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Report on Geotechnical Investigation

Proposed Redevelopment of Singleton Gym and Swim Facility
Civic Avenue, Singleton

Prepared for
Facility Design Group

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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.

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Report on Geotechnical Investigation
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1. Introduction

This report presents the results of a geotechnical investigation undertaken for the proposed redevelopment of the Singleton Gym and Swim Facility, located on Civic Avenue, Singleton. The investigation was commissioned by Mr Graeme Roberts on behalf of Facility Design Group in an order to proceed with works form dated 20 August 2014. The work was undertaken with reference to Douglas Partners Pty Ltd (DP) proposal NCL140161 (Rev 2) dated 19 August 2014.

The aim of the investigation was to assess subsurface conditions at the site and provide comments on the following:

- Site geology;
- Depth to groundwater if encountered within test depths;
- Presence of existing filling;
- Presence of acid sulfate soils;
- Site classification in accordance with AS2870 (Ref 1);
- Site sub-soil class for earthquake design with reference to AS1170.4-2007 (Ref 2);
- Design parameters for high level footings and the need for piled foundations; and
- Estimated settlements for high level footings.

The investigation included drilling of boreholes at six locations, together dynamic penetrometer testing, followed by laboratory testing, engineering analysis and reporting. Details of the field work are given in this report, together with comments relating to the issues outlined above.

For the purposes of the investigation, the client provided a drawing showing the proposed layout of the redeveloped site.

2. Site Description

The site is located on Civic Avenue, Singleton (refer Figure 1) and is an irregular shaped parcel of land covering an area of 11,500 m^2. The site is bounded by open paddocks to the north-west, an existing commercial development to the east and south-west and car parking areas to the south.

Figure 1: Aerial photo of site sourced from Google Earth

The existing development on the site includes a number of existing buildings, housing gym facilities, change rooms and offices, together with three in ground pools (refer Figures 2 to 4).

Figure 2: Existing pool in northern area of the site

Figure 3: Shed and infants pool in eastern area of the site

Figure 4: Existing gym building in southern area of the site

The ground surface at the site is relatively flat with the exception of a spectator mound located to the north of the main pool.

A mound of filling was present in the south-western area of the site (in the area of Bore 2) and was about 10 m to 15 m in diameter and up to 1 m to 1.5 m in height.

Reference to the statewide digital contour mapping indicates that surface levels at the site (outside the mounded areas) are about RL 42 AHD.

3. Regional Geology, Acid Sulfate Soil

Reference to the 1:100 000 Hunter Coalfields Geological Series Sheet indicates that the site is underlain by Quaternary Alluvium, which typically comprises sand, silt, clay and gravel.

Reference to the 1:25 000 Soil Conservation Service of New South Wales Acid Sulfate Soil Risk Map indicates that the site lies within an area mapped as having no known occurrence of acid sulfate soils.

4. Previous Nearby Investigations

DP has undertaken a number of previous investigations in the vicinity of the site, including the following:

- Proposed Nursing Home in Combo Lane, located approximately 60 m to the south-east of the site (Project 7825). This investigation included the drilling of six bores to depths ranging from 2.95 m to 8.45 m. Conditions encountered included hard silty clay to about 2 m depth, underlain by loose to medium dense sand;
- Proposed Facility Upgrade, 1 Civic Avenue, Singleton, approximately 150 m south of the site (Project 39758). This investigation included the drilling of two bores to 6 m depth. Conditions encountered included filling to about 1 m depth, underlain by very stiff to hard clay; and
- Proposed Library, Queen Street, Singleton, approximately 300 m to the south-west of the site (Project 31655). This investigation included the excavation of six pits to depths ranging from 2.7 m to 2.9 m. Conditions encountered included filling to depths of up to 0.6 m, underlain by silty sand to about 1 m to 2 m, which was underlain by hard sandy clay.

Various laboratory testing has been undertaken on soil samples from this previous investigation, which are discussed in Section 7.

5. Field Work Methods

The field work was carried out on 11 September 2014 and comprised the drilling of six test bores (designated Bores 1 to 6). The bores were drilled using a 4WD mounted continuous push tube sampling rig which thrust various diameter stainless steel sampling tubes into the ground under hydraulic and pneumatic force. The bores were drilled to 3 m depth.

Dynamic penetrometer testing (DCP) was undertaken to depths ranging from 1.05 m to 2.25 m adjacent to each bore location.

Samples of the soils encountered in the bores were collected at regular depth intervals by a geotechnical engineer who also prepared engineering logs of the subsurface conditions.

The bore locations were selected by DP and the approximate locations are shown on Drawing 1 in Appendix C.

6. 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 in Appendix A, which explain the descriptive terms and classification methods used in the logs.

The general conditions encountered were dark brown sandy clay topsoil to depths ranging from 0.1 m to 0.2 m, overlying stiff to very stiff dark brown sandy clay. An exception to this profile was encountered in Bore 2 where sandy clay filling was present to 1.5 m depth.

No free groundwater was observed during the drilling of the bores. It should be noted that groundwater conditions are dependent on factors such as soil permeability and recent weather conditions and will vary with time.

7. Laboratory Testing

Laboratory testing was undertaken on a sample of the sandy clay collected from 1.3 m depth in Bore 3. Detailed results of the testing are attached and summarised in Table 1 below together with relevant laboratory test results from previous nearby investigations.

Table 1: Results of Laboratory Testing

Bore	Depth (m)	Description	FMC (%)	Iss (% per Δ pF)	Pocket Penetrometer Before Soaking (kPa)	Pocket Penetrometer After Soaking (kPa)
Present Investigation						
3	1.3 – 1.5	Dark brown SANDY CLAY	16.5	0.8	290	160
Previous Investigations						
39758 (Bore 1)	2.5 – 2.8	Silty Clay	16.8	2.6	-	-
39758 (Bore 2)	1.0 – 1.3	Silty Clay	12.6	1.4	-	-

Notes to Table 1:
FMC – Field Moisture Content
Iss – Shrink-Swell Value

Plasticity testing was also undertaken on a sample of sandy clay from Project 39655 (Pit 1 at 2.3 m) and returned a plasticity index of 27% and a linear shrinkage of 14.5%.

8. Proposed Development

Review of the concept plans provided indicate that the proposed development includes the following:

- Additions to the western end of the existing building, covering an area of approximately 35 m by 25 m, which will house a new pool together with various associated rooms;
- Additions to the eastern end of the existing building, covering an area of approximately 13 m by 13 m.

These additions are shown on Drawing 1 in Appendix C.

9. Comments

9.1 Site Classification

Site classification to AS 2870-2011 (Ref 1) is for residential footings and not strictly applicable to commercial developments. However, the principles of footing design and site maintenance presented herein should be taken into account for buildings / structures such as that proposed for the site.

The presence of existing buildings and localised deep filling at the site would necessitate a Class P classification based on procedures presented in AS 2870-2011 (Ref 1).

In areas of the site that are not affected by existing filling or existing buildings site classification can be based on ground movement limits, which are defined by the characteristic surface movement (y_s). The parameter y_s represents the surface movement expected at a site between dry and wet periods, and can be estimated from soil shrinkage and instability indices, I_{PS} and I_{PT} respectively; and design suction change which provides an indication of the suction profile with depth within a soil, based on the climatic region of the site.

Based on the results of the laboratory testing characteristic surface movements in the range 20 – 40 mm have been calculated for the site based on methods outlined in AS 2870 (Ref 1). Therefore, the reactivity of these areas of the site are typical of Class M site as outlined in AS2870 (Ref 1).

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” and with AS 2870-2011.

Masonry walls should be articulated in accordance with TN61 (Ref 3) to minimise the effects of differential movement.

9.2 Foundations and Settlement

High level footings founded in very stiff to hard sandy clay, as encountered in all bores (except Bore 2) at depths ranging from 0.1 m to 0.2 m should be proportioned for a maximum allowable bearing pressure of 100 kPa. All footing excavations should be inspected and tested prior to casting of concrete to confirm the suitability of the foundation strata.

Higher allowable bearing pressures, of up to 200 kPa may be applicable provided that all footing excavations are inspected and tested by DP prior to casting of concrete.

In the vicinity of Bore 2, where filling was encountered to 1.5 m depth, deep pad footings or short piles may be required to support the structural loads in the very stiff to hard sandy clay. Alternatively the filling associated with the mound in this area could be removed to expose the underlying natural soils. Appropriate articulation should be provided to the structure in areas where the footings are founded at different depths to cater for the likely differential movements, which may be up to 40 mm.

Settlements for high level pad footings within the very stiff to hard clay, loaded to 100 kPa are anticipated to be less than 10 mm. Similar pads loaded to 200 kPa are anticipated to experience settlements in the order of 10 mm to 15 mm.

It is recommended that further investigation is undertaken in the vicinity of Bore 2 prior to construction to confirm the extent of the filling.

9.3 Seismic Site Sub-Soil Class

Using the procedures described in AS1170.4 – 2007 (Ref 2) an earthquake hazard factor of 0.12 was estimated for the site. AS1170.4 – 2007 indicates a site sub-soil Class C_e (shallow soil site) for earthquake design based on the assumption that the alluvial soils do not extend to greater than 45 m. Inspection of driller's reports from registered groundwater wells in the Singleton area (GW030937, GW030939, GW030940, GW030949, GW061208) indicates shale at depths of less than 20 m in the region.

10. References

1. Australian Standard AS 2870-2011, "Residential Slabs and Footings", Standard Association of Australia.
2. Australian Standards AS 1170.4-2007, *Structural design actions, Part 4: Earthquake actions in Australia*, October 2007, Standards Australia.
3. Cement and Concrete Aggregates Australia, TN61, "Articulated Walling".

11. Limitations

Douglas Partners (DP) has prepared this report for the proposed re-development of the Singleton Gym and Swim facility at Civic Avenue, Singleton with reference to DP's proposal (Ref NCL140161(Rev2) dated 19 August 2014. The work was carried out under DP Conditions of Engagement.

This report is provided for the exclusive use of Design Facility Group for the specific project and purpose 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. Further the report is valid (for the purposes of disposal of material) for a period of nine months only from the date of issue.

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

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

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

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

The 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 environmental components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Please note that Part 5.6, Section 143 of the POEO Act 1997 states that is an offence for waste to be transported to a place that cannot lawfully be used as a facility to accept that waste. It is the duty of the owner and transporter of the waste to ensure that the waste is disposed of appropriately and that suitable records are obtained and kept. DP accepts no liability for the unlawful disposal of waste materials from any site. DP accepts no responsibility for the material tracking, loading, management, transport or disposal of waste from the site. It is the duty of the owner and transporter of the waste to ensure that the waste is disposed of appropriately.

Douglas Partners Pty Ltd

Appendix A

CSIRO-BTF18
About this Report
Sampling Methods
Soil Descriptions
Symbols and Abbreviations
Borehole Logs (Bores 1 to 6)
Results of Dynamic Penetrometer Testing

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

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

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

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

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

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

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

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

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

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

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

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

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

Trees can cause shrinkage and damage

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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

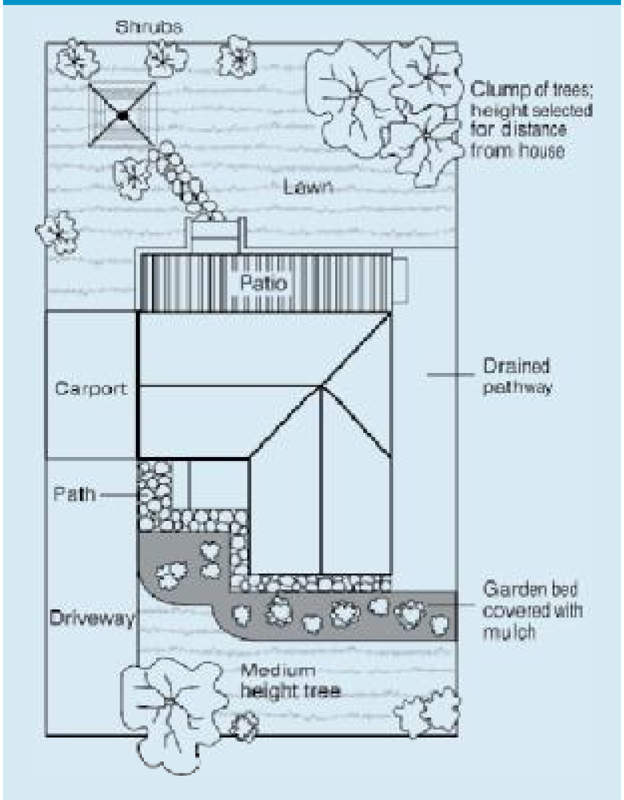
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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About this Report

Douglas Partners

Introduction

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

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

Copyright

Borehole and Test Pit Logs

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

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

Groundwater

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

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

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

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

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

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

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

About this Report

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Sampling

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

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

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

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

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

  4,6,7
  N=13

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

  15, 30/40 mm

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

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

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

Soil Descriptions

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.

Symbols & Abbreviations

Introduction

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

Drilling or Excavation Methods

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

Water

▷	Water seep
▽	Water level

Sampling and Testing

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

Description of Defects in Rock

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

Defect Type

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

Orientation

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

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

Coating or Infilling Term

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

Coating Descriptor

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

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

- Asphalt
- Road base
- Concrete
- Filling

Soils

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

Sedimentary Rocks

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

Metamorphic Rocks

- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks

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

BOREHOLE LOG

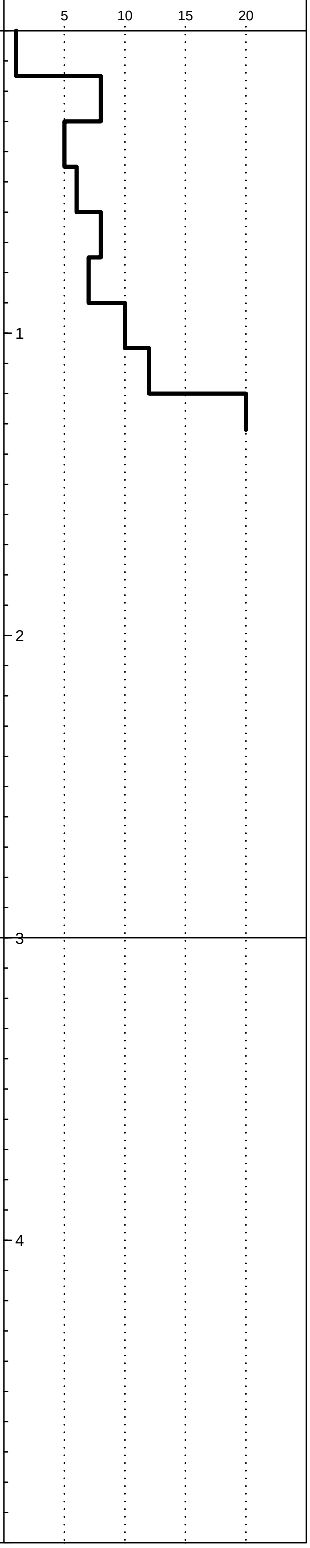
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - Dark brown, sandy clay topsoil with some rootlets, M<Wp		D	0.05			
	0.4	SANDY CLAY - Stiff to very stiff, dark brown sandy clay with trace of rootlets, M<Wp		D	0.5			
	1	From 0.9m, becomes hard and brown		D	1.0		pp = 250-300	
	2			D	2.0		pp >500	
	3.0	Bore discontinued at 3.0m, limit of investigation		D	3.0		pp >500	

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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

BOREHOLE LOG

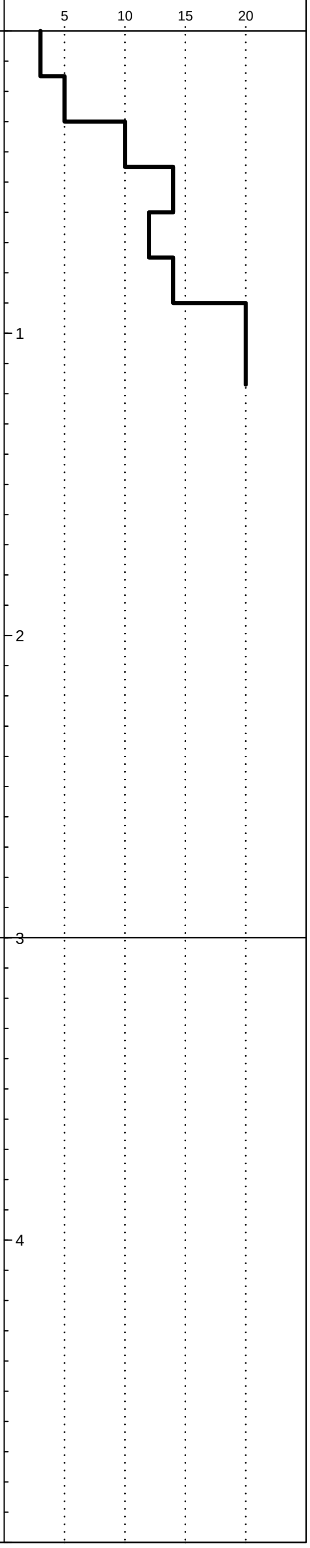
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
	0.1	FILLING - Dark brown, sandy clay topsoil with some rootlets, M<Wp		D	0.05			
		FILLING - Brown, sandy clay with a trace of gravel and organics, M<Wp		D	0.5			
1				D	1.0			
	1.5	SANDY CLAY - Very stiff, brown sandy clay, M<Wp						
2				D	2.0		pp >500	
3	3.0	Bore discontinued at 3.0m, limit of investigation		D	3.0		pp >500	
4								

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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

BOREHOLE LOG

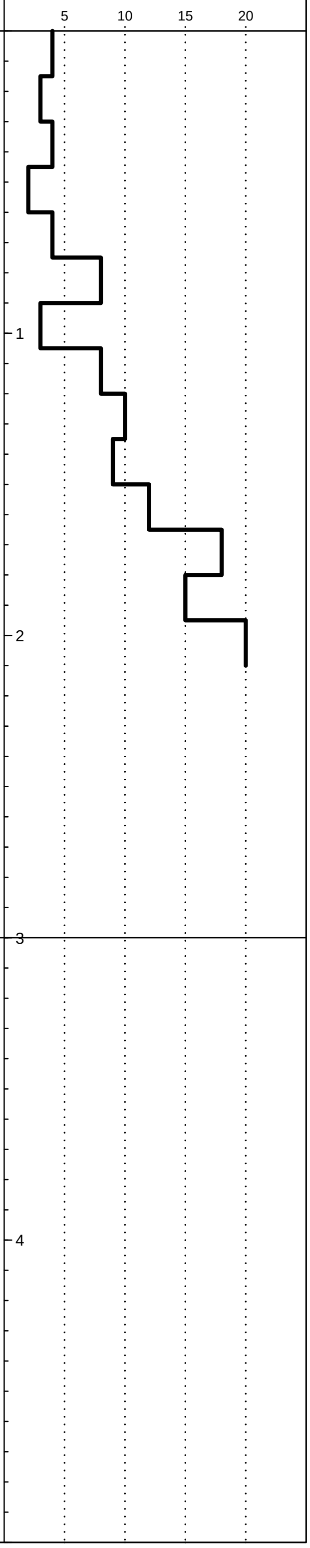
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - Dark brown, sandy clay topsoil with some rootlets, M<Wp		D	0.05			
	0.1	SANDY CLAY - Stiff, dark brown sandy clay, M<Wp		D	0.5			
		At 0.75m, becoming very stiff						
	1			D	1.0		pp = 140-160	
				U_{50}	1.3 – 1.5			
		From 1.75, becomes hard and brown						
	2			D	2.0		pp = 300-350	
		From 2.7m, sand and clay lenses						
	3.0	Bore discontinued at 3.0m, limit of investigation		D	3.0		pp = 200-250	
	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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

BOREHOLE LOG

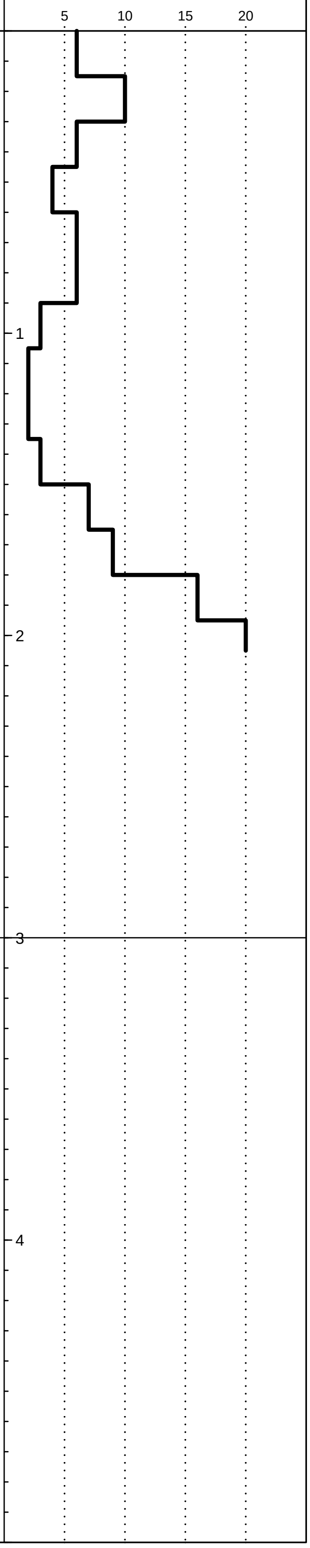
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILLING - Brown-grey, sandy clayey gravel topsoil filling, with some rootlets, damp		D	0.05			
	0.2	SANDY CLAY - Stiff dark brown, sandy clay, M<Wp						
		From 0.4m, trace of organics		D	0.5			
	1			D	1.0		pp = 150-200	
	1.3	SANDY CLAY - Very stiff, brown sandy clay, M<Wp						
				U_{50}	1.5 – 1.75			
		From 1.8m, becoming hard						
	2			D	2.0		pp >500	
	3 3.0	Bore discontinued at 3.0m, limit of investigation		D	3.0		pp >500	
	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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

BOREHOLE LOG

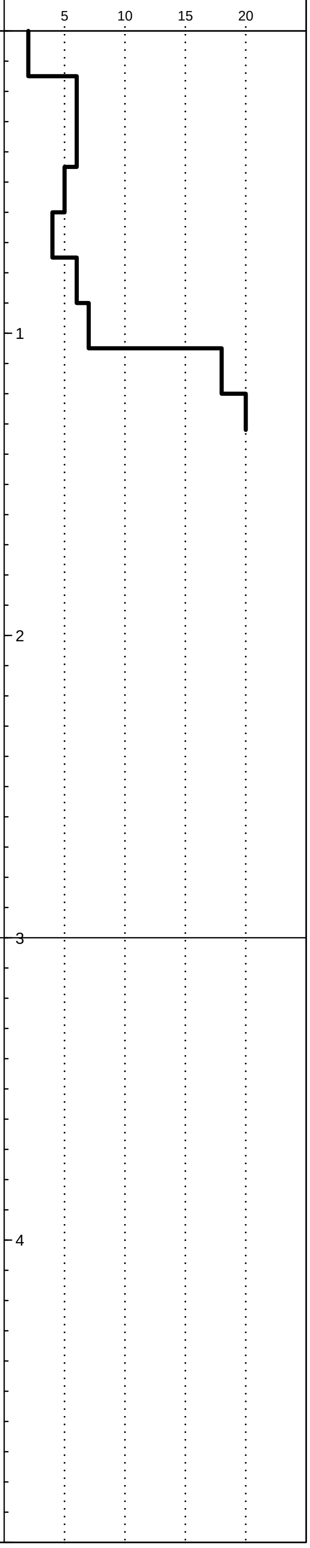
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL - Dark brown, sandy clay topsoil with some rootlets, M<Wp		D	0.05			
		SANDY CLAY - Stiff, dark brown sandy clay, M<Wp		D	0.5			
	1	At 0.9m, becomes very stiff		D	1.0		pp = 300-250	
		At 1.1m, becomes hard and brown						
	2			D	2.0		pp >500	
	3 3.0	Bore discontinued at 3.0m, limit of investigation		D	3.0		pp >500	
	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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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BOREHOLE LOG

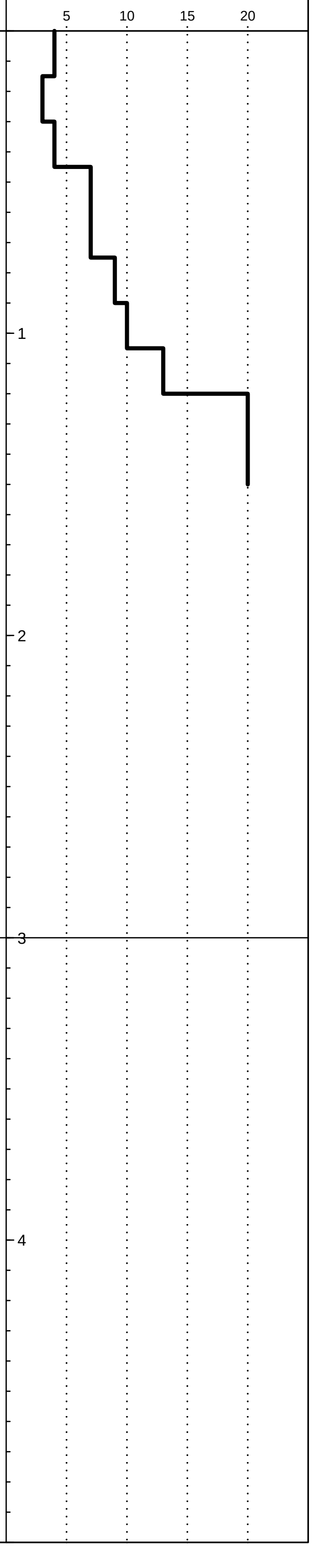
CLIENT: Facility Design Centre
PROJECT: Proposed Development
LOCATION: Civic Avenue, Singleton

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 6
PROJECT No: 81592
DATE: 11/9/2014
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL - Dark brown, sandy clay topsoil with some rootlets, M<Wp		D	0.05			
		SANDY CLAY - Stiff, dark brown sandy clay, M<Wp						
		From 0.45m, becomes very stiff		D	0.5			
	1			D	1.0		pp = 100-200	
		From 1.1m, becoming hard brown						
	2			D	2.0		pp >500	
	3.0			D	3.0		pp >500	
		Bore discontinued at 3.0m, limit of investigation						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Toyota 4 x 4 **DRILLER:** TJW **LOGGED:** TJW **CASING:** Nil
TYPE OF BORING: 60mm diameter push tube rig
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

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
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Warabrook NSW 2304
PO Box 324
Hunter Region MC NSW 2310
Phone (02) 4960 9600
Fax (02) 4960 9601

Results of Dynamic Penetrometer Tests

Client	Facility Design Centre	**Project No.**	81592
Project	Proposed Re-development	**Date**	11/9/2014
Location	Civic Avenue, Singleton	**Page No.**	1 of 1

Test Locations	1	2	3	4	5	6				
RL of Test (AHD)										
Depth (m)	**Penetration Resistance** Blows/150 mm									
0.00 – 0.15	1	3	4	6	2	4				
0.15 – 0.30	8	5	3	10	6	3				
0.30 – 0.45	5	10	4	6	6	4				
0.45 – 0.60	6	14	2	4	5	7				
0.60 – 0.75	8	12	4	6	4	7				
0.75 – 0.90	7	14	8	6	6	9				
0.90 – 1.05	10	20	3	3	7	10				
1.05 – 1.20	12	20/120	8	2	18	13				
1.20 – 1.35	20/120		10	2	20/120	20				
1.35 – 1.50			4	3		20				
1.50 – 1.65			12	7						
1.65 – 1.80			18	9						
1.80 – 1.95			15	16						
1.95 – 2.10			20	20/100						
2.10 – 2.25										
2.25 – 2.40										
2.40 – 2.55										
2.55 – 2.70										
2.70 – 2.85										
2.85 – 3.00										
3.00 – 3.15										
3.15 – 3.30										
3.30 – 3.45										

Test Method	AS 1289.6.3.2, Cone Penetrometer	☑	**Tested By**	TJW
	AS 1289.6.3.3, Sand Penetrometer	☐	**Checked By**	**MPG**

Remarks Ref = Refusal, 25/110 indicates 25 blows for 110 mm penetration

Appendix B

Laboratory Test Results

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
Unit 5, 3 Teamster Close
Tuggerah NSW 2259
Phone (02) 4351 1422
Fax (02) 4351 1410

Result of Shrink-Swell Index Determination

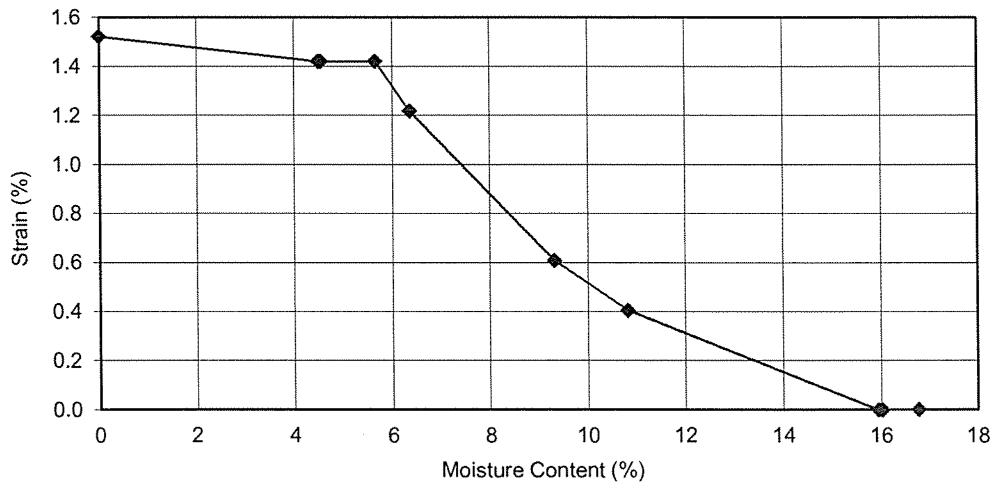
Client :	Facility Design Group	**Project No. :**	81592.00
		Report No. :	CC14-105_1
Project :	Singleton Gym and Swin Facility	**Report Date :**	5.5.2014
		Date Sampled :	11.9.2014
Location :	Civic Avenue, Singleton	**Date of Test:**	25.9.2014
Test Location :	Bore 3		
Depth / Layer :	1.3-1.5m	**Page:**	1 of 1

CORE SHRINKAGE TEST

Shrinkage - air dried	1.4 %
Shrinkage - oven dried	1.5 %
Significant inert inclusions	0.0 %
Extent of cracking	MC
Extent of soil crumbling	0.0 %
Moisture content of core	16.0 %

SWELL TEST

Pocket penetrometer reading at initial moisture content	290 kPa
Pocket penetrometer reading at final moisture content	160 kPa
Initial Moisture Content	16.5 %
Final Moisture Content	16.8 %
Swell under 25kPa	0.0 %



SHRINK-SWELL INDEX Iss 0.8% per Δ pF

Description:	Dark brown sandy clay
Test Method(s):	AS 1289.7.1.1, AS 1289.2.1.1
Sampling Method(s):	Sampled by Douglas Partners' Engineers

Extent of Cracking:
- **UC** - Uncracked
- **SC** - Slightly cracked
- **MC** - Moderately cracked
- **HC** - Highly cracked
- **FR** - Fractured

Remarks: _

Note that NATA accreditation does not cover the performance of pocket penetrometer readings

NATA Accredited Laboratory Number: 828

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

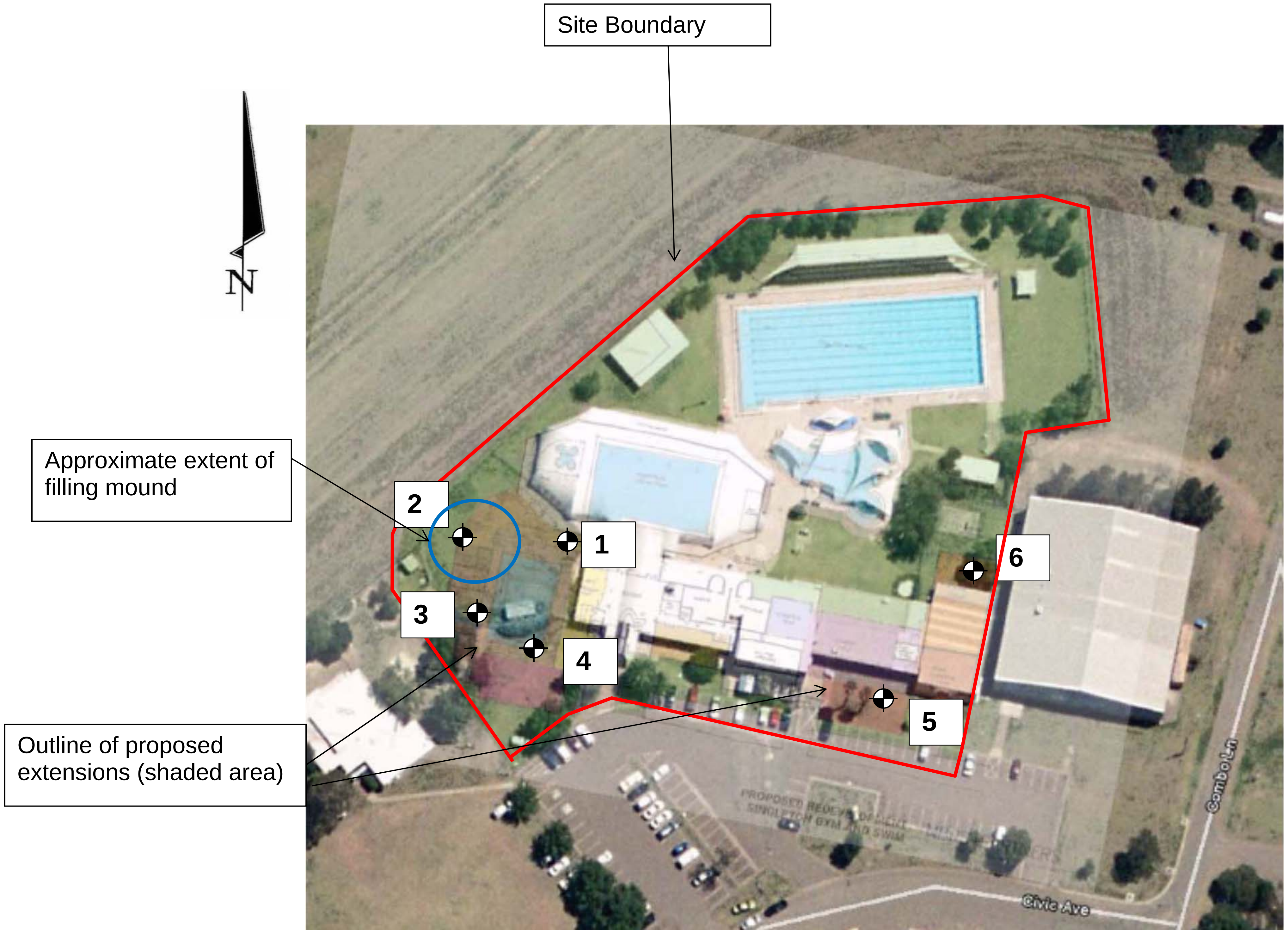
NATA ACCREDITED FOR TECHNICAL COMPETENCE

Tested: AG
Checked: BWO

Bradley Orrock
Senior Technician

Appendix C

Drawing 1 – Test Location Plan



Locality Plan

LEGEND

⌖ Approximate Test Bore Location

Notes

Drawing adapted from Google Earth image and plan provided by client

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Facility Design Group	TITLE: **Test Location Plan Singleton Gym and Swim Civic Avenue, Singleton**	PROject No: 81592
	OFFICE: Newcastle / DRAWN BY: MPG		DRAWING No: 1
	SCALE: 1:1000@A3 / DATE: 1 October 2014		REVISION: 0