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Report on Geotechnical Investigation

Proposed High School
105-107 Mitchell Street, Wee Waa

Prepared for
Built (NSW) Pty Ltd

Project 210883.00
May 2022

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

Document details

Project No.	210883.00	Document No.	R.002.Rev0
Document title	Report on Geotechnical Investigation Proposed High School		
Site address	105-107 Mitchell Street, Wee Waa		
Report prepared for	Built (NSW) Pty Ltd		
File name	210883.00.R.002.Rev0.High School		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	John Niland	Michael Gawn	11 May 2022

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	0	Rebecca Deegan, Built (NSW) Pty Ltd

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

	Signature	Date
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bsi. ISO 9001 Quality Management
FS 604853

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Table of Contents

Report on Geotechnical Investigation
Proposed High School
105-107 Mitchell Street, Wee Waa

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed high school at 105-107 Mitchell Street, Wee Waa. The investigation was commissioned in an email dated 24 March 2022 by Scott Cameron of Built (NSW) Pty Ltd and was undertaken with reference to Douglas Partners Pty Ltd (DP) proposal 210883.00.P.002.Rev1 dated 24 March 2022.

It is understood that the proposed high school development includes the construction of school buildings, a carpark and a sports oval (soccer field and grass athletic track).

Previous geotechnical testing by others for the high school site included four bores drilled to 4 m depth and laboratory Atterberg limits tests and indicated Class P site classification with ground surface movement up to 125 mm.

A geotechnical investigation for the proposed school buildings was required to assess subsurface conditions and provide comment on the following:

- Groundwater level;
- Site classification;
- Shallow and piled footing design parameters including allowable bearing pressure and shaft adhesion; and
- Options for footing designs with the anticipated ground surface movement at the site.

The investigation included the drilling of four boreholes, dynamic penetrometer testing and laboratory testing of selected soil samples. The details of the field work are presented in this report, together with information on the items listed above.

DP (2022) has performed a previous investigation at Wee Waa which included a borehole (Bore 1) at the south-eastern part of the school site. The borehole log from Bore 1 from the previous investigation is included in Appendix A

2. Site Description

The site is located at 105-107 Mitchell Street, Wee Waa (refer Figure 1 and Figure 2). The site is a relatively flat grassed reserve with some trees in places. There are also existing shallow grassed drains at parts of the site.

Figure 1: From Mitchell Street looking north towards the site.

Figure 2: From the north-western part of the site looking south-east.

3. Regional Geology

Reference to the NSW Seamless Geology mapping data indicates that the site is underlain by riverine plain material typically comprising clay, sand and silt.

4. Field Work

4.1 Field Work Methods

The field work was undertaken on 5 and 6 April 2022 and comprised the drilling of four boreholes (Bores 101 and 103 to 105) and four dynamic penetrometer tests (DPTs 101 and 103 to 105) undertaken at the respective bore locations. The bores were drilled with a four wheel drive truck mounted rotary drilling rig equipped with spiral flight augers for drilling in soil. The bores were terminated in dense to very dense clayey sand at 10.25 m to 10.45 m depth, which was the target depth for the investigation.

Standard penetration tests (SPTs) were performed at selected depths in each bore.

The drill rig was planned to drill another bore (Bore 102), however, was unable to access the bore location due to the drill rig being bogged attempting access to the test location after a rain event overnight on 6 April 2022.

The DPTs were terminated at 0.6 m to 1.05 m depth generally due to decreasing depth penetration per hammer blow.

An engineering geologist from DP logged the subsurface profile in each bore and took disturbed and undisturbed tube samples at regular depth intervals for subsequent laboratory testing and identification purposes.

The test locations were set out by an engineering geologist using a dGPS. The approximate locations of the tests are indicated on Drawing 1 in Appendix C.

4.2 Field Work Results

The subsurface conditions encountered in the bores are presented in detail in the borehole logs in Appendix A. These should be read in conjunction with the accompanying notes (Sampling Methods, Soil Descriptions and Symbols and Abbreviations) which explain the descriptive terms and classification methods used in the preparation of the logs. The results of the DPTs are shown graphically on the borehole logs and are tabulated on a separate results sheet in Appendix A.

A summary of the subsurface conditions encountered in the bores is presented in Table 1 below.

Table 1: Summary of Subsurface Conditions in the Bores

Location	101	103	104	105
Stratum	**Depth Range (m)**			
Silty Clay: Stiff, becoming very stiff to hard, with sand in parts	0.0 – 6.5	0.0 – 5.2	0.0 – 2.3	0.0 – 6.5
Silty Sand: Dense to very dense	-	-	2.3 – 6.0	-
Clayey Sand: Dense to very dense	6.5 – 10.26	5.2 – 10.3	6.0 – 10.45	10.25

Selected soil samples from the bores are shown in Figure 3 to Figure 5.

Figure 3: Bore 101, SPT 1.0 – 1.45 m, very stiff to hard silty clay.

Figure 4: Bore 104, SPT 2.5 – 2.95 m, dense to very dense silty sand with clay.

Figure 5: Bore 105, SPT 7.0 – 7.30 m, very dense clayey sand.

There was no free groundwater observed in the bores whilst augering. The use of water as a drilling fluid below augered depths precluded observation of groundwater. It should be noted that groundwater levels are affected by factors such as climatic conditions and soil permeability and will therefore vary with time.

5. Laboratory Testing

Laboratory testing comprised two Atterberg limits tests and four shrink-swell tests on the silty clay material retrieved from the bores. The detailed laboratory test reports are included in Appendix B and the results are summarised in Table 2 and Table 3.

Table 2: Results of Laboratory Atterberg Limits Testing

Bore	Depth (m)	Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
101	0.5	Brown mottled grey silty clay	69	18	51
105	0.5	Brown mottled grey silty clay	65	19	46

Table 3: Results of Laboratory Shrink Swell Testing

Bore	Depth (m)	Description	FMC (%)	Iss (% per ∆pF)
101	1.5 – 1.7	Brown mottled grey silty clay	15.8	4.1
103	0.5 – 0.8	Brown mottled grey silty clay	17.5	4.2
104	0.5 – 0.75	Brown mottled grey silty clay	13.2	3.0
104	1.5 – 1.75	Brown mottled grey silty clay	12.0	2.2

Notes to table:

FMC: Field Moisture Content

Iss: Shrink-Swell Index

6. Comments

6.1 Site Classification and Reactive Soil Considerations

Site classification of foundation soil reactivity indicates the propensity of the ground surface to move with ‘normal’ seasonal moisture variation. The magnitude of moisture related seasonal ground movements should be considered in design of structures. The site classification is based on procedures presented in AS 2870 (2011) Residential Slabs and Footings, the typical soil profiles revealed at the test locations and the results of laboratory testing.

The site classification is Class P due to the presence of existing trees at the site. Trees can lead to appreciable changes in local soil suction stresses and consequential clay shrink-swell soil movements. The consequence of the Class P classification is the requirement for footing systems to be engineer-designed.

With reference to AS 2870 (2011) Wee Waa is situated within a semi-arid zone and hence a depth of design suction soil change (H_s) of 4.0 m is considered appropriate. A crack depth factor of 0.5 was used for the assessment.

As a guide for footing design, the range of characteristic surface movement, y_s value, for the site in its current condition is estimated to be about 80 mm to 110 mm which is within the Class E-D range of characteristic soil movement (AS:2870 indicates characteristic surface movement of greater than 75 mm for Class E) under normal seasonal moisture fluctuations, without the influence of trees.

Appendix H and its commentary of AS 2870-2011, “A Guide to Design of Footings for Trees“, provides guidance and a method to estimate potential surface movements due to tree induced suction change for existing and possible new trees (e.g. extreme drying effects). However, it does not provide a method to determine maximum potential surface movements due to tree induced suction change (e.g. extreme swell effects) in the event the trees are removed immediately prior to construction. Appendix H of AS 2870 indicates that, for tree removal or dying trees, ultimate bending moment strength (M_u) for centre and edge heave should not be less than 1.5 times cracking moment capacity (M_{cr}) for footing design methods. Additional information on the design of footings based on differential mound movement is also provided in AS 2870. It is recommended that if trees are to be removed, they should be removed well ahead of building construction (preferably more than 12 months) to allow some rehydration of the clay.

Based on the methods presented in AS 2870:2011, surface movements greater than normal seasonal effects due to the influence of trees (y_t), is estimated to be about 15 mm to 45 mm.

These surface movements should be taken into account when calculating the differential mound movement (y_m) as defined in AS 2870:2011.

The site classification, as above, is based on the information obtained from the bores and on the results of laboratory testing and has involved interpolation between data points. In the event that the conditions encountered on site are different to those presented in this report, it is recommended that advice be obtained from this office.

It should be noted that this classification is dependent on proper site maintenance, which should be carried out in accordance with the attached CSIRO Sheet BTF-18, “Foundation Maintenance and Footing Performance: A Homeowners Guide” in Appendix A and with AS 2870-2011.

Masonry walls should be articulated in accordance with TN61 (CCAA, 2008) to minimise the effects of differential movement.

The site classification should be revised if cutting or filling is undertaken in proposed building areas, as required by AS 2870, 2011. Clay soil, if used as fill in the building area, could have an adverse effect on shrink-swell movements, leading to a more severe site classification and increased characteristic free surface movement, y_s. The planting of trees in proximity of a structure could also affect site classification and therefore should be avoided.

6.2 Footings

6.2.1 Design Options

Footing design would need to consider and accommodate the estimated movement from reactive soils, including swell pressure on piles. Options for reducing the effects of movement from reactive soils include:

- Placement of low reactivity material (e.g. low permeability crushed rock placed and compacted as controlled fill) at the site. Increased thickness of low reactivity fill material would have a reduction in estimated ground surface movement. Consideration could also be given to excavating reactive clay soil and replacing with low reactivity fill material – additional subsurface drainage may also be required;
- Support the school buildings using piles founded with sufficient depth below the ‘active’ soil zone (4 m depth at this site). This would entail construction of piles to a sufficient depth below the active zone so that the friction on the pile shaft below the active zone is greater than the heave uplift forces acting on the pile shaft in the active zone; or
- Installation of sleeved piles within the upper portion of the reactive soils. The upper portion of the pile in the active zone is isolated from the surrounding soil by the provision of an annulus and could

be achieved by a permanent oversized casing or the provision of loose material around the shaft of the pile.

Independent structures which are tolerant of surface movements may be suitable to be founded on high level footings, provided the anticipated reactive soils movements can be catered for in the design and construction.

6.2.2 High Level Pad Footings

Shallow footings may be appropriate for independent structures. Such footings should be founded in stiff or stronger natural silty clay or controlled fill (as per as AS3798) at a depth of at least 0.4 m and for footing widths up to 1 m wide should be proportioned for a maximum allowable bearing pressure of 150 kPa in stiff to very stiff or stronger natural silty clay and 100 kPa in controlled fill.

Settlement of up to about 10 mm is expected for shallow footings founded in stiff or stronger clay or controlled fill and proportioned as above. Such settlement would be independent of and may be additive to reactive soil movements, which as discussed in Section 6.1, are of significantly greater magnitude.

6.2.3 Piles

Published information consistently indicates that the pile portions founded within the ‘active’ zone of soil (4.0 m depth for this site) will experience uplift during clay swelling phases. Information on the converse effects of soil shrinkage during drying on pile performance is less clear, although it is logical to assume a lesser impact on vertical pressures as the soil potentially shrinks away from the pile shaft.

No testing has been undertaken to date to assess the likely magnitude of swelling pressures imposed by the reactive soil on any piles (or footings) within the active zone (i.e. above 4.0 m depth). The magnitude of shrink-swell induced vertical pile movement will be largely governed by the depth of pile penetration, with increased penetration (ideally as deep as possible below the ‘active’ zone) correspondingly reducing the predicted pile head movements relative to the predicted surface movements. For shallower piles, the vertical movement is likely to increase (relative to the predicted surface movements), together with a corresponding increased risk/rate of progressive pile jacking.

The relationship between pile penetration and reduction in vertical movement is difficult to predict, with limited information to develop relationships for predicting uplift forces and movement from soil swell. Variance in soil shear strength with depth as well as pile shape, weather patterns, and groundwater level fluctuations, and hence seasonal soil moisture content variations also add to the complexity of predicting pile performance.

For preliminary design piles founded in very stiff or stronger natural clay could be proportioned for a maximum allowable end bearing pressure of 350 kPa at greater than 4 x pile diameters below finished ground level. A maximum allowable shaft adhesion of 15 kPa is considered appropriate in very stiff or stronger natural clay for the section of shaft greater than 2 m below finished ground level, noting that swelling pressures may be acting on the upper portions of the shaft.

Bored pile excavations should be cleaned of all loose material and if water is present in the pile hole the water should be removed or the concrete should be added to the base of the pile hole using a tremie pipe to displace water above the concrete. Accordingly, it is recommended that DP be engaged during construction to undertake pile hole inspections prior to the placement of reinforcement and concrete.

6.3 General Design Inclusions

Given the presence of extremely reactive soils at the site it is recommended that all services to the proposed structures are provided with flexible connections, which can tolerate possible differential settlement.

6.4 Recommended Additional Investigation

It is recommended that further analysis is performed once the preferred footing option is known. This could include further subsurface investigation, laboratory testing for swell pressure which may result from changes in moisture content within the reactive soils, analysis of the preferred footing option and recommended site preparation measures.

7. References

AS 2870. (2011). *Residential Slabs and Footings.* Standards Australia.

CSIRO. (2012). *Building Technology File 18: Foundation Maintenance and Footing Performance – A Homeowner's Guide.* BTF-18: CSIRO Publishing, Commonwealth Scientific and Industrial Research Organisation.

DP (2022), *Report on Geotechnical Investigation, Proposed Flood Mitigation Works, Mitchell Street, Charles Street and Namoi River Flood Conveyance Channel, Wee Waa*, Douglas Partners Pty Ltd, Reference 210883.00.R.001.Rev0, dated 8 March 2022.

8. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at 105-107 Mitchell Street, Wee Waa with reference to DP's proposal 210883.00.P.002.Rev1 dated 24 March 2022 and acceptance received from Scott Cameron of Built (NSW) Pty Ltd in an email dated 24 March 2022. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Built (NSW) 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.

The assessment of typical safety hazards arising from this advice is restricted to the geotechnical components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

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

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

Douglas Partners Pty Ltd

Appendix A

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.

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.

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO
PUBLISHING
BTF 18-2011
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 2870-2011, 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, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes

1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

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.

Trees can cause shrinkage and damage

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 causes 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 2870-2011.

AS 2870-2011 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.

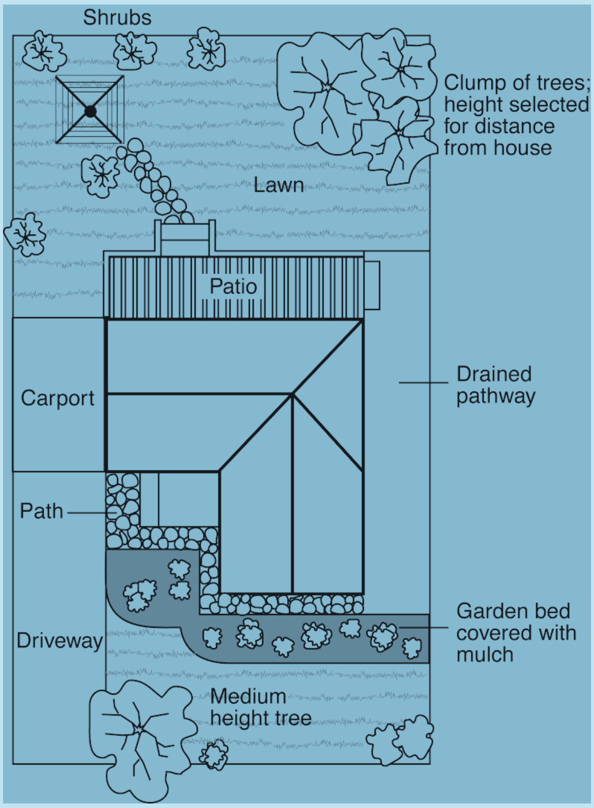
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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
CSIRO PUBLISHING Locked Bag 10, Clayton South VIC 3169
Tel (03) 9545 8400 1300 788 000 www.publish.csiro.au
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Sampling Methods

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.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are generally based on Australian Standard AS1726:2017, Geotechnical Site Investigations. 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	19 - 63
Medium gravel	6.7 - 19
Fine gravel	2.36 – 6.7
Coarse sand	0.6 - 2.36
Medium sand	0.21 - 0.6
Fine sand	0.075 - 0.21

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

The proportions of secondary constituents of soils are described as follows:

In fine grained soils (>35% fines)

Term	Proportion of sand or gravel	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	>30%	Sandy Clay
With	15 – 30%	Clay with sand
Trace	0 - 15%	Clay with trace sand

In coarse grained soils (>65% coarse)
- with clays or silts

Term	Proportion of fines	Example
And	Specify	Sand (70%) and Clay (30%)
Adjective	>12%	Clayey Sand
With	5 - 12%	Sand with clay
Trace	0 - 5%	Sand with trace clay

In coarse grained soils (>65% coarse)
- with coarser fraction

Term	Proportion of coarser fraction	Example
And	Specify	Sand (60%) and Gravel (40%)
Adjective	>30%	Gravelly Sand
With	15 - 30%	Sand with gravel
Trace	0 - 15%	Sand with trace gravel

The presence of cobbles and boulders shall be specifically noted by beginning the description with ‘Mix of Soil and Cobbles/Boulders’ with the word order indicating the dominant first and the proportion of cobbles and boulders described together.

Soil Descriptions

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
Friable	Fr	-

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	Density Index (%)
Very loose	VL	<15
Loose	L	15-35
Medium dense	MD	35-65
Dense	D	65-85
Very dense	VD	>85

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;
- Extremely weathered material – formed from in-situ weathering of geological formations. Has soil strength but retains the structure or fabric of the parent rock;
- Alluvial soil – deposited by streams and rivers;
- Estuarine soil – deposited in coastal estuaries;
- Marine soil – deposited in a marine environment;
- Lacustrine soil – deposited in freshwater lakes;
- Aeolian soil – carried and deposited by wind;
- Colluvial soil – soil and rock debris transported down slopes by gravity;
- Topsoil – mantle of surface soil, often with high levels of organic material.
- Fill – any material which has been moved by man.

Moisture Condition – Coarse Grained Soils

For coarse grained soils the moisture condition should be described by appearance and feel using the following terms:

Dry (D)	Non-cohesive and free-running.
Moist (M)	Soil feels cool, darkened in colour. Soil tends to stick together. Sand forms weak ball but breaks easily.
Wet (W)	Soil feels cool, darkened in colour. Soil tends to stick together, free water forms when handling.

Moisture Condition – Fine Grained Soils

For fine grained soils the assessment of moisture content is relative to their plastic limit or liquid limit, as follows:

- ‘Moist, dry of plastic limit’ or ‘w <PL’ (i.e. hard and friable or powdery).
- ‘Moist, near plastic limit’ or ‘w ≈ PL (i.e. soil can be moulded at moisture content approximately equal to the plastic limit).
- ‘Moist, wet of plastic limit’ or ‘w >PL’ (i.e. soils usually weakened and free water forms on the hands when handling).
- ‘Wet’ or ‘w ≈LL’ (i.e. near the liquid limit).
- ‘Wet’ or ‘w >LL’ (i.e. wet of the liquid limit).

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

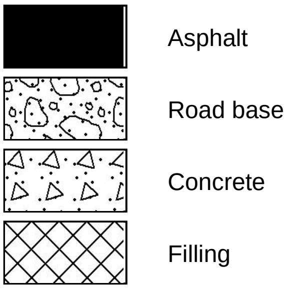
Other

fg	fragmented
bnd	band
qtz	quartz

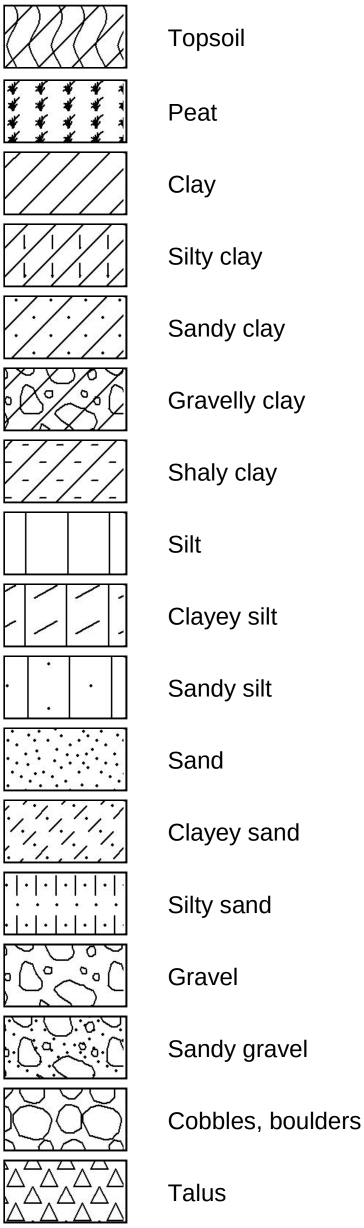
Symbols & Abbreviations

Graphic Symbols for Soil and Rock

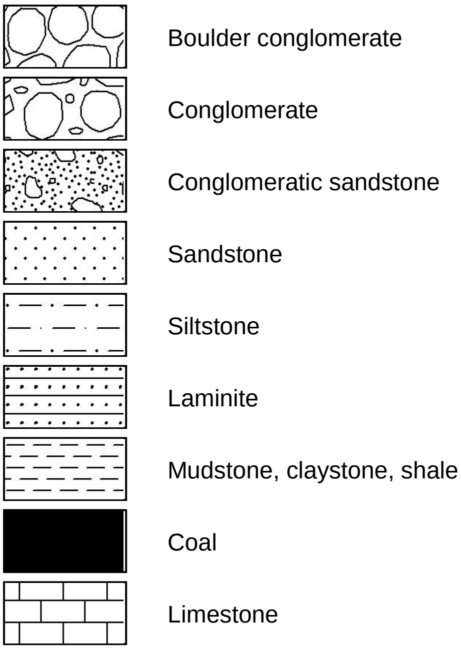
General



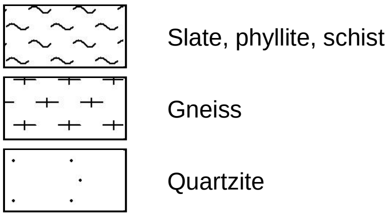
Soils



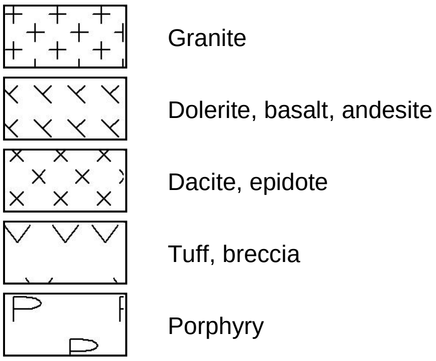
Sedimentary Rocks



Metamorphic Rocks



Igneous Rocks



BOREHOLE LOG

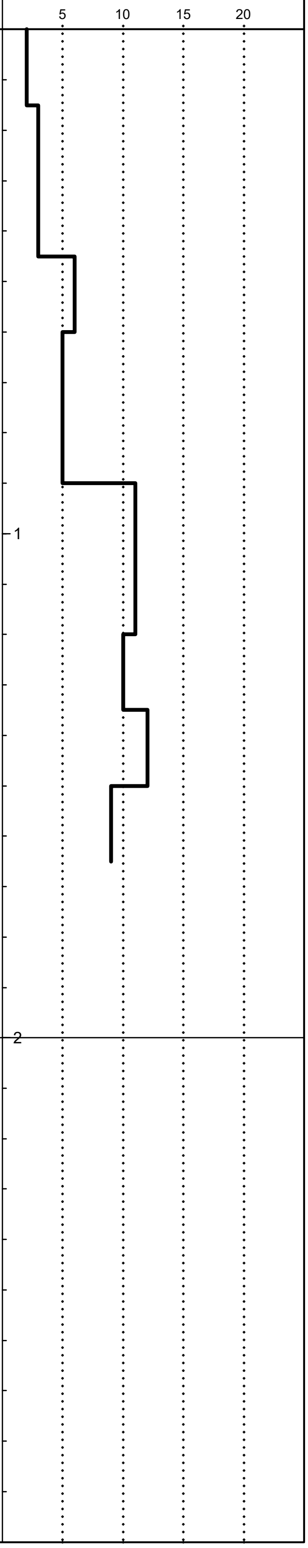
CLIENT: Built (NSW) Pty Ltd
PROJECT: Proposed Flood Mitigation Works
LOCATION: Mitchell Street, Charles Street and Namoi River Flood Conveyance Channel, Wee Waa

SURFACE LEVEL: 190.5 AHD
EASTING: 735058
NORTHING: 6654014
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 210883.00
DATE: 10/2/2022
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
		Silty CLAY (CL): low plasticity, brown, trace organics, w<PL, stiff to very stiff, alluvial		D	0.1			
					0.2		pp >400	
		- from 0.2m: no organics						
190				D	0.5			
					0.8		pp >400	
		- from 0.9m: very stiff to hard						
	1							
					1.2		pp >400	
				D	1.3			▷
189		- from 1.5m: brown and slightly orange brown						
					1.6		pp >400	
					1.8		pp >400	
	2 2.0	Bore discontinued at 2.0m- limit of investigation						
188								

Dynamic Penetrometer Test (blows per 150mm)



RIG: Hand Tools and Utility Mounted Rig **DRILLER:** MJH **LOGGED:** MJH **CASING:** Uncased

TYPE OF BORING: 75mm diameter Hand Auger then 60mm diameter Continuous Push Tube Sampler

WATER OBSERVATIONS: No free groundwater observed

REMARKS: Location coordinates are in MGA94 Zone 55 J. RL interpolated from survey plan supplied by client

☐ 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

Photo 1: Bore 1

Photo 2: Bore 1

Douglas Partners
Geotechnics / Environment / Groundwater

Flood Mitigation Works		PROJECT:	210883
Mitchell Street to Namoi		Plate	1
River, Wee Waa		REV:	A
Client	Built (NSW) Pty Ltd	DATE:	21-Feb-22

BOREHOLE LOG

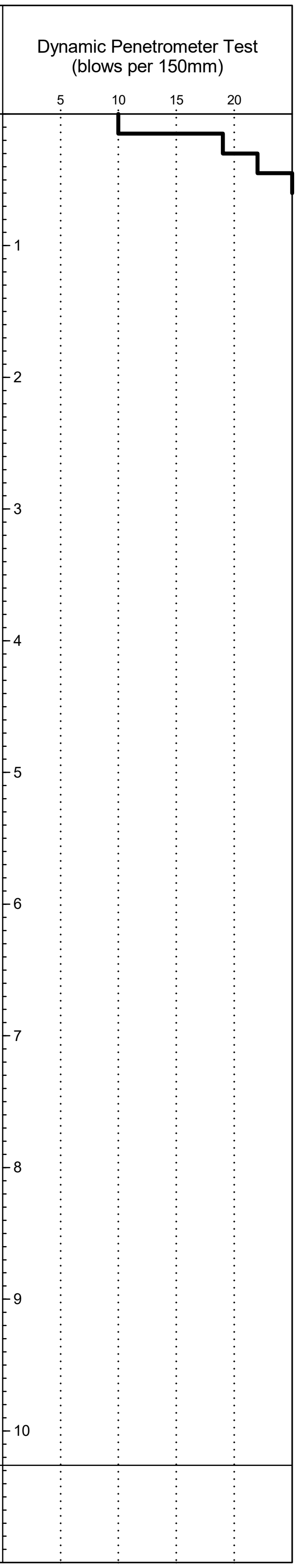
CLIENT: Built (NSW) Pty Ltd
PROJECT: Proposed High School
LOCATION: 105 - 107 Mitchell Street, Wee Waa

SURFACE LEVEL: 190.4 AHD
EASTING: 735066
NORTHING: 6654089
DIP/AZIMUTH: 90°/--

BORE No: 101
PROJECT No: 210883.00
DATE: 5/4/2022
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
		Silty CLAY CH: high plasticity, brown mottled grey, trace rootlets w<PL, very stiff to hard, alluvial		A	0.1			
				A	0.5			
				S	1.0 1.45		pp >400 4,10,14 N = 24	
				U_{50}	1.5 1.7			
		from 2.2m, trace fine grained sand						
				S	2.5 2.95		pp >400 3,12,13 N = 25	
				S	4.0 4.45		pp >400 5,10,15 N = 25	
		from 5.5m, with fine grained sand		S	5.5 5.95		pp >400 6,12,18 N = 30	
	6.5	Clayey SAND SC: fine to medium grained, brown, trace fine grained gravel, dry to moist, dense to very dense, alluvial						
				S	7.0 7.3		19,25 refusal	
				S	10.0 10.26		pp >400 20,25/110 refusal	
	10.26	Bore discontinued at 10.26m, limit of investigation.						

RL: 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180
Depth: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10



RIG: DT100 **DRILLER:** Hickman **LOGGED:** Ussher **CASING:** 2.5m HQ

TYPE OF BORING: SFA TC-bit to 2.5m, then rotary water flush to 10.0m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS: Location coordinates are in MGA94 Zone 55 J. Differential GPS, coordinates and RL approximate.

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

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

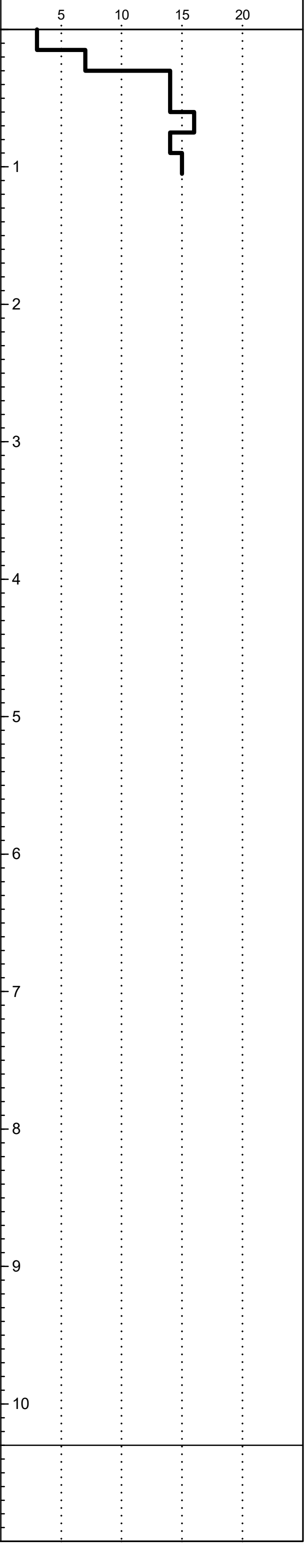
CLIENT: Built (NSW) Pty Ltd
PROJECT: Proposed High School
LOCATION: 105 - 107 Mitchell Street, Wee Waa

SURFACE LEVEL: 190.5 AHD
EASTING: 734993
NORTHING: 6653997
DIP/AZIMUTH: 90°/--

BORE No: 103
PROJECT No: 210883.00
DATE: 5/4/2022
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
		Silty CLAY CH: high plasticity, brown mottled grey, trace rootlets, dry to moist, w<PL, stiff, alluvial from 0.15m, very stiff from 0.3m, very stiff to hard		A	0.1			
				A	0.5			
				U_{50}	0.5 0.8		pp >400	
				S	1.0 1.3		pp >400 8,25/150 refusal	
	1.8	Silty CLAY CH: high plasticity, brown, dry to moist, w<PL, very stiff to hard, alluvial						
				S	2.5 2.92		pp >400 6,17,25/120 refusal	
		from 3.8m, with fine grained sand						
				S	4.0 4.3		pp >400 10,25/150 refusal	
	5.2	Clayey SAND SC: fine to medium grained, brown, trace silt, dense to very dense, alluvial						
				S	5.5 5.8		14,29/150 refusal	
		from 6.5m, light grey brown						
				S	7.0 7.3		17,30/150 refusal	
		from 9.0m, brown, fine grained, very dense						
				S	10.0 10.3		pp >400 17,42 refusal	
	10.3	Bore discontinued at 10.3m, limit of investigation.						

Dynamic Penetrometer Test (blows per 150mm)



RIG: DT100 **DRILLER:** Hickman **LOGGED:** Ussher **CASING:** 5.5m HQ
TYPE OF BORING: SFA TC-bit to 5.5m, then rotary water flush to 10.3m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Location coordinates are in MGA94 Zone 55 J. Differential GPS, coordinates and RL approximate.

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

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

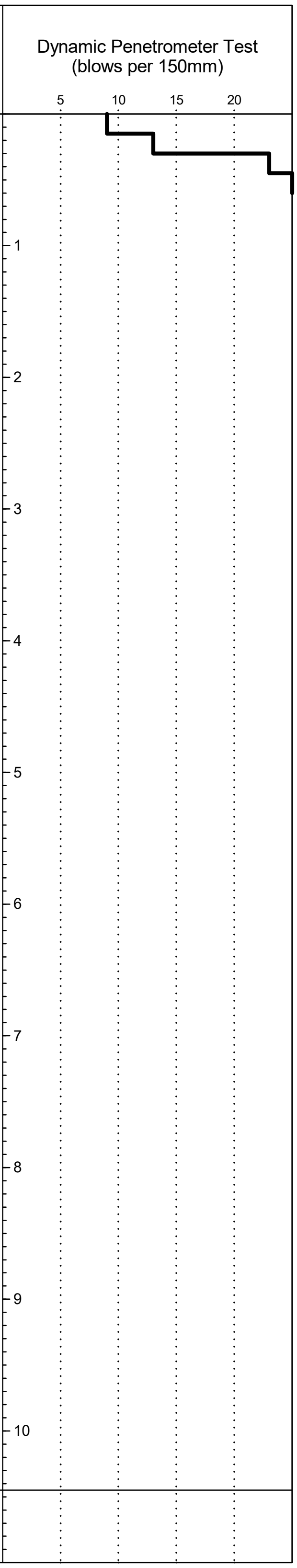
BOREHOLE LOG

CLIENT: Built (NSW) Pty Ltd
PROJECT: Proposed High School
LOCATION: 105 - 107 Mitchell Street, Wee Waa

SURFACE LEVEL: 190.5 AHD
EASTING: 734932
NORTHING: 6654034
DIP/AZIMUTH: 90°/--

BORE No: 104
PROJECT No: 210883.00
DATE: 6/4/2022
SHEET 1 OF 1

Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
	Silty CLAY CH: high plasticity, brown mottled grey, trace fine grained sand, dry, w<PL, very stiff to hard, alluvial, trace rootlets to 0.1m depth	A	0.1			
		A	0.5			
		U_{50}	0.5 0.75		pp >400	
		S	1.0 1.3		pp >400 7,2,3 N = 5	
		U_{50}	1.5 1.75		pp >400	
2.3	Silty SAND SM: fine grained, brown, with clay, dry, w<PL, dense to very dense, alluvial	S	2.5 2.95		pp >400 6,20,24 N = 44	
		S	4.0 4.44		pp >400 13,19,25/140 refusal	
		S	5.5 5.75		23,25/100 refusal	
6.0	Clayey SAND SC: fine grained, brown, trace silt, dry, w<PL, very dense, alluvial	S	7.0 7.23		pp >400 19,25/80 refusal	
		S	10.0 10.45		pp >400 9,14,21 N = 35	
10.45	Bore discontinued at 10.45m, limit of investigation.					



RIG: DT100 **DRILLER:** Hickman **LOGGED:** Ussher **CASING:** 2.5m HQ
TYPE OF BORING: SFA TC-bit to 2.5m, then rotary water flush to 10.45m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Location coordinates are in MGA94 Zone 55 J. Differential GPS, coordinates and RL approximate.

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

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

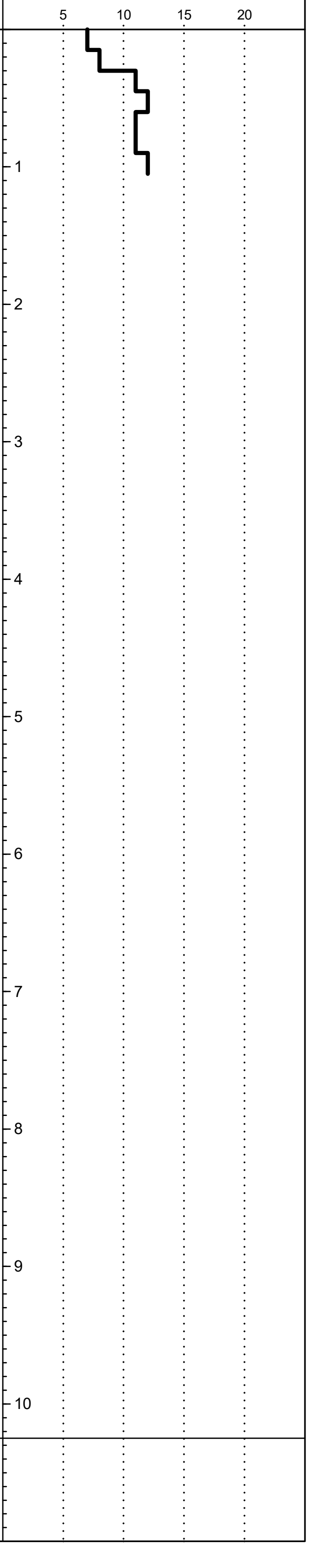
CLIENT: Built (NSW) Pty Ltd
PROJECT: Proposed High School
LOCATION: 105 - 107 Mitchell Street, Wee Waa

SURFACE LEVEL: 190.4 AHD
EASTING: 735025
NORTHING: 6654011
DIP/AZIMUTH: 90°/--

BORE No: 105
PROJECT No: 210883.00
DATE: 6/4/2022
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
190.4	0.0	Silty CLAY CH: high plasticity, brown mottled grey, trace fine grained sand, dry, very stiff		A	0.1			
				A	0.5			
		from 1.0m, very stiff to hard		S	1.0 1.15		pp >400 7 Discontinued due to damaged SPT	
		from 1.9m, brown						
				S	2.5 2.95		pp >400 6,10,12 N = 22	
				S	4.0 4.42		pp >400 6,21,25/120 refusal	
		from 5.0m, grey mottled brown						
				S	5.5 5.95		pp = 320 6,10,15 N = 25	
	6.5	Clayey SAND SC: fine grained, brown, trace silt, dry, w<PL, dense to very dense, alluvial						
				S	7.0 7.3		pp >400 10,18 refusal	
				S	10.0 10.25		14,25/100 refusal	
	10.25	Bore discontinued at 10.25m, limit of investigation.						

Dynamic Penetrometer Test (blows per 150mm)



RIG: DT100 **DRILLER:** Hickman **LOGGED:** Ussher **CASING:** 2.5m HQ
TYPE OF BORING: SFA TC-bit to 2.5m, then rotary water flush to 10.25m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: Location coordinates are in MGA94 Zone 55 J. Differential GPS, coordinates and RL approximate.

☐ 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

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
18 Lawson Crescent
Coffs Harbour NSW 2450
Phone: (02) 6650 3200

Results of Dynamic Penetrometer Tests
Dynamic Cone Penetrometer - DCP

Client Built (NSW) Pty Ltd
Project Proposed High School
Location 105 - 107 Mitchell Street, Wee Waa

Project No. 210883.00
Date 05-06/04/2022
Page No. 1 of 1

Test Location	101	103	104	105						
Depth (m)	**Penetration Resistance** Blows/150 mm									
0.00 - 0.15	10	3	9	7						
0.15 - 0.30	19	7	13	8						
0.30 - 0.45	22	14	23	11						
0.45 - 0.60	25	14	25	12						
0.60 - 0.75		16		11						
0.75 - 0.90		14		11						
0.90 - 1.05		15		12						
1.05 - 1.20										
1.20 - 1.35										
1.35 - 1.50										
1.50 - 1.65										
1.65 - 1.80										
1.80 - 1.95										
1.95 - 2.10										
2.10 - 2.25										
2.25 - 2.40										
2.40 - 2.55										
2.55 - 2.70										
2.70 - 2.85										
2.85 - 3.00										

Test Method AS 1289.6.3.2, Cone Penetrometer ●
AS 1289.6.3.3, Sand Penetrometer ○

Tested By RU
Checked By JBN

Remarks Ref = Refusal, 24/110 indicates 24 blows for 110 mm penetration

Appendix B

Laboratory Test Results

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Coffs Harbour Laboratory
18 Lawson Crescent Coffs Harbour NSW 2450
Phone: (02) 6650 3200
Email: Brandon.Cameron@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Brandon Cameron
Assistant Laboratory Manager
Laboratory Accreditation Number: 828

Report Number:	**210883.00-2**
Issue Number:	1
Date Issued:	28/04/2022
Client:	Built (NSW) Pty Ltd Level 4, Sydney NSW 2000
Contact:	Rebecca Deegan
Project Number:	210883.00
Project Name:	Proposed High School
Project Location:	105-107 Mitchell Street, Wee Waa NSW
Work Request:	16163
Sample Number:	CF-16163E
Date Sampled:	04/04/2022
Dates Tested:	14/04/2022 - 27/04/2022
Sampling Method:	Sampled by Engineering Department *The results apply to the sample as received*
Sample Location:	**Bore 101 , Depth: 0.5m**
Material:	Brown Mottled Grey Silty Clay

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	69		
Plastic Limit (%)	18		
Plasticity Index (%)	**51**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	25.2

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Coffs Harbour Laboratory
18 Lawson Crescent Coffs Harbour NSW 2450
Phone: (02) 6650 3200
Email: Brandon.Cameron@douglaspartners.com.au

Report Number:	**210883.00-2**
Issue Number:	1
Date Issued:	28/04/2022
Client:	Built (NSW) Pty Ltd Level 4, Sydney NSW 2000
Contact:	Rebecca Deegan
Project Number:	210883.00
Project Name:	Proposed High School
Project Location:	105-107 Mitchell Street, Wee Waa NSW
Work Request:	16163
Sample Number:	CF-16163F
Date Sampled:	04/04/2022
Dates Tested:	14/04/2022 - 27/04/2022
Sampling Method:	Sampled by Engineering Department *The results apply to the sample as received*
Sample Location:	**Bore 105 , Depth: 0.5m**
Material:	Brown Mottled Grey Silty Clay

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Brandon Cameron
Assistant Laboratory Manager
Laboratory Accreditation Number: 828

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	65		
Plastic Limit (%)	19		
Plasticity Index (%)	**46**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	15.2

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Port Macquarie Laboratory
Unit 2, 32 Geebung Drive Port Macquarie NSW 2444
Phone: (02) 6581 5992
Email: adam.jeffery@douglaspartners.com.au

Report Number: **210883.00-2PM**
Issue Number: 1
Date Issued: 27/04/2022
Client: Built (NSW) Pty Ltd
Level 4, Sydney NSW 2000
Contact: Rebecca Deegan
Project Number: 210883.00
Project Name: Proposed High School
Project Location: 105-107 Mitchell Street, Wee Waa NSW
Work Request: 16163
Dates Tested: 14/04/2022 - 19/04/2022
Location: 105-107 Mitchell Street, Wee Waa

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Adam Jeffery
Senior Technician
Laboratory Accreditation Number: 828

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	CF-16163A	CF-16163B	CF-16163C	CF-16163D	
Date Sampled	04/04/2022	04/04/2022	04/04/2022	04/04/2022	
Date Tested	19/04/2022	19/04/2022	19/04/2022	19/04/2022	
Material Source	U50	U50	U50	U50	
Sample Location	Bore 101 (1.5-1.7m)	Bore 103 (0.5-0.8m)	Bore 104 (0.5-0.75m)	Bore 104 (1.5-1.75m)	
Inert Material Estimate (%)	**	**	**	**	
Pocket Penetrometer before (kPa)	>600	>600	>600	>600	
Pocket Penetrometer after (kPa)	210	210	230	260	
Shrinkage Moisture Content (%)	15.9	17.9	12.6	12.5	
Shrinkage (%)	**3.2**	**4.2**	**1.6**	**2.0**	
Swell Moisture Content Before (%)	15.8	17.5	13.2	12.0	
Swell Moisture Content After (%)	22.9	24.5	19.9	19.6	
Swell (%)	**8.5**	**6.8**	**7.7**	**3.9**	
Shrink Swell Index Iss (%)	**4.1**	**4.2**	**3.0**	**2.2**	
Visual Description	Brown Mottled Grey Silty Clay	Brown Mottled Grey Silty Clay	Brown Mottled Grey Silty Clay	Brown Mottled Grey Silty Clay	
Cracking	SC	SC	UC	SC	
Crumbling	No	No	No	No	
Remarks	**	**	**	**	

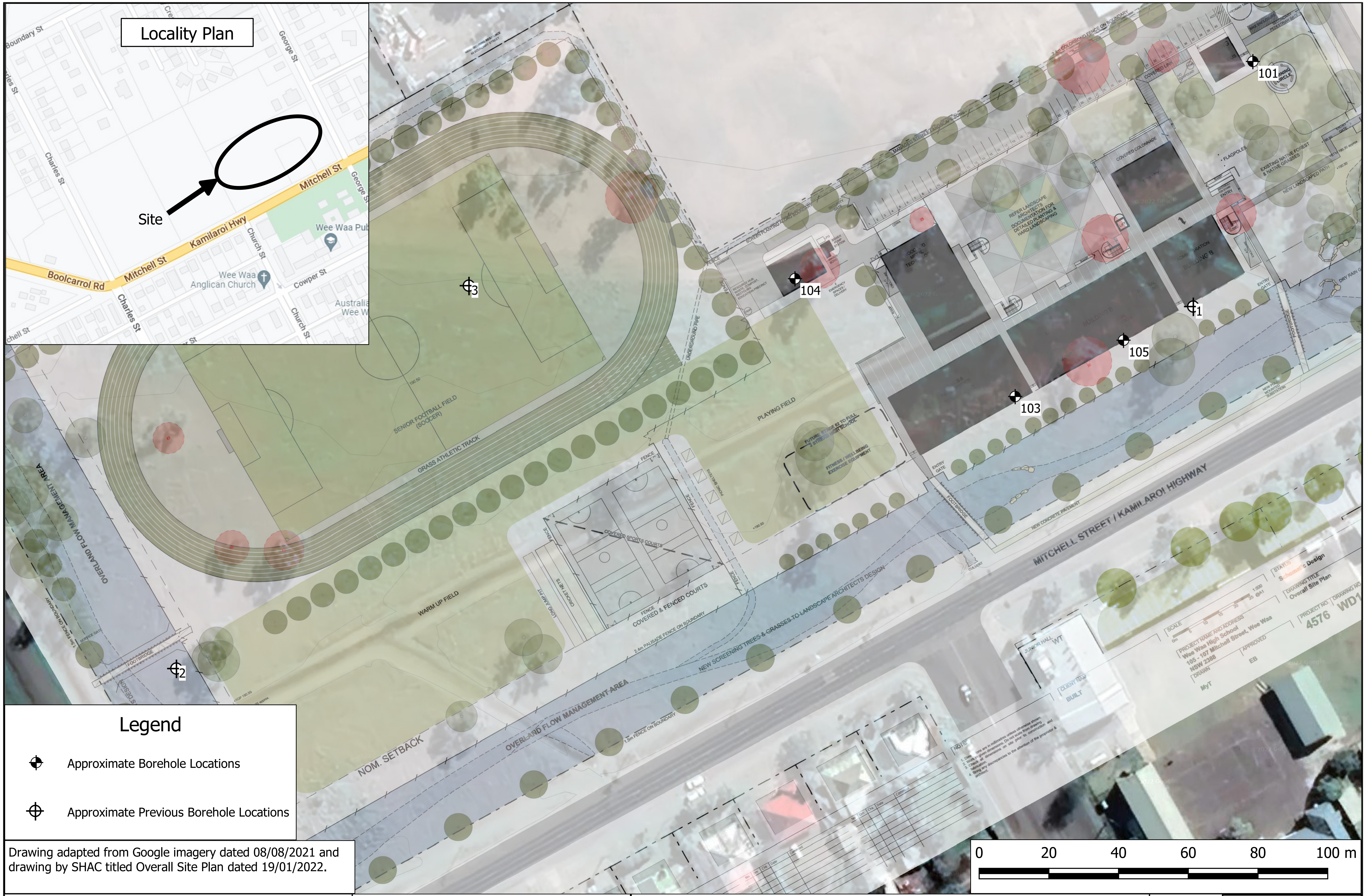
Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.

Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.

NATA Accreditation does not cover the performance of pocket penetrometer readings.

Appendix C

Drawing 1 - Test Location Plan



Legend

⯐	Approximate Borehole Locations
⌖	Approximate Previous Borehole Locations

Drawing adapted from Google imagery dated 08/08/2021 and drawing by SHAC titled Overall Site Plan dated 19/01/2022.

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT:	Built (NSW) Pty Ltd		
OFFICE:	Coffs Harbour	DRAWN BY:	Ussher
SCALE:	1:1000 @ A3	DATE:	11-05-2022

TITLE: **Test Location Plan**

Proposed High School

105 - 107 Mitchell Street, Wee Waa

PROJECT No:	210883.00
DRAWING No:	1
REVISION:	0