reactivity filling (e.g. ripped shale or sandstone).[3 & 4]	M

Notes:
1. Site Classifications based on AS2870.
2. Design of slabs and footings for a Class 'P' site should be based on engineering principles.
3. Filling should be placed under Level 1 testing conditions (refer Section 8.2.3).
4. Materials considered to be either non-reactive or of very low reactivity include ripped shale and sandstone. Proposed filling should be checked by a geotechnical engineer prior to confirm material is suitable for this classification.

8.4.2 Foundation Design

Design of footings founded in controlled filling, or very stiff or better natural clays could be proportioned on the basis of a maximum allowable base bearing pressure of 150 kPa. Where weathered rock is exposed at founding level or piles are drilled, footings could be proportioned for a maximum allowable bearing pressure of 700 kPa. If weathered rock is encountered during footing excavation, then all footings for the structure must be founded in rock in order to provide uniform founding conditions. Foundations proportioned on the basis of these parameters should experience settlements of not greater than 1% of the footing width/diameter.

These parameters assume all footings are free of water and loose debris immediately prior to pouring concrete. All footings in one structure should be founded on the same strata to achieve uniform founding conditions and limit the potential for differential movement between different parts of the structure.

Footings should be inspected by a suitably qualified engineer prior to steel and concrete placement to confirm the adequacy of the founding stratum for the adopted design pressure.

8.4.3 Site Maintenance

Reference should be made to Appendix B of AS2870, which provides advice on normal maintenance requirements to ensure the adequate performance of structures that have been designed and constructed in accordance with AS2870.

A copy of the CSIRO Building Technology File BTF 18 entitled, 'Foundation Maintenance and Footing Performance, A Homeowners Guide', which further describes appropriate site maintenance requirements set out within Appendix B of AS2870 is included in Appendix E.

8.5 Pavements

Based on the conditions encountered in the current investigation and the results of the laboratory testing, it is suggested that pavements at the site be designed based on a soaked CBR value of 2 %. Pavements should be placed on a subgrade prepared in accordance with the recommendations provided in Section 8.2.3. DP understands that the design of the pavements will be carried out by others.

The performance of pavements is dependent on the provision of adequate surface and subsoil drainage.

8.6 Drainage

Surface and subsurface drainage for the buildings and pavements should be incorporated into the design.

Care should be taken to avoid external influences on the soil moisture-regime. Detailing of surface and subsurface drainage should be aimed at avoiding substantial wetting of the soils beneath building areas. Surface water should be directed away from building or hardstand areas and the upper section of services trenches should be backfilled with compacted clay soil to avoid the trench acting as an inlet drain.

8.7 Erosion Potential

The results of Emerson Crumb testing on samples collected on site generally indicate moderately dispersive soils. Subsurface and surface drainage will need to be designed to avoid concentrated flows of water which could potentially accelerate the soils erosion. It is considered, however, that the erosion hazard within the areas proposed for buildings and pavements would be within usually accepted limits which could be managed by appropriate engineering and land management practices.

Appropriate management techniques could include:

- Efficient drainage systems for buildings and roads to prevent water saturation of, or concentrated stormwater flow over bare soils.
- Regular inspection and maintenance of drainage systems to prevent water saturation that might otherwise occur in the event of a leak or blockage.
- Appropriate and prompt installation of topsoil and grassing of bare soils and batters to minimise erosion and scour.
- Mixing of gypsum into sodic soils and filling so as to improve soil structure.
- Adequate measures such as silt fences to limit water runoff at the downslope boundaries of the site.
- Use of a low permeability and low erosion potential soils on the edge of the fill platform for a distance of at least 5 m.
- The use of a geotextile within the fill batter to limit erosion potential and moisture infiltration.

9. Limitations

Douglas Partners (DP) has prepared this report for a project at 54 Terry Road, Rouse Hill in accordance with DP's proposal dated 16 May 2018 and acceptance received from Celesteem Rouse Hill Development Pty Ltd dated 27 May 2018. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Celesteem Rouse Hill Development Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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

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

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

Douglas Partners Pty Ltd

Appendix A

About This Report

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

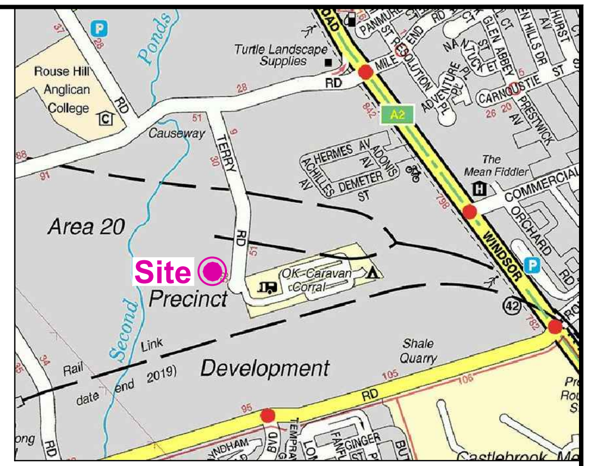
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate 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

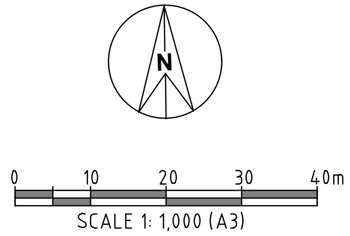
The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawings



Location Plan



LEGEND:-

- Test Pit and DCP Test Location and Number
- Test Bore and Groundwater Well Location and Number
- Site Boundary

NOTE:-

1. Test locations are approximate only and are shown with reference to existing site features.
2. Image obtained from Google Earth Pro. and Near Map. Date of imagery 29-05-2018.
3. Plan adapted from Drawing No.05617 provided by Higgins Surveyors.

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CLIENT: Prisma Rouse Hill Development Pty Ltd		TITLE: **Site and Test Location Plan**	PROJECT No: 94508.00
OFFICE: Sydney	DRAWN BY: JST	**Proposed Townhouse Development**	DRAWING No: 1
SCALE: As shown	DATE: 25 June 2018	**54 Terry Road, Rouse Hill**	REVISION: 0

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Appendix C

Field Work Results

Rock Descriptions

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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

Soil Descriptions

Douglas Partners

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.

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

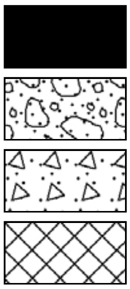
Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

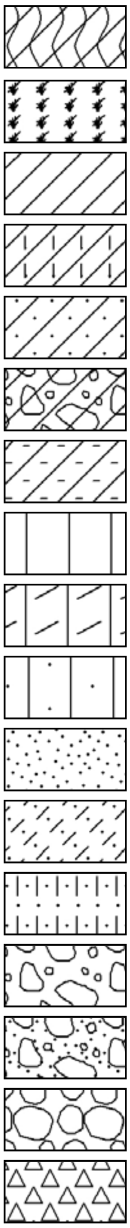
Graphic Symbols for Soil and Rock

General



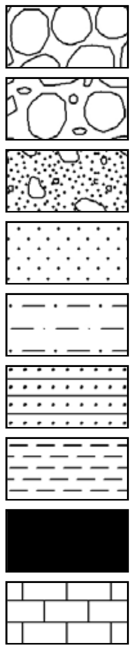
- Asphalt
- Road base
- Concrete
- Filling

Soils



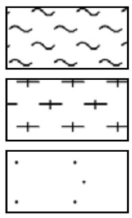
- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks



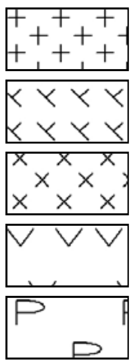
- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks



- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks



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

TEST PIT LOG

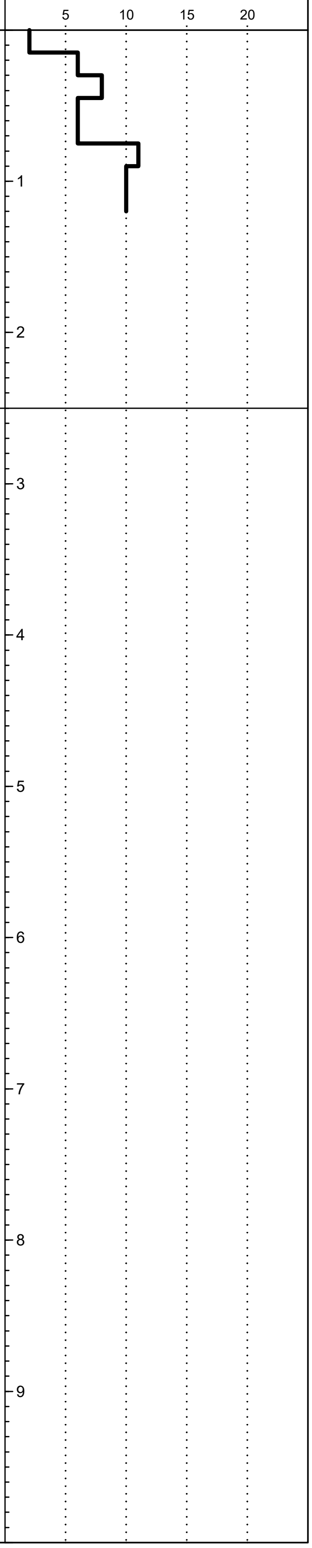
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 46.4 mAHD
EASTING: 306403
NORTHING: 6270348

PIT No: 8
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
	0.03	TOPSOIL FILLING - dark brown silty clay topsoil filling, with some vegetation						
46		FILLING - red brown slightly sandy clayey silt filling, with building rubble bricks and concrete, metal staining, moist		D	0.4 0.5			
	0.8			B				
	1	FILLING - red brown slightly sandy clayey silt filling, trace of rootlets, trace of gravel, moist		D	0.9 1.0			
45	1.5	SILTY CLAY - stiff red brown silty clay, with a trace of rootlets and ironstone gravel		D	1.5 1.6		pp = 150	
	1.6				1.7		pp = 300	
	2	SILTY CLAY - very stiff red brown silty clay, with some ironstone gravel bands		D	1.9 2.0 2.1		pp >300	
44	2.3	SILTY CLAY - very stiff red brown mottled grey silty clay		D	2.4 2.5			
	2.5	Pit discontinued at 2.5m						

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator **LOGGED:** ZM **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

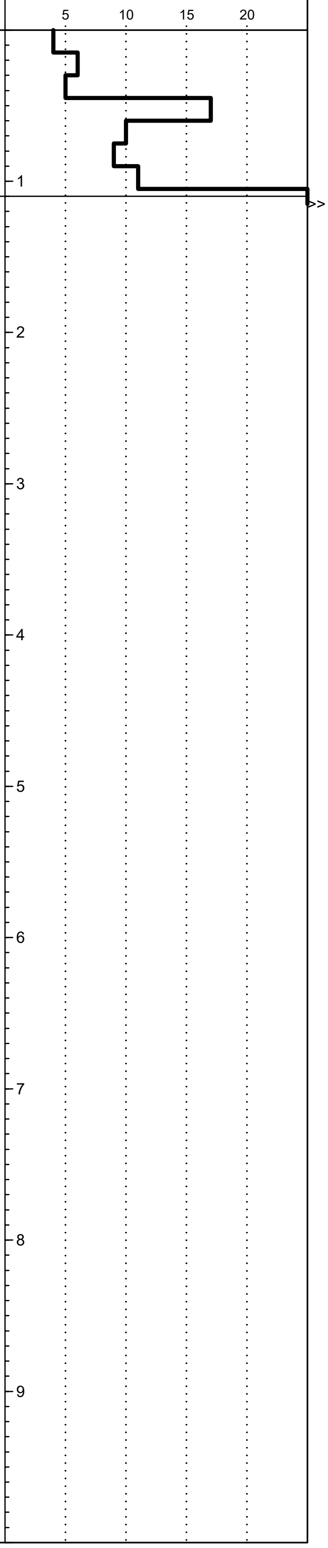
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 48.7 mAHD
EASTING: 306539
NORTHING: 6270392

PIT No: 1
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
	FILLING - brown gravelly clay filling	D	0.1–0.2			
0.3	SILTY CLAY - very stiff red brown silty clay, moist	D	0.4–0.5		pp >300	
		B				
0.8	SILTY CLAY - very stiff grey mottled red silty clay, with some ironstone gravel, moist	D	0.9–1.0		pp = 250	
1.0	SILTY CLAY - very stiff grey silty clay	D	1.05–1.1			
1.05	SHALE - extremely low to very low strength grey weathered shale, with some ironstone bands					
1.1	Pit discontinued at 1.1m - Practical refusal at 1.1m on at least low strength shale					

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator
LOGGED: ZM
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

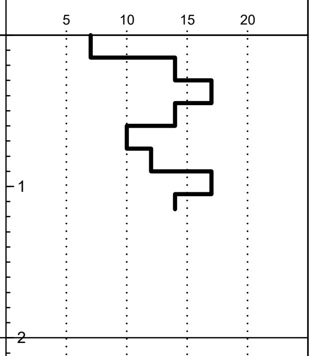
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 47.6 mAHD
EASTING: 306512
NORTHING: 6270325

PIT No: 2
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Sampling Type	Sampling Depth	Sample	Results & Comments	Water
0.25	TOPSOIL - dark brown silty clay topsoil, with a trace of rootlets					
0.6	SILTY CLAY - very stiff red brown mottled grey silty clay	D	0.4–0.5		pp >300	
0.8	SILTY CLAY - very stiff red brown mottled grey silty clay, with some ironstone gravel					
1.2	SILTY CLAY - very stiff light grey silty clay, with a trace of ironstone gravel	D	0.9–1.0		pp >300	
1.8	SHALE - extremely low strength, extremely weathered light grey shale, with ironstone gravel bands	D	1.5–1.6		pp >300	
2.0	SHALE - very low and low strength dark grey shale, with extremely low strength bands and ironstone gravel bands	D	1.9–2.0			
	Pit discontinued at 2.0m					

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator
LOGGED: ZM
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

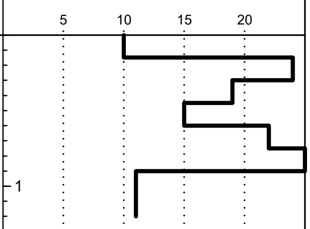
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 46.7 mAHD
EASTING: 306475
NORTHING: 6270326

PIT No: 4
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Sampling Type	Sampling Depth	Results & Comments
0.25	TOPSOIL FILLING - dark brown silty clay topsoil filling, with some vegetation and traces of rootlets			
0.6	FILLING - red brown silty clay filling, with some shale fragments (possible ripped shale), some concrete fragments (moderately compacted), humid	D	0.4–0.5	
			0.7	pp >300
1.0	SILTY CLAY - very stiff grey mottled red silty clay, with a trace of ironstone gravel, slightly moist	D	0.9–1.0	
			1.2	pp = 250
1.7	SILTY CLAY - very stiff grey mottled red silty clay, with some ironstone gravel, slightly moist (possible extremely weathered shale)	D	1.4–1.5	pp >300
2.1	SHALE - extremely low strength, extremely weathered light grey mottled red shale, with ironstone gravel bands 1.9m: large ironstone fragments	D	1.9–2.0	
	Pit discontinued at 2.1m			

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator **LOGGED:** ZM **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: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 47.3 mAHD
EASTING: 306479
NORTHING: 6270372

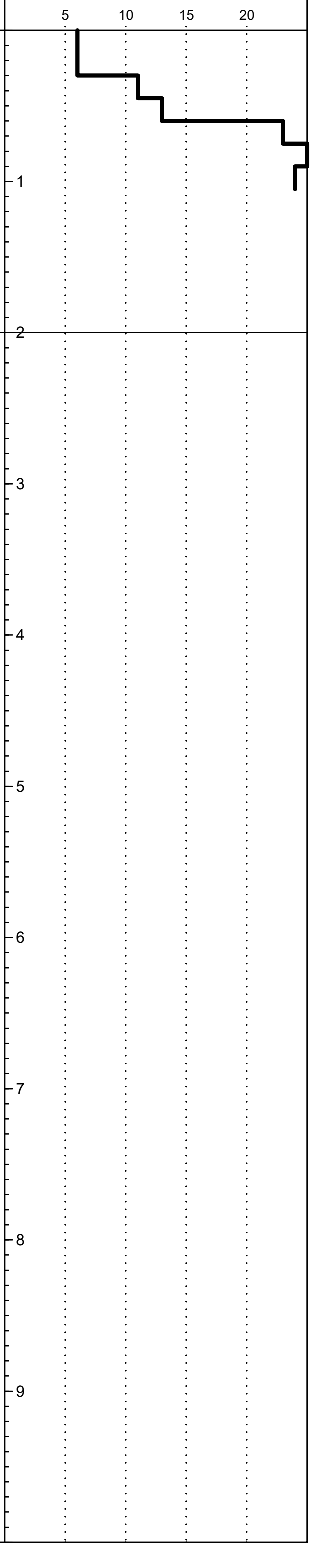
PIT No: 3
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata
0.01	TOPSOIL FILLING - brown clayey silt topsoil filling, with vegetation
0.5	FILLING - red brown clayey silt filling, with a trace of rootlets
	SILTY CLAY - very stiff red brown silty clay, with a trace of ironstone gravel and rootlets (possible filling)
1.2	SILTY CLAY - very stiff red brown silty clay, with some roots/timber fragments
1.5	SILTY CLAY - hard light grey mottled red silty clay, with a trace of ironstone gravel, slightly moist
1.8	SHALE - extremely low strength, extremely weathered grey mottled red shale
2.0	Pit discontinued at 2.0m

Sampling & In Situ Testing

Type	Depth	Sample	Results & Comments
D	0.05–0.1		
D	0.4–0.5		pp >300
D	0.9–1.0		
	1.4		pp >300
D	1.5–1.6		pp = 250
	1.7		pp >300
D	1.9–2.0		

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator
LOGGED: ZM
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: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 46.4 mAHD
EASTING: 306438
NORTHING: 6270298

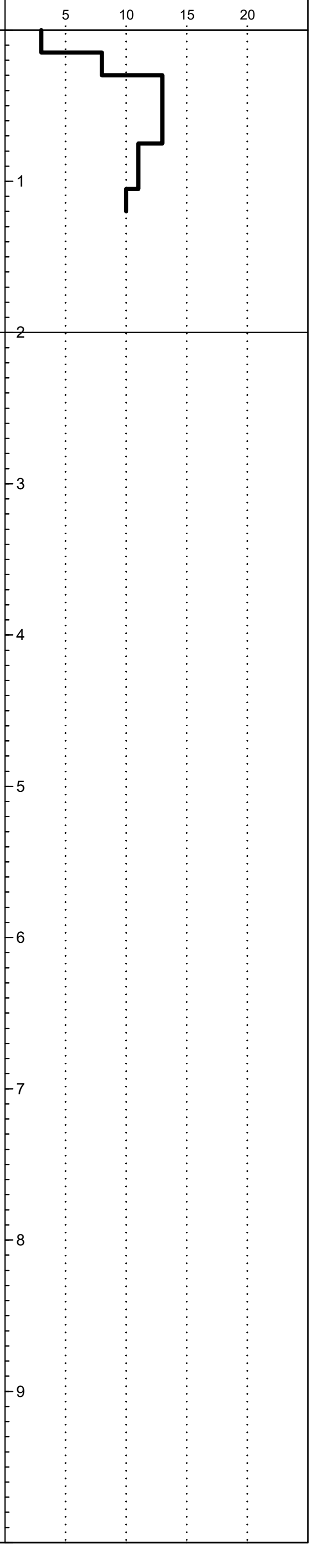
PIT No: 5
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata
0.15	TOPSOIL - dark brown silty clay topsoil, with some vegetation
0.4	SILTY CLAY - red brown silty clay, with a trace of ironstone gravel
	SILTY CLAY - very stiff red brown mottled brown silty clay, slightly moist
1.0	SILTY CLAY - very stiff grey mottled red silty clay, with some ironstone gravel, moist to slightly moist
1.5	SILTY CLAY - very stiff light grey mottled red silty clay, with some ironstone gravel
1.8	SHALE - extremely low strength, extremely weathered grey shale
2.0	Pit discontinued at 2.0m

Type	Depth	Sample	Results & Comments
D	0.4 0.5		pp >300
B			
D	0.9 1.0		pp = 250
	1.2		pp >300
D	1.4 1.5		
D	1.5 1.6		pp >300

Water: —

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator **LOGGED:** ZM **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

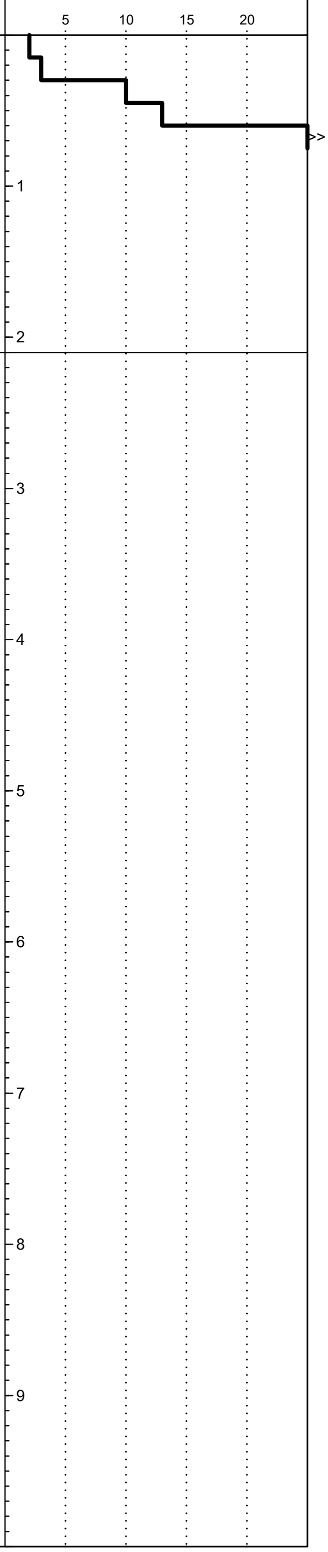
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 45.9 mAHD
EASTING: 306400
NORTHING: 6270316

PIT No: 6
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments
	0.15	TOPSOIL - dark brown sandy, silty clay topsoil				
		SILTY CLAY - very stiff red brown silty clay, with a trace of rootlets (possible filling)	D	0.4 0.5		pp >300
	0.6	SILTY CLAY - very stiff red brown silty clay, with a trace of ironstone gravel, slightly moist	D	0.9 1.0		pp = 250
45	1.0	SILTY CLAY - very stiff red brown mottled grey silty clay, with a trace of ironstone gravel		1.2		pp >300
			D	1.4 1.5		
	1.6	SILTY CLAY - stiff to very stiff grey mottled orange brown silty clay, with a trace of ironstone gravel		1.6		pp = 190
44			D	1.9 2.0		
	2.1	Pit discontinued at 2.1m				

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator
LOGGED: ZM
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
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TEST PIT LOG

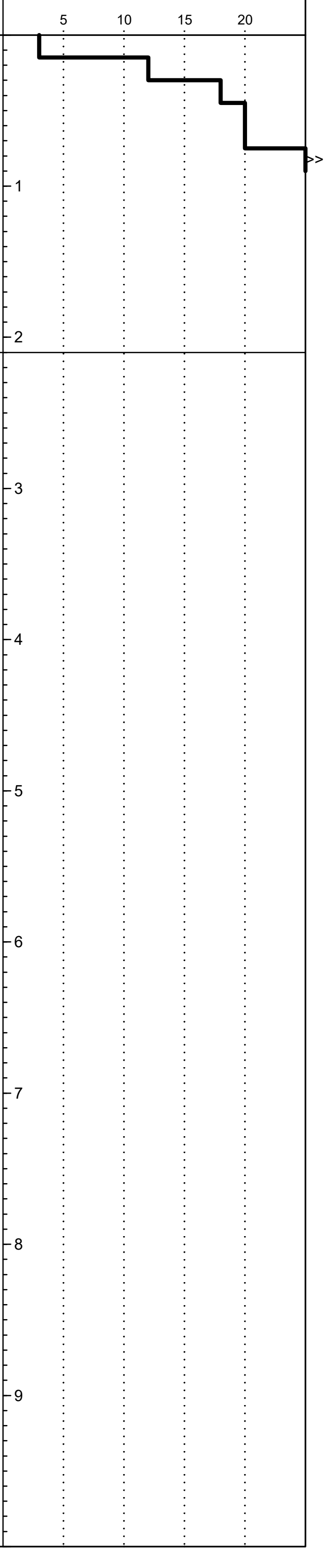
CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 45.5 mAHD
EASTING: 306367
NORTHING: 6270279

PIT No: 9
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Sampling Type	Sampling Depth	Results & Comments
0.0–0.2	TOPSOIL - brown to dark brown silty clay topsoil			
0.2–0.5	SILTY CLAY - red brown silty clay, with a trace of ironstone gravel, moist (possible filling)	D	0.4–0.5	pp >300
0.5–1.6	SILTY CLAY - very stiff red brown silty clay, with a trace of ironstone gravel, moist	D	0.9–1.0	pp >300
		D	1.4–1.5	pp = 250
1.6–1.9	SILTY CLAY - very stiff grey mottled red silty clay, with a trace of ironstone gravel, moist	D	1.9–2.0	pp >300
1.9–2.1	SILTY CLAY - hard light grey mottled red silty clay (possible weathered shale)			
2.1	Pit discontinued at 2.1m			

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator
LOGGED: ZM
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: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 46.7 mAHD
EASTING: 306403
NORTHING: 6270350

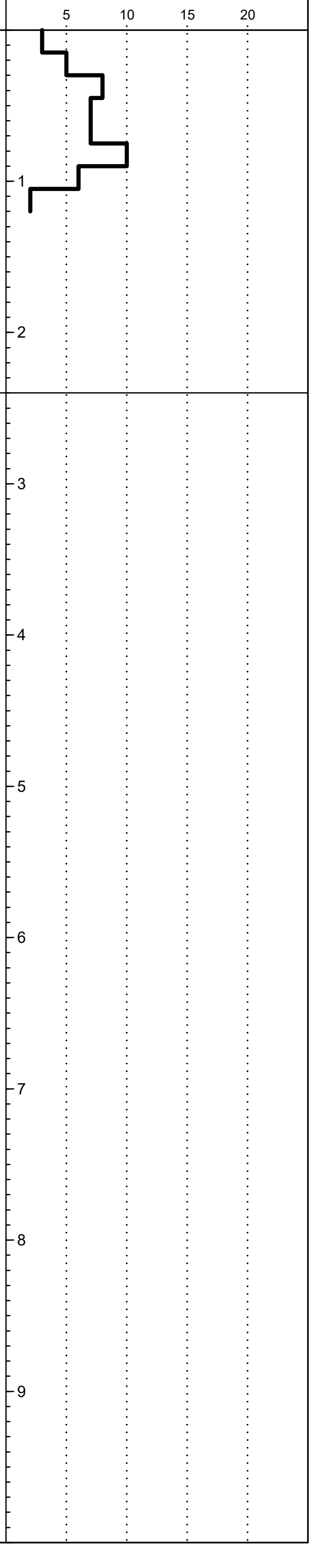
PIT No: 7
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Graphic Log
0.03	TOPSOIL FILLING - dark brown silty clay topsoil filling, with some vegetation	Fill
1.2	FILLING - red brown silty clay filling, with a trace of grey shale, boulders, bricks, green plastic lining, roots and timber fragments	Fill
1.5	FILLING - red brown silty clay filling, with some ironstone gravel	Fill
1.8	FILLING - red brown silty clay filling, with some concrete and glass fragments	Fill
2.2	FILLING - red brown silty clay, with some grey silty clay	Fill
2.4	FILLING - red brown silty clay filling, with some ironstone gravel 2.3m: some dark silty clay (possibly alluvial) very silty, with some quartz like gravel, moist	Fill
	Pit discontinued at 2.4m	

Sampling & In Situ Testing

Type	Depth	Sample	Results & Comments
D	0.4–0.5		
D	0.9–1.0		
D	1.4–1.5		
D	1.9–2.0		
D	2.3–2.4		

Dynamic Penetrometer Test (blows per 150mm)



RIG: 3.5 tonne mini excavator **LOGGED:** ZM **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: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 47.5 mAHD
EASTING: 306509
NORTHING: 6270327

PIT No: 10
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Type	Sample Depth	Results & Comments
0.0 – 0.25	TOPSOIL - dark brown silty clay topsoil, with a trace of rootlets	A	0.0–0.1	
0.25 – 0.7	SILTY CLAY - light brown silty clay, humid	A	0.4–0.5	
0.7 – 1.5	SILTY CLAY - light grey, mottled red brown silty clay	A	0.9–1.0	
		U	1.0–1.27	
1.5 – 2.8	SHALE - extremely low strength, extremely weathered light green shale with a trace of ironstone bands	A	1.9–2.0	
2.8 – 5.0	SHALE - very low and low strength highly weathered, dark grey shale, with bands of extremely low strength shale and ironstone bands	A	2.9–3.0	
	- below 4m increasing to low to medium strength	A	3.9–4.0	
		A	4.9–5.0	
5.0	Pit discontinued at 5.0m			

Dynamic Penetrometer Test (blows per mm): 5, 10, 15, 20 — no results plotted.

RIG: Scout **LOGGED:** PF **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed while drilling

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: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 47.7 mAHD
EASTING: 306485
NORTHING: 6270367

PIT No: 11
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

Depth (m)	Description of Strata	Sample Type	Sample Depth	Results & Comments
0.0–0.3	TOPSOIL - brown silty clay topsoil with a trace of rootlets	A	0.0–0.1	
0.3–0.8	SILTY CLAY - red brown mottled brown silty clay, occasional ironstone gravel bands, moist	A	0.4–0.5	
0.8–2.0	SILTY CLAY - light grey mottled red brown silty clay, with a trace of ironstone gravel	A	0.9–1.0	
		U	1.0–1.4	
		A	1.9–2.0	
2.0–3.5	SHALE - extremely low strength, extremely weathered, light grey shale with a trace of ironstone gravel - below 2.8m becoming extremely low to very low strength	A	2.9–3.0	
3.5–5.0	SHALE - low to medium strength, highly weathered, dark grey and brown shale, with a trace of ironstone bands - below 4.5m becoming dark grey	A	3.9–4.0	
		A	4.9–5.0	
5.0	Pit discontinued at 5.0m			

Dynamic Penetrometer Test (blows per mm): 5, 10, 15, 20

RIG: Scout
LOGGED: PF
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed while drilling

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
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TEST PIT LOG

CLIENT: Celesteem Rouse Hill Development Pty Ltd
PROJECT: Proposed Townhouse Development
LOCATION: 54 Terry Road, Rouse Hill

SURFACE LEVEL: 46.1 mAHD
EASTING: 306412
NORTHING: 6270319

PIT No: 12
PROJECT No: 94508.00
DATE: 15/6/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm)
46	0.2	TOPSOIL - dark brown silty clay topsoil, with a trace of rootlets and gravel		A	0.0–0.1				
	0.8	SILTY CLAY - brown silty clay, with a trace of ironstone gravel, humid		A	0.4–0.5				
45	2.0	SILTY CLAY - red brown mottled brown silty clay, with occasional ironstone gravel bands, moist		A	0.9–1.0				
				U	1.0–1.4				
44	2.7	SILTY CLAY - light grey mottled red brown silty clay, with a trace of ironstone gravel, moist		A	1.9–2.0				
43	3.8	SHALE - extremely low and very low strength, extremely to moderately weathered, light grey shale, with a trace of ironstone bands		A	2.9–3.0				
42	5.0	SHALE - low and medium strength, high to moderately weathered grey shale, with ironstone banding		A	4.9–5.0				
41		Pit discontinued at 5.0m							

RIG: Scout **LOGGED:** PF **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed while drilling

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 D

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: tim.white@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Tim White
Lab manager

NATA Accredited Laboratory Number: 828

Report Number: **94508.00-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389A
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Remarks: Field moisture content = 19.7%
Sample Location: **TP 1 (0.5m - 1.0m)**
Material: SILTY CLAY - red brown mottled grey silty clay

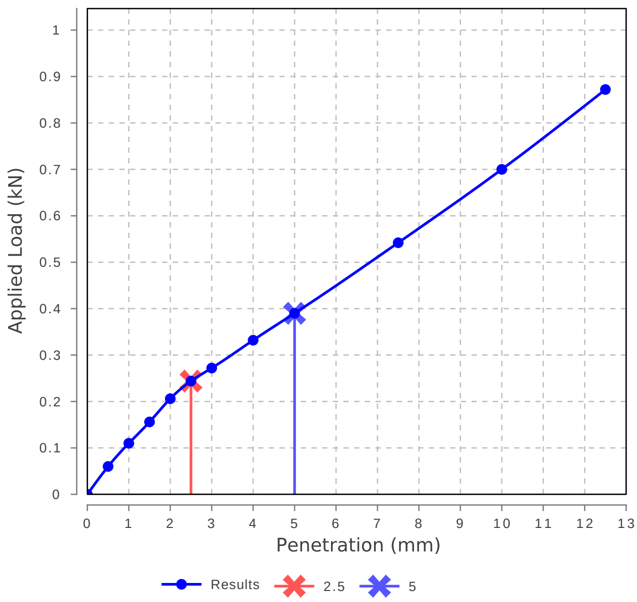
California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.80		
Optimum Moisture Content (%)	20.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.78		
Field Moisture Content (%)	19.7		
Moisture Content at Placement (%)	20.6		
Moisture Content Top 30mm (%)	26.7		
Moisture Content Rest of Sample (%)	21.7		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	48		
Swell (%)	1.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	61		
Plastic Limit (%)	19		
Plasticity Index (%)	**42**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	17.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description	As above		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		

California Bearing Ratio



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: tim.white@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

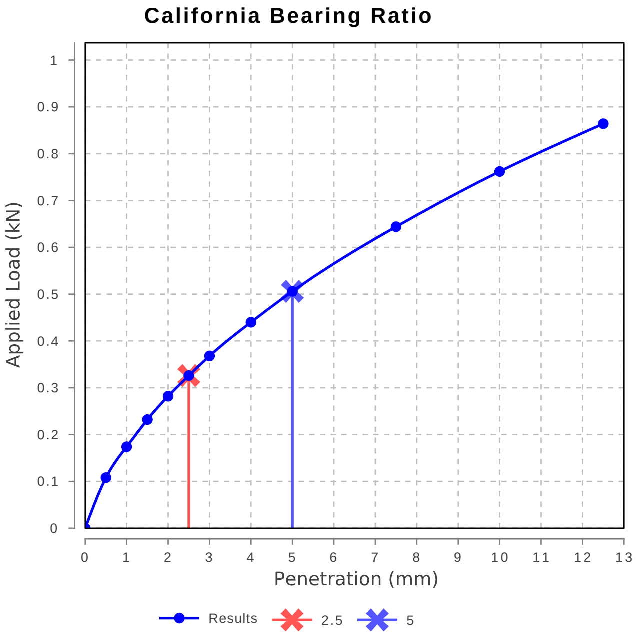
NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Tim White
Lab manager

NATA Accredited Laboratory Number: 828

Report Number: **94508.00-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389B
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 5 (0.5m - 1.0m)**
Material: SILTY CLAY - red brown mottled red silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.67		
Optimum Moisture Content (%)	22.5		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.64		
Field Moisture Content (%)	19.5		
Moisture Content at Placement (%)	22.4		
Moisture Content Top 30mm (%)	29.9		
Moisture Content Rest of Sample (%)	23.3		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96		
Swell (%)	2.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater

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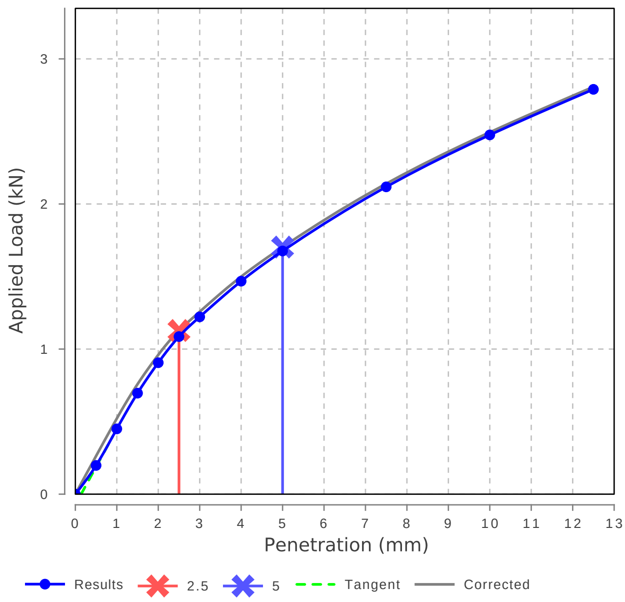
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Tim White
Lab manager

NATA Accredited Laboratory Number: 828

Report Number: **94508.00-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389C
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Remarks: Field moisture content = 14.3%
Sample Location: **TP 8 (0.5m - 1.0m)**
Material: FILLING – red brown, slightly sandy clayey silt filling, trace of gravel

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**9**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.71		
Optimum Moisture Content (%)	18.5		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.69		
Field Moisture Content (%)	14.3		
Moisture Content at Placement (%)	18.6		
Moisture Content Top 30mm (%)	21.6		
Moisture Content Rest of Sample (%)	20.0		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	37		
Plastic Limit (%)	19		
Plasticity Index (%)	**18**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	7.5		
Cracking Crumbling Curling	Cracking		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description	As above		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		

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
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Email: tim.white@douglaspartners.com.au

Report Number: **94508.00-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389E
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Remarks: Field moisture content = 14.5%
Sample Location: **BH 10 (1.0m - 1.27m)**
Material: SILTY CLAY - red brown mottled grey silty clay with ironstone gravel

Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Tim White
Lab manager
NATA Accredited Laboratory Number: 828

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

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	None		

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater

Report Number:	**94508.00-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	04/07/2018
Client:	Prisma Rouse Hill Development Pty Ltd PO Box 20732, World Square NSW 2002
Contact:	Mark Ng
Project Number:	94508.00
Project Name:	Proposed Townhouse Development
Project Location:	54 Terry Road, Rouse Hill
Work Request:	389

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Approved Signatory: Tim White
Lab manager
NATA Accredited Laboratory Number: 828

Shrink Swell Index AS 1289 7.1.1 & 2.1.1			
Sample Number	18-389D	18-389F	18-389G
Sampling Method	Sampled by Engineering Department	Sampled by Engineering Department	Sampled by Engineering Department
Date Sampled	18/06/2018	18/06/2018	18/06/2018
Date Tested	20/06/2018	20/06/2018	20/06/2018
Material Source	U50 push tube	U50 push tube	U50 push tube
Sample Location	BH 4 (1.0m - 1.4m)	BH 11 (1.0m - 1.4m)	BH 12 (1.0m -1.4m)
Inert Material Estimate (%)	8	0	1
Pocket Penetrometer before (kPa)	>600	>600	>600
Pocket Penetrometer after (kPa)	40	250	150
Shrinkage Moisture Content (%)	14.8	13.5	19.6
Shrinkage (%)	**1.1**	**0.6**	**2.7**
Swell Moisture Content Before (%)	14.8	13.6	19.2
Swell Moisture Content After (%)	28.0	21.2	27.7
Swell (%)	**1.0**	**2.8**	**2.4**
Shrink Swell Index Iss (%)	**0.9**	**1.1**	**2.2**
Visual Description	SILTY CLAY - grey mottled red silty clay with ironstone gravel	SILTY CLAY - red brown mottled grey silty clay with ironstone gravel	SILTY CLAY - red brown mottled grey silty clay with ironstone gravel
Cracking	Slightly Cracked	Slightly Cracked	Slightly Cracked
Crumbling	No	No	No
Remarks	**	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

Material Test Report

Report Number: **94508.00-1**
Issue Number: 1
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389A
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Remarks: Field moisture content = 19.7%
Sample Location: **TP 1 (0.5m - 1.0m)**
Material: SILTY CLAY - red brown mottled grey silty clay

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Approved Signatory: Tim White
Lab manager

NATA Accredited Laboratory Number: 828

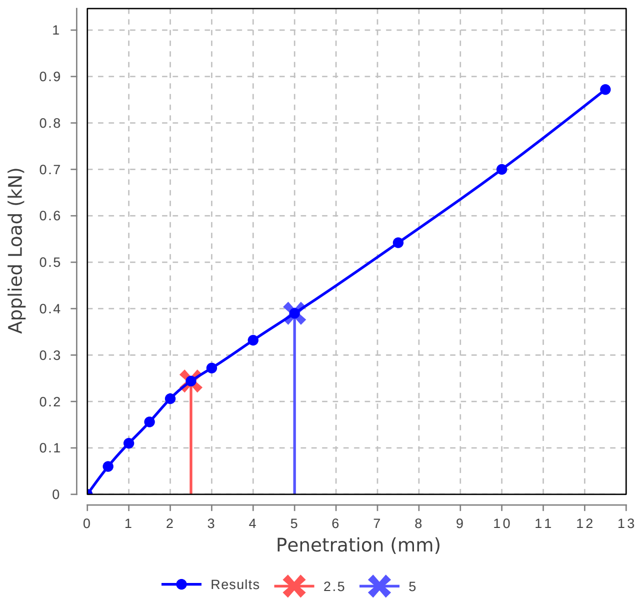
California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.80		
Optimum Moisture Content (%)	20.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.78		
Field Moisture Content (%)	19.7		
Moisture Content at Placement (%)	20.6		
Moisture Content Top 30mm (%)	26.7		
Moisture Content Rest of Sample (%)	21.7		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	48		
Swell (%)	1.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	61		
Plastic Limit (%)	19		
Plasticity Index (%)	**42**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	17.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description	As above		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		

California Bearing Ratio



Material Test Report

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Report Number:	**94508.00-1**
Issue Number:	1
Date Issued:	04/07/2018
Client:	Prisma Rouse Hill Development Pty Ltd PO Box 20732, World Square NSW 2002
Contact:	Mark Ng
Project Number:	94508.00
Project Name:	Proposed Townhouse Development
Project Location:	54 Terry Road, Rouse Hill
Work Request:	389
Sample Number:	18-389B
Date Sampled:	18/06/2018
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 5 (0.5m - 1.0m)**
Material:	SILTY CLAY - red brown mottled red silty clay

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Lab manager

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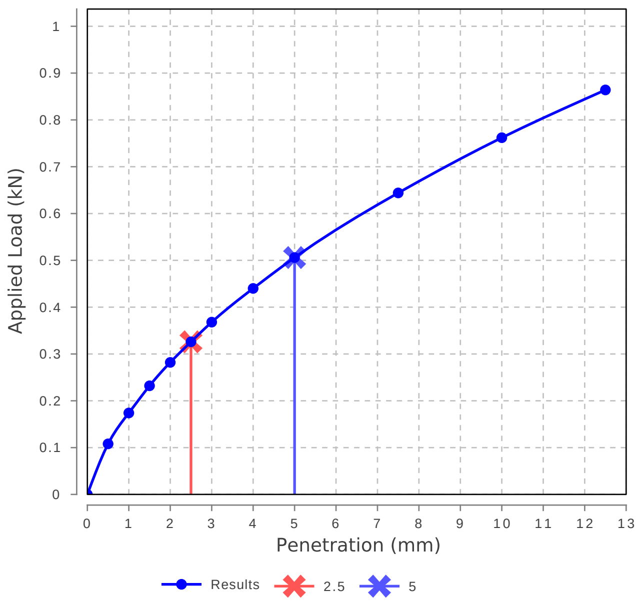
California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.67		
Optimum Moisture Content (%)	22.5		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.64		
Field Moisture Content (%)	19.5		
Moisture Content at Placement (%)	22.4		
Moisture Content Top 30mm (%)	29.9		
Moisture Content Rest of Sample (%)	23.3		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96		
Swell (%)	2.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

California Bearing Ratio



Material Test Report

Report Number:	**94508.00-1**
Issue Number:	1
Date Issued:	04/07/2018
Client:	Prisma Rouse Hill Development Pty Ltd PO Box 20732, World Square NSW 2002
Contact:	Mark Ng
Project Number:	94508.00
Project Name:	Proposed Townhouse Development
Project Location:	54 Terry Road, Rouse Hill
Work Request:	389
Sample Number:	18-389C
Date Sampled:	18/06/2018
Sampling Method:	Sampled by Engineering Department
Remarks:	Field moisture content = 14.3%
Sample Location:	**TP 8 (0.5m - 1.0m)**
Material:	FILLING - brown silty sand filling

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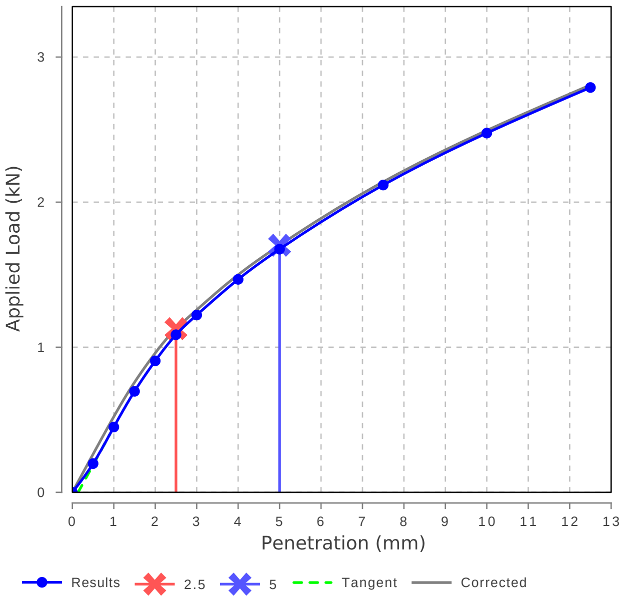
California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**9**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.71		
Optimum Moisture Content (%)	18.5		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.69		
Field Moisture Content (%)	14.3		
Moisture Content at Placement (%)	18.6		
Moisture Content Top 30mm (%)	21.6		
Moisture Content Rest of Sample (%)	20.0		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	96		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

California Bearing Ratio



Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	37		
Plastic Limit (%)	19		
Plasticity Index (%)	**18**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	7.5		
Cracking Crumbling Curling	Cracking		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description	As above		
Nature of Water	Distilled		
Temperature of Water (°C)	20		
* Mineral Present	Carbonate		

Material Test Report

Report Number: **94508.00-1**
Issue Number: 1
Date Issued: 04/07/2018
Client: Prisma Rouse Hill Development Pty Ltd
PO Box 20732, World Square NSW 2002
Contact: Mark Ng
Project Number: 94508.00
Project Name: Proposed Townhouse Development
Project Location: 54 Terry Road, Rouse Hill
Work Request: 389
Sample Number: 18-389E
Date Sampled: 18/06/2018
Sampling Method: Sampled by Engineering Department
Remarks: Field moisture content = 14.5%
Sample Location: **BH 10 (1.0m - 1.27m)**
Material: SILTY CLAY - red brown mottled grey silty clay with ironstone gravel

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

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.5		
Cracking Crumbling Curling	None		

Material Test Report

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Client:	Prisma Rouse Hill Development Pty Ltd PO Box 20732, World Square NSW 2002
Contact:	Mark Ng
Project Number:	94508.00
Project Name:	Proposed Townhouse Development
Project Location:	54 Terry Road, Rouse Hill
Work Request:	389

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Shrink Swell Index AS 1289 7.1.1 & 2.1.1			
Sample Number	18-389D	18-389F	18-389G
Sampling Method	Sampled by Engineering Department	Sampled by Engineering Department	Sampled by Engineering Department
Date Sampled	18/06/2018	18/06/2018	18/06/2018
Date Tested	20/06/2018	20/06/2018	20/06/2018
Material Source	U50 push tube	U50 push tube	U50 push tube
Sample Location	BH 4 (1.0m - 1.4m)	BH 11 (1.0m - 1.4m)	BH 12 (1.0m -1.4m)
Inert Material Estimate (%)	8	0	1
Pocket Penetrometer before (kPa)	>600	>600	>600
Pocket Penetrometer after (kPa)	40	250	150
Shrinkage Moisture Content (%)	14.8	13.5	19.6
Shrinkage (%)	**1.1**	**0.6**	**2.7**
Swell Moisture Content Before (%)	14.8	13.6	19.2
Swell Moisture Content After (%)	28.0	21.2	27.7
Swell (%)	**1.0**	**2.8**	**2.4**
Shrink Swell Index Iss (%)	**0.9**	**1.1**	**2.2**
Visual Description	SILTY CLAY - grey mottled red silty clay with ironstone gravel	SILTY CLAY - red brown mottled grey silty clay with ironstone gravel	SILTY CLAY - red brown mottled grey silty clay with ironstone gravel
Cracking	Slightly Cracked	Slightly Cracked	Slightly Cracked
Crumbling	No	No	No
Remarks	**	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

Appendix E

CSIRO Notes “Foundation Maintenance and Footing Performance, A Homeowners Guide”

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.

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.

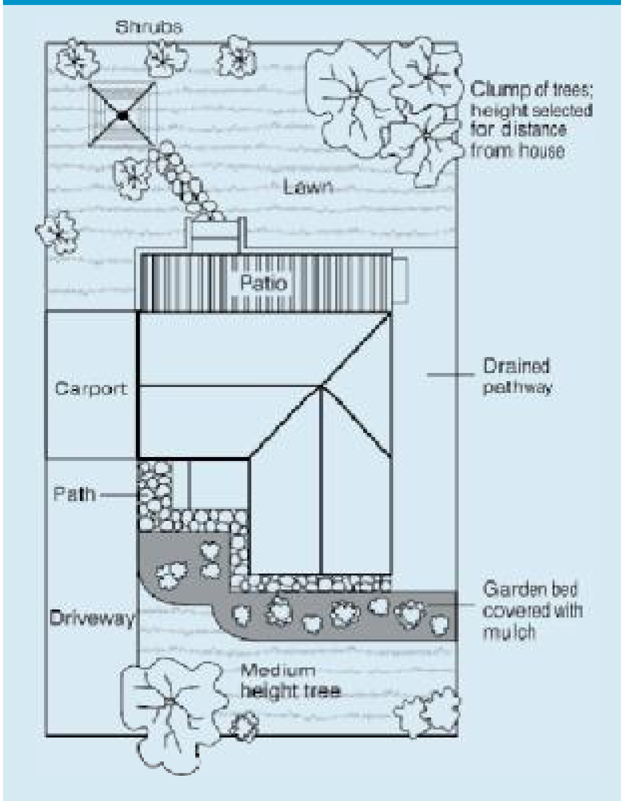
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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