ACT Geotechnical Engineers Pty Ltd

THE DOMA GROUP

PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT

GEOTECHNICAL INVESTIGATION REPORT

JULY 2016

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31 July 2016
Our ref: HR/C8247

The Doma Group
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Attention: Mr Alex Moulis

Dear Sir

PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT

GEOTECHNICAL INVESTIGATION REPORT

We are pleased to present our geotechnical investigation for the proposed CSIRO redevelopment on Section 38, in Campbell, ACT.

The report outlines the methods and results of exploration, describes site subsurface conditions, presents results of laboratory testing, and provides recommendations for building footing design, site earthworks, and site drainage.

Should you require any further information regarding this report, please do not hesitate to contact our office.

Yours faithfully
ACT Geotechnical Engineers Pty Ltd

Hermann Retief
Geotechnical Engineer

THE DOMA GROUP

PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT

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PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT

GEOTECHNICAL INVESTIGATION REPORT

1 INTRODUCTION

In response to a request by The Doma Group, ACT Geotechnical Engineers Pty Ltd conducted a geotechnical investigation for the proposed CSIRO redevelopment on Section 38, in Campbell, ACT.

The project may involve the construction of several multi-storey apartment buildings of up to nine storeys, as well as one and two storey townhouses. The development may potentially have one and two-level basements.

The aim of the investigation was to:

(i) Identify subsurface conditions, including the extent and nature of any fill materials, natural soil profile, bedrock type and depth, and groundwater presence.

(ii) Provide site classification to AS2870 "Residential Slabs & Footings".

(iii) Recommend suitable footing systems for the buildings including founding strata and allowable bearing pressures.

(iv) Advise on preparation of subgrades for building slabs and pavements.

(v) Advise on excavation conditions and suitability of excavated materials for use in controlled fill platforms and construction of structure platforms.

(vi) Advise on stable batter slopes, and provide low retaining wall design parameters.

(vii) Provide indicative design CBR values.

(viii) Provide the Earthquake Site Factor.

(ix) Advise on site drainage and other relevant geotechnical issues.

2 SITE DESCRIPTION & GEOLOGY

Section 38, Campbell, ACT is bounded by a retirement village to the north-east, Campbell High School to the south-east, Limestone Avenue to the south-west, and undeveloped land the north-west. Figure 1 shows the site locality.

The roughly rectangular-shaped site is ~350m long x ~150m wide. The site is on the lower south-western slopes of Mount Ainslie, and the ground generally dips towards the south-west. Figure 2 shows the current site layout with the auger hole and borehole locations.

The 1:50,000 Canberra, Queanbeyan & Environs Geology Map (Reference 1) documents the site to be underlain by Silurian age Ainslie Volcanics bedrock that includes dacite and agglomerate.

3 INVESTIGATION METHODS

The field investigation was carried out between 18 and 20 July 2016, comprising the following:

- 14 auger boreholes to 3m depth or earlier refusal in bedrock
- 4 cored boreholes to 8m depth

A JCB 3CX Backhoe with an auger attachment was used to drill the 14 auger boreholes, designated 1A to 14A, terminating in weathered bedrock at between 1.2m and 3m depth.

The four augered and cored boreholes, designated BH1 to BH4, were drilled by trailer-mounted Gemco 210D drill-rig. The overburden soils were augered using a 110mm continuous flighted helix auger equipped with a tungsten tipped “V” bit. An NMLC triple-tube core barrel (~52mm I.D) equipped with diamond impregnated drill bit was used to core the bedrock. Water, with a bio-degradable polymer additive to improve core recovery was used as the recirculating fluid.

The locations of the auger boreholes and coreed boreholes are shown on Figure 2, and the auger hole and cared borehole logs, including core photographs, are included in Appendix A.

Core retrieved from boreholes BH1 to BH4 was placed in metal core trays. Following drilling, the core was photographed and selected sections tested for point-load strength. The point-load test results are listed in Appendix B.

The borehole profiles were visually logged in accordance with the Unified Soil Classification System (USCS). Definitions of geotechnical engineering terms used on the auger hole and cored borehole logs, including a copy of the USCS chart, are provided in Appendix C.

4 INVESTIGATION RESULTS

4.1 Subsurface Conditions

Investigation auger holes 1A to 14A and cored boreholes BH1 to BH4 found the subsurface profile of the site to comprise:

Geological Profile	Typical Depth Interval	Description
TOPSOIL	0m to 0.05m/0.5m	SANDY SILT & SILTY SAND; low plasticity silt, fine to coarse sand, brown, dark brown, pale brown, grey-brown, dark grey, some sub-angular gravels up to 10mm size, some grass roots, dry to moist, moist, loose, soft. Not encountered in auger hole 1A.
UNCONTROLLED FILL	0m/0.05m to 0.6m/1.3m	SANDY CLAY & SANDY SILT; low to medium and medium plasticity fines, fine to coarse sand, dark red-brown, orange-brown, some asphalt fragments, some rounded gravels up to 10mm size, moist, firm to stiff. Only encountered in auger holes 1A and 12A.
SLOPEWASH	0.1m/0.2m to 0.2m/0.3m	SANDY SILT; low plasticity silt, fine to medium sand, pale grey, pale grey-brown, dry to moist, soft. Only encountered in auger holes 5A, 6A, 7A, 13A and 14A.
ALLUVIAL/ RESIDUAL SOIL	0.1m/0.6m to 0.5m/1.6m	SANDY CLAY & CLAYEY SAND; mostly low and low to medium plasticity fines, some medium, medium to high and high plasticity clay, fine to medium sand, fine to coarse sand, brown, pale brown, red-brown, orange-brown, grey-brown, pale yellow-brown, grey, some iron staining, some silt, some ferruginous nodules up to 6mm size, some sub-angular gravels up to 3mm size, dry to moist, moist, stiff to very stiff, medium dense to dense. Not encountered in auger hole 1A.
BEDROCK	Below 0.5m/1.6m	DACITE; fine to coarse grained, brown, pale brown, yellow-brown, pale yellow-brown, orange-brown, grey, green-grey, blue-grey, yellow-grey, pale yellow-brown, red-brown, pale grey, some blue speckles, dry to moist, dry; SILTSTONE; very fine grained, pale pink-brown, dry & SANDSTONE; fine to coarse grained, yellow-brown, yellow, trace ferruginous nodules up to 6mm size, dry. Extremely weathered (EW) and extremely weak, extremely to highly weathered (EW/HW) and very weak and highly weathered (HW) and weak rock, generally grading to highly to moderately weathered (HW/MW), moderately weathered (MW) and weak to medium strong, then moderately to slightly weathered (MW/SW), slightly weathered (SW), slightly weathered to fresh (SW/Fr) and fresh, medium strong to very strong rock.

Uncontrolled fill was only encountered in auger holes 1A and 12A to 0.6m/1.3m depth. Bedrock was encountered in all auger holes below 0.5m/1.6m depth. A single-level basement excavation is expected to expose a mix or medium strong to very strong bedrock over the foundation, while a two-level basement excavation is expected to expose mostly very strong to extremely strong bedrock over the foundation.

Table 1 below is a summary of the depth to weak or medium strong rock and the depth to very strong or extremely strong rock bedrock encountered in each borehole.

TABLE 1

Depth to Bedrock in Boreholes

Borehole	Location	Depth to Weak or Medium Strong Bedrock	Depth to Very Strong or Extremely Strong Bedrock
BH1	Eastern Side of Site	0.8m	0.85m
BH2	Near Centre of Site (Eastern Side)	4.0m	>8.0m
BH3	Near Centre of Site (Western Side)	1.4m	3.3m
BH4	Western Side of Site	1.8m	5.2m

4.2 Groundwater

Groundwater was not encountered within the 1.2m/8.05m excavation depth, and permanent groundwater is not expected within the proposed 6m excavation depth. However perched groundwater may be present at shallower depth within the more pervious soils, especially at the interface of the uncontrolled fill and natural soils.

4.3 Point-Load Strength Index Testing

Point-load strength index tests were carried out on selected representative rock core specimens from boreholes BH1 to BH4. The index values were used to derive the approximate compressive strength of the rock by applying the empirical relationship $q_u = 24 \times I_s(50)$ (Reference 2), where q_u is the ultimate compressive strength. The test method and calculation of point load strength index $I_s(50)$ is in accordance with the test methods outlined by the International Society for Rock Mechanics (Reference 3). The results of the testing are tabulated in Appendix B.

The estimated compressive strengths of the dacite bedrock are summarised in Table 2 below.

TABLE 2

Estimated Rock Compressive Strengths

Rock Weathering Grade	Estimated Compressive Strength (MPa)		No. of Point-Load Tests
	Range	Average	
HW, HW/MW & MW Dacite	4.3 – 46.6	12.9	8
MW/SW, SW & SW/Fr Dacite	16.1 – 84.7	52.5	10
Fr Dacite	82.3 – 177.8	115.6	7

The HW, HW/MW & MW dacite bedrock is expected to have compressive strengths ranging from about 4MPa to 50MPa, the MW/SW, SW & SW/Fr dacite bedrock is expected to have compressive strengths of 15MPa to 100MPa, while the Fr dacite bedrock is expected to have compressive strengths of up to 200MPa.

5 DISCUSSION & RECOMMENDATIONS

5.1 Site Classification

Based on the expected shrink-swell properties of the underlying natural soils, we estimate the characteristic ground surface movement y_s defined by AS2870 for extreme seasonal changes in ground moisture would be between 30mm and 40mm, therefore Class "M" (moderately reactive) in accordance with AS2870 "Residential Slabs & Footings" (Reference 4) guidelines.

Deemed to comply footing designs provided by AS2870 are applicable specifically to residential-style one and two storey structures, or buildings with similar loads and super structure stiffness.

Uncontrolled fill was found to be present in the area around auger holes 1A and 12A to 0.6m/1.3m depth. The uncontrolled fill is greater than 0.4m depth and therefore these areas are classified a Class "P" (problem site) in accordance with the requirements of AS2870. If footings are founded in the natural soils/weathered bedrock below the fill or the fill is removed, or replaced with a properly constructed controlled fill of a suitable low and/or medium plasticity soil, then footings can be proportioned for a Class "M" (moderately reactive) site.

5.2 Building Footings & Groundslabs

The project may involve the construction of several multi-storey apartment buildings of up to nine storeys, as well as one and two storey townhouses. The development may potentially have one and two-level basements. A single-level basement excavation is expected to expose a mix or medium strong to very strong bedrock over the foundation, while a two-level basement excavation is expected to expose mostly very strong to extremely strong bedrock over the foundation.

Shallow pad and strip footings for structures constructed near existing grade should be founded in the natural alluvial/residual soils or newly placed controlled fill (Section 5.3), below any topsoil, silty slopewash soils and uncontrolled fill. Alternatively, bored piers founding in the EW/HW and less weathered bedrock below 0.8m/4.0m can be used.

For structures with a one or two-level basement, pad and strip footings are expected to found in weathered bedrock. A single-level basement excavation is expected to expose mostly HW/MW and MW bedrock, while a two-level basement excavation is expected to expose mostly MW/SW, SW, and less-weathered bedrock.

Recommended allowable end-bearing pressures for various footing systems are provided in Table 3.

TABLE 3

Recommended Allowable End-Bearing Pressures for Footings

Foundation Material Type	Expected Depth Below Existing Levels	Allowable End-Bearing Pressure				
		Strips	**Pads**	**Piers**	**Shaft Adhesion (Downward Loading)**	**Shaft Adhesion (Uplift Loading)**
Newly Constructed Controlled Fill	-	100kPa	125kPa	N.A.	N.A.	N.A.
Very Stiff to Hard and Medium Dense to Dense Alluvial/Residual Soils & EW Bedrock	0.1m/0.6m	125kPa	150kPa	200kPa	20kPa	10kPa
EW/HW & HW Bedrock	0.8m/4.0m	400kPa	500kPa	700kPa	70kPa	35kPa
HW/MW & MW Bedrock	0.8m/3.0m	1500kPa	2000kPa	3000kPa	300kPa	150kPa
MW/SW & Less Weathered	0.85m/>8.0m	3000kPa	5000kPa	6000kPa	600kPa	300kPa

All footing excavations should be inspected and approved by an experienced geotechnical engineer to confirm the foundation material and design values, and to ensure the excavations are clean and stable.

Groundslabs can be constructed on the newly constructed controlled fill, natural soils or weathered bedrock following the removal of any silty topsoil, existing fill, soft or wet soils, or disturbed ground. Following excavation to required level, slab areas on soil should be proof-rolled by a pad-foot roller to check for any weak, wet or deforming soils that may require replacement. Suitable replacement fill should be compacted at about OMC in not thicker than 150mm layers to not less than 95%ModMDD.

If required for design of ground slabs, a modulus of subgrade reaction of 30kPa/mm can be assumed for a controlled fill or natural soil foundation and 100kPa/mm for a cut, EW/HW & less weathered bedrock foundation.

5.3 Controlled Fill Construction

For construction of controlled fill platforms for structures, it is recommended:

- Areas be fully stripped of all topsoil, silty slopewash, uncontrolled fill and disturbed ground. A general stripping depth of 0.1m/1.3m is expected.
- Stripped soil foundations be cross-ripped, moisture conditioned, and proof-rolled by a vibratory pad-foot roller of not less than 9 tonne static mass to check for any weak or wet areas that require replacement.
- Replacement fill and platform fill of suitable materials (Section 5.4) be compacted to required level in not thicker than 150mm layers to not less than 95%ModMDD at about optimum moisture content.

Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 or 2 responsibility as defined in AS3798 - 1996 "Guidelines on Earthworks for Commercial & Residential Developments" (Reference 5).

5.4 Excavatability Assessment

The measure of the excavatability of bedrock is dependent on two important factors - (1) the compressive strength of the rock, and (2) the nature and spacing of the defects in the rock. Charts have been developed to assist in providing a guide to what plant is required for given rock conditions. A copy of the chart is provided in Figure 4. The green zone on the "Rock Excavation Chart" in Figure 3 shows the area corresponding to the expected rock and excavations conditions at this site.

<u>Upper 1m/2m of Subsurface Profile</u>

Assuming a soil or weak (EW/HW & HW) rock with compressive strengths less than 10MPa and defect spacing less than 300mm, based on these charts, the rock would be expected to be diggable using conventional excavator digging and ripping. This type of rock is expected in the upper 1m/2m of the profile except for the profile in the vicinity of borehole BH1, where very strong rock was encountered at 0.85m depth.

<u>Subsurface Below 1m/2m Depth</u>

Assuming a weak to medium strong (HW/MW, MW, and MW/SW) rock with compressive strengths of 10MPa to 50MPa, based on these charts, where defect spacing is less than about 200mm, the rock would be expected to be rippable. Where the defect spacing is greater than this, the rock is not rippable, and rock hammering would be required. Given that the defect spacing of the rock is typically between 50mm and 300mm, the majority of the rock is expected to be rippable, with some rock hammering required. It is assessed that a large dozer (D8 or D9) would be able to rip the majority of the rock to the required maximum depths, with only minimal, localised rock hammering required. This type of rock is expected below 1m/2m depth, extending to greater than ~8m depth.

5.5 Excavation Conditions

Given the above data, our assessment of the expected excavation conditions is as follows:

- Excavations for the first basement level may be (to ~3m depth) would be through topsoil, slopewash, uncontrolled fill and colluvial soils and weathered bedrock, the overburden soils and EW, EW/HW, HW and HW/MW can all be dug by backhoe and excavator. MW and less weathered bedrock is expected to be encountered below about 1m/1.5m depth, will require heavy excavator or dozer (D8 or D9) ripping, with some localised rock hammering. However, excavations for the second basement level (from ~3m to ~6m depth) would mostly require heavy rock hammering. Table 4 below indicates the excavation conditions at each borehole.

- Drilling of soldier pier holes could be conducted using a large piering rig (such as a 'Soilmec'), of at least 30 tonnes.

TABLE 4

Expected Bedrock Strength & Excavation Conditions

Borehole Location	Depth Interval	Expected Rock Strength & Defect Spacing	Required Excavation Equipment
BH1	0m to ~0.9m	Soil & weak rock - defect spacing <60mm	Excavator
	~0.9m to 8m	Very strong rock - defect spacing of 30mm to >300mm	Heavy (dozer) ripping and rock hammering
BH2	0m to 4m	Soil & weak rock - defect spacing <60mm	Excavator
	4m to 8m	Weak to medium strong rock - defect spacing of 30mm to 300mm	Mostly heavy (dozer) ripping, some rock hammering
BH3	0m to ~1.7m	Soil & weak rock - defect spacing <60mm	Excavator
	~1.7m to 3.3m	Medium strong rock - defect spacing of 30mm to 300mm	Mostly heavy (dozer) ripping, some rock hammering
	3.3m to 8m	Very strong rock - defect spacing of 100mm to >300mm	Heavy (dozer) ripping and mostly rock hammering
BH4	0m to ~3.4m	Soil & weak rock - defect spacing <60mm	Excavator
	~3.4m to 5.2m	Medium strong rock - defect spacing of 30mm to >300mm	Mostly heavy (dozer) ripping, some rock hammering
	~5.2m to 8m	Very strong rock - defect spacing of 100mm to >300mm	Heavy (dozer) ripping and mostly rock hammering

5.6 Use of Excavated Material

Any low to medium plasticity clayey/sandy alluvial/residual or clayey uncontrolled fill soils, could be used in controlled fill construction provided that they are within +/- 2% of optimum moisture content and there are no particles greater than 75mm in size. The weak and medium strong rock would break down to a clayey sandy gravel or gravelly clayey sand, and would make an excellent select fill material. The stronger rock could also be used as select fill or even sub-base material, but would have to be passed through a crusher to break down to suitable size. Otherwise, it could be used as gabion rock or rip-rap rock.

The silty topsoil, slopewash and uncontrolled fill, and any medium to high plasticity clay is not typically suitable for controlled fill, but could be used in non-structural applications such as landscaping.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

Permanent groundwater is expected below at least 8m depth. Temporary perched seepages can be present at shallower depth following rain, but should be readily controllable during construction.

5.7 Temporary Excavation Support

Temporary site excavations to 1.5m depth can be formed near-vertical, although the loose topsoil, and uncontrolled fill should be cut at 1(H):1(V). Deeper temporary cuts should be formed no steeper than 1(H):1(V). Alternatively, where space limitations preclude battering back, temporary support options include:

(i) Soldier piers and tie-back anchors with horizontal lagging or reinforced shotcrete supporting the vertical face between piers
(ii) Battering back at between 0.25 to 0.5(H):1(V), and stabilising the face with reinforced shotcrete.

Soldier piers can be socketed into dacite/siltstone/sandstone bedrock below basement level, with lateral support provided by passive resistance in the socketed section, or by rock anchors, or strutting from the foundation floors, or by a combination of these. Soldier piers could be spaced at typically 3 to 5 pier diameters, with horizontal lagging or structural shotcrete applied between the piers as the basement is progressively excavated. Alternatively, semi-contiguous piers at 1.5 to 2 pier diameter spacings without lagging could be used.

Design earth/rock pressures and lateral resistance parameters for temporary support systems are given in Section 5.5. The overall stability against failure of support systems should be checked. For temporary stability, a minimum factor of safety of 1.5 should be used.

Any permanent unsupported batters in soil and EW/HW and less weathered bedrock should be formed no steeper than 2(H):1(V). Permanent soil batters would need to be protected against erosion, either by stone pitching, shotcreting, or other suitable means.

5.8 Design Parameters for Temporary Excavation Support Systems

5.8.1 Lateral Pressure on Tied-Back Walls

Design horizontal earth/rock pressures to excavation floor level for soldier piers progressively tied back by tensioned ground anchors, and for walls strutted from the basement floor, can be calculated using a trapezoidal pressure distribution given by (See Figure 4):

$$\sigma_h = (6H \times \frac{4z}{H}) + 0.4q \qquad \text{For } z < 0.25H$$

$$\sigma_h = (6H) + 0.4q \qquad \text{For } z > 0.25H$$

where,

σ_h is the horizontal earth/rock pressure acting on the back of the wall, in kPa
H is the total height of the full excavation to be supported, in metres
z is the depth from the top of the excavation, in metres
q is any uniformly distributed vertical surcharge acting on the ground surface at the top of the excavation, in kPa

The above expression takes no account of groundwater pressure, as it is assumed the temporary walls will be fully drained and permanent groundwater is expected below the proposed basement floor level. Where the walls are to be covered by shotcrete and/or where these will be incorporated into a permanent basement wall, synthetic drainage strips should be placed against the excavated face, leading to subsoil collector pipes at the base of the excavation, taken to a basement pump out sump. Additional earth pressures due to footings of adjacent structures may also have to be considered.

5.8.2 Lateral Pressure on Cantilevered Soldier Pier Walls

Design horizontal earth/rock pressures on soldier pile walls which derive their full support by cantilevering from the bedrock below the basement level, can be calculated using a pressure distribution given by (See Figure 5):

$$\sigma_h = 6z + 0.4q$$

where,

σ_h is the horizontal earth/rock pressure acting on the back of the wall, in kPa
z is the depth below the top of the excavation in contact with the soldier piers, in metres
q is any uniformly distributed vertical surcharge acting on the ground surface at the top of the excavation, in kPa

The first term in the above expression is a triangular pressure distribution, the second a uniform distribution. Again, it is assumed that adequate drainage will be provided to prevent build-up of groundwater behind the walls.

5.8.3 Passive Resistance

The horizontal passive resistance provided by socketed sections of soldier piers in weathered bedrock below excavation floor level can be calculated as:

$\sigma_p = 15z$	(Natural Soil & EW bedrock)
$\sigma_p = 100z$	(EW/HW & HW bedrock)
$\sigma_p = 200z$	(HW/MW & less weathered bedrock)

where,
σ_p is the allowable passive pressure acting on the front of the pier/footing at depth z, in kPa
z is the pier socket length below excavation level in weathered bedrock, in metres

The effective width of a socketed pier for calculation of allowable passive resistance can be assumed to be equivalent to twice its actual width, except where the centre to centre distance between the piers is two diameters or less, in which case the soldier piers can be considered to act as one continuous wall.

5.8.4 Tie-Back Anchors

Recommended allowable grout-to-soil and grout-to-bedrock bond values are as follows:

Natural Soil	30kPa
EW/HW, HW & HW/MW bedrock	150kPa
MW & less weathered bedrock	400kPa

Some anchors should be proof-tested by pull-out tests to confirm the suitability of these allowable bond values especially any anchor holes that encounter groundwater.

It is recommend that ground anchors be inclined downward at between 5° and 20°, and that the "fixed" (anchored) section for calculation of pullout capacity be assumed to be the section of each anchor extending beyond the 45° line from the basement floor. Tensioned cable anchors should be used in preference to passive (non-tensioned) anchors.

5.9 Permanent Basement Retaining Walls

Basement walls can be constructed to incorporate the excavation temporary support walls, or constructed separately, with the space backfilled later or braced by horizontal struts to the temporary support wall. Basement walls that incorporate or are rigidly strutted to the excavation temporary supports should be designed to cater for the same lateral earth pressure distribution given in Section 5.5.1 in respect of the tied-back walls.

Basement walls constructed in open excavation and backfilled later should be designed on the basis of the lateral earth pressures given in Section 5.5.2 for cantilevered soldier pile walls.

Backfill behind walls constructed separate from the excavation support walls should be clean, granular and free-draining. To prevent surface water entering the backfill, the upper 1m could consist of a less pervious clayey soil.

5.10 Pavement Subgrades

Pavement subgrades should be prepared as outlined in Section 5.3. On-grade carpark subgrades are expected to comprise natural soils or newly placed controlled fill, and pavements can be designed using a subgrade CBR value of 3%. Pavements with cut in-situ weathered bedrock subgrades, can be designed using a CBR value of 15%. Exposed subgrades should be inspected by a geotechnical engineer to check the recommended design CBR value.

5.11 Earthquake Site Factor

The Geoscience website (Reference 6) lists the earthquake acceleration coefficients for major centres to be considered in structural design. The Campbell area has an acceleration coefficient of 0.06.

Section 4 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 7) summarises the Site Subsoil Class which depends on the subsurface conditions at the site in question. A Site Subsoil Class C_e is applicable for this project.

5.12 Site Drainage

Permanent groundwater is not expected within the proposed 6m excavation depth, however perched groundwater may be present at shallower depth within the more pervious soils, especially at the interface of the uncontrolled fill and natural soils.

Suitable surface drainage should be provided to ensure that rainfall run-off or other surface water cannot pond against buildings or pavements. Subsoil drains should be provided along the upslope sides of buildings and pavements. Drainage should be provided behind all retaining walls.

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REFERENCES

Reference 1 Bureau of Mineral Resources, Commonwealth of Australia, “Canberra, Queanbeyan & Environs - 1:50,000 Engineering Geology Series”, 1980.

Reference 2 Broch, E. & Franklin, J. A. (1972), "The Point-Load Strength Test", trans., Inst. Min. Metall.

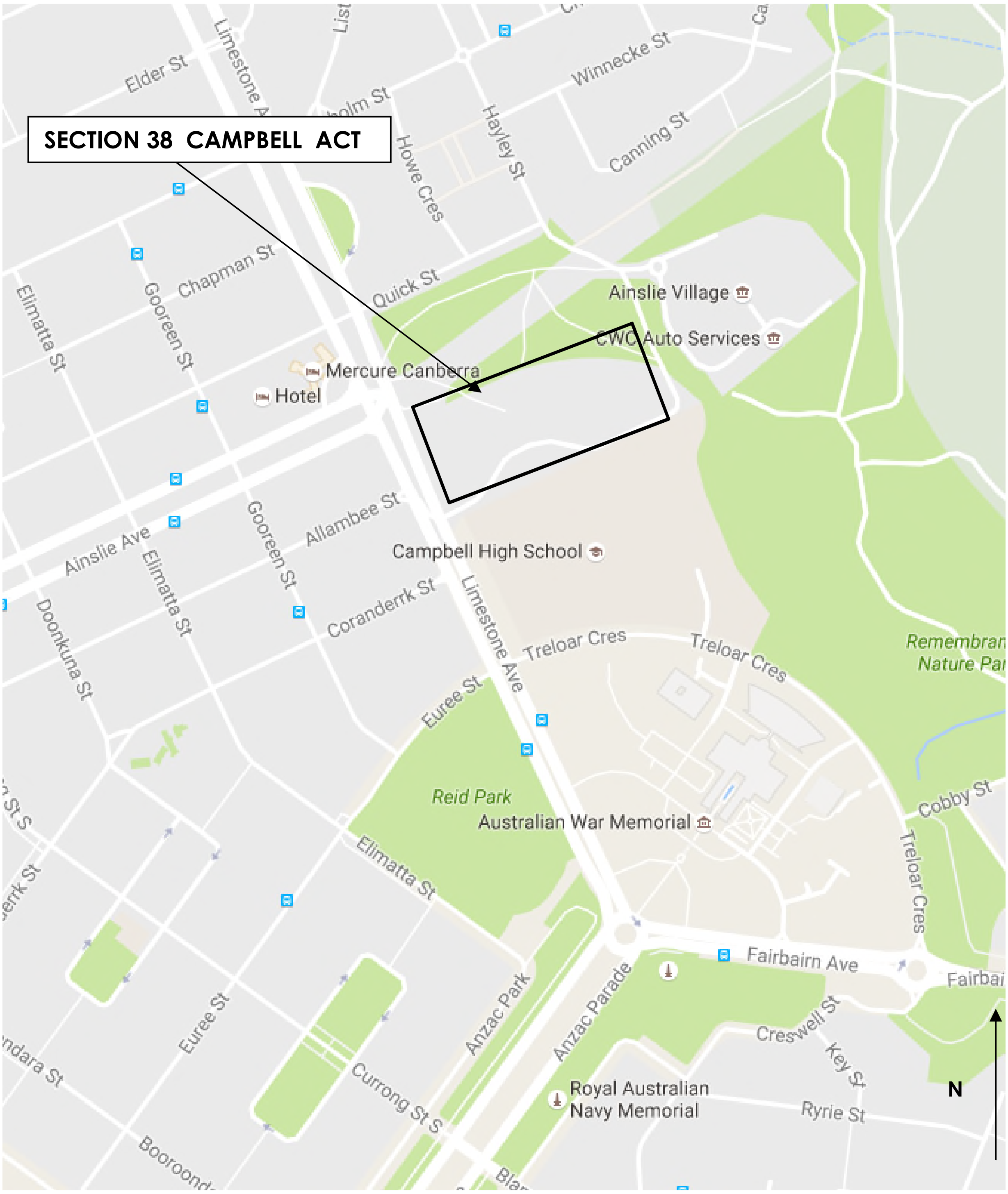
Reference 3 ISRM (1972), "Suggested Methods for Determining the Uniaxial Compressive Strength of Rock Materials and the Point Load Strength Index", Committee on Laboratory Tests - Document No.1, Int. Soc. Rock Mechanics.

Reference 4 Standards Australia, “AS2870 - Residential slabs and footings - Construction”, 2011.

Reference 5 Standards Australia, “AS3798 - Guidelines on Earthworks for Commercial & Residential Developments”, 2007.

Reference 6 Geoscience Australia - http://www.ga.gov.au/darwin-view/hazards.xhtml# 29 July 2016.

Reference 7 Standards Australia, “AS1170.4 - Minimum Design Loads on Structures Part 4: Earthquake Loads”, 1993.



THE DOMA GROUP
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SECTION 38 CAMPBELL ACT
SITE LOCALITY

ACT Geotechnical Engineers Pty Ltd	C8247	FIGURE 1

LEGEND

○ - Location of Auger Hole/Borehole (Depth to EW/HW & Less Weathered Bedrock)

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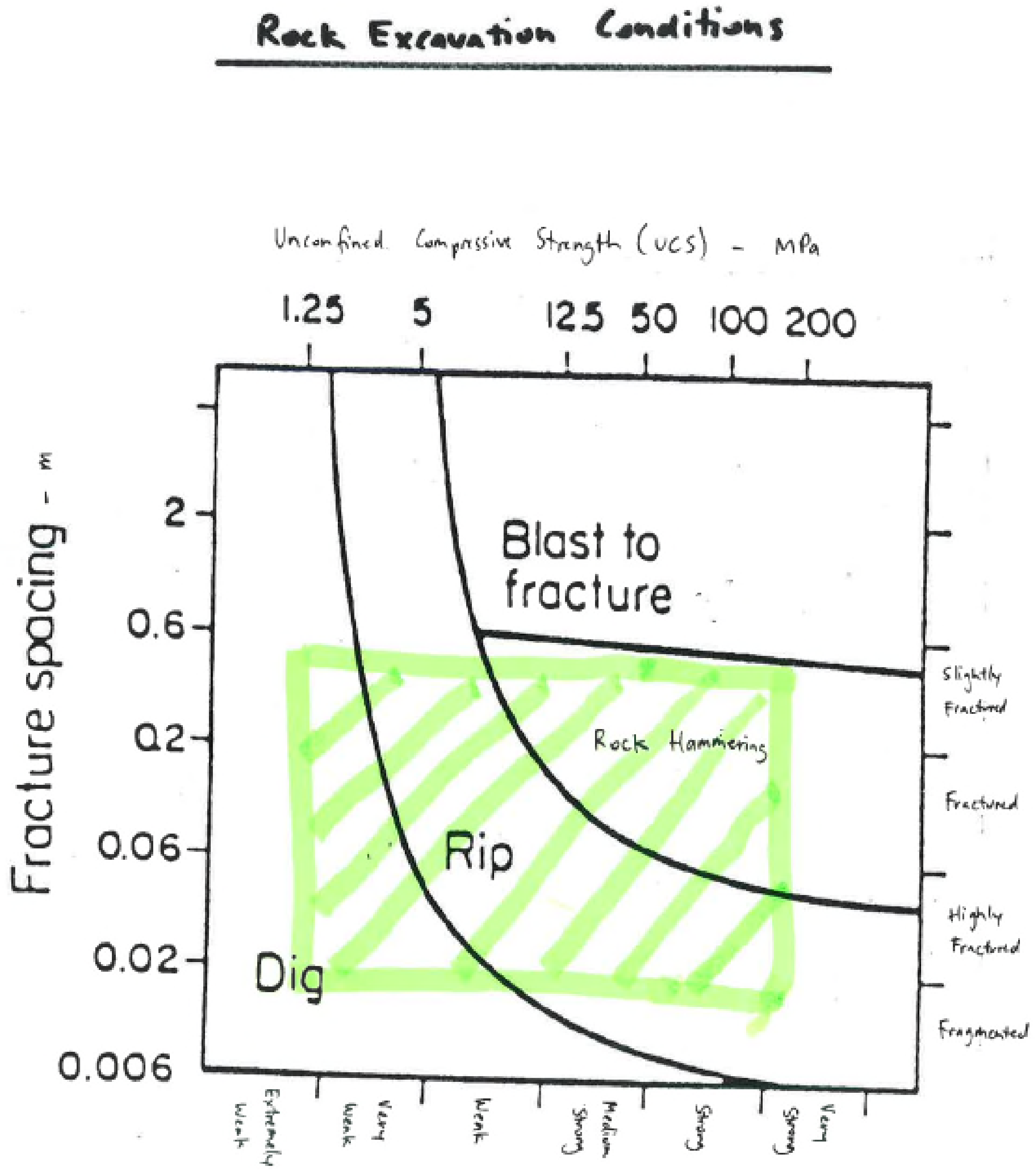
RECENT AERIAL PHOTOGRAPH & LOCATIONS OF AUGER HOLES & CORED BOREHOLES

ACT Geotechnical Engineers Pty Ltd	**C8247**	**FIGURE 2**



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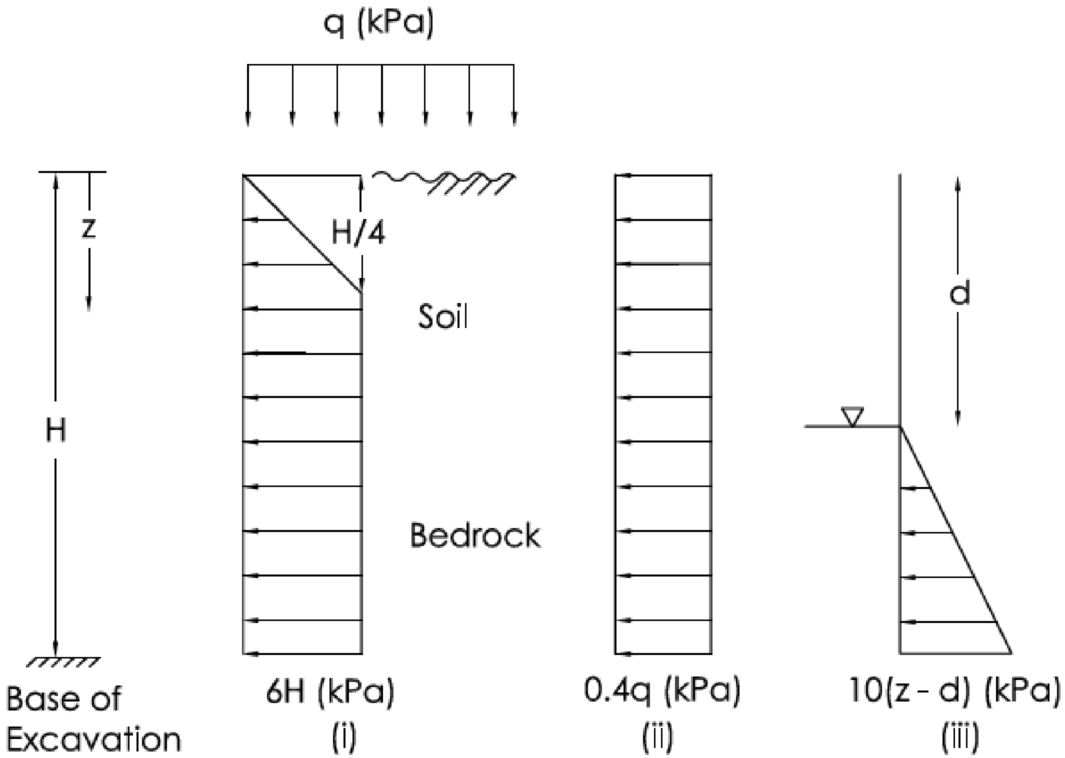
ROCK EXCAVATION CONDITIONS CHART

ACT Geotechnical Engineers Pty Ltd	**C8247**	**FIGURE 3**



Total Design Lateral Pressure =

(i) Soil/Rock Pressure + (ii) Uniform Surface Surcharge Pressure + (iii) Hydrostatic Pressure (below groundwater level) + (iv) Adjacent Footing Imposed Pressure (not shown)

RECOMMENDED DESIGN LATERAL EARTH PRESSURE FOR TIED BACK WALLS

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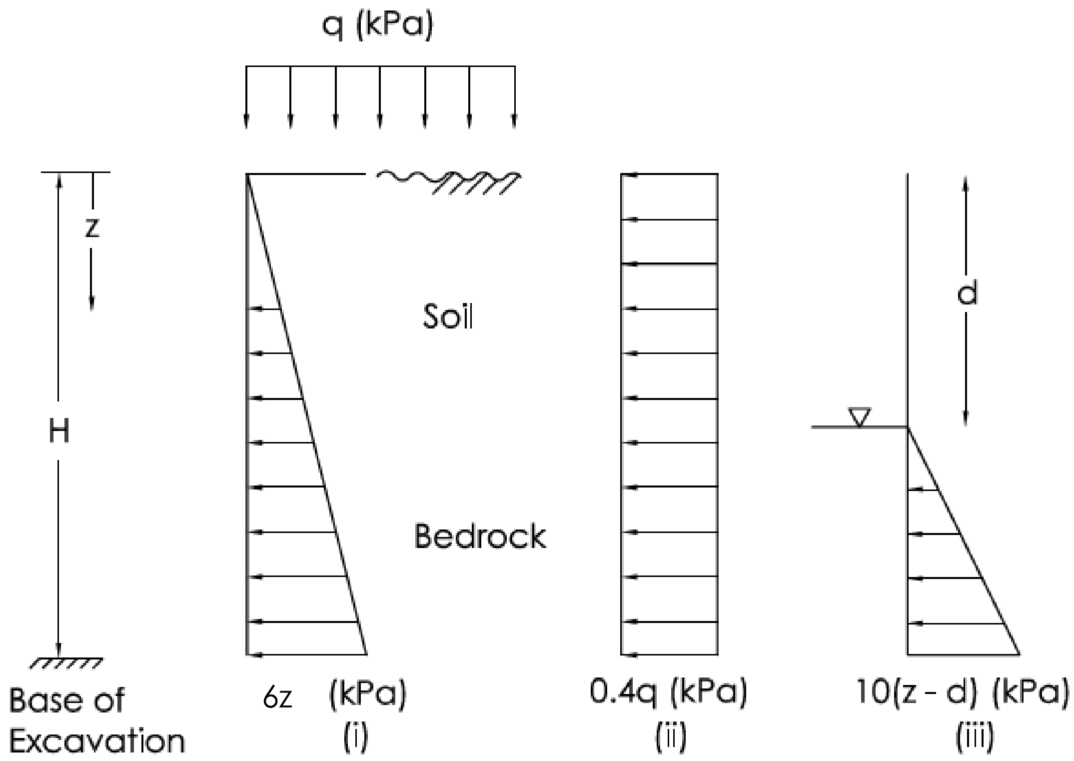
PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT
RECOMMENDED DESIGN LATERAL EARTH PRESSURE FOR TIED BACK WALLS

ACT Geotechnical Engineers Pty Ltd	**C8247**	**FIGURE 4**



Total Design Lateral Pressure =

(i) Soil/Rock Pressure + (ii) Uniform Surface Surcharge Pressure + (iii) Hydrostatic Pressure (below groundwater level) + (iv) Adjacent Footing Imposed Pressure (not shown)

RECOMMENDED DESIGN LATERAL EARTH PRESSURE FOR CANTILEVER WALLS

THE DOMA GROUP
PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT
RECOMMENDED DESIGN LATERAL EARTH PRESSURE FOR CANTILEVER WALLS

ACT Geotechnical Engineers Pty Ltd	C8247	FIGURE 5

APPENDIX A

Auger Hole Logs 1A to 14A & Cored Boreholes BH1 to BH4

Excavation Log

Excavation No.	1A
Sheet	1 of 1
Job No.	C8247
Location : See Figure 2	
Surface Level : Not Known	

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.0 – 1.3		CL	SANDY CLAY; low to medium plasticity fines, fine to coarse sand, dark red-brown, some silt, some asphalt fragments, dry to moist.	STIFF		FILL
			1.3 – 1.7			EW/HW SILTSTONE; very fine grained, pale pink-brown, dry.	VERY WEAK ROCK		EW/HW BEDROCK
			1.7			EXCAVATION TERMINATED AT 1.7m DUE TO AUGER REFUSAL IN MW BEDROCK			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0

Logged By : AB Date : 18/7/16 Checked By : Date :

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Excavation Log

Excavation No.	2A
Sheet	1 of 1
Job No.	C8247
Location	See Figure 2
Surface Level	Not Known

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.15		SM	SILTY SAND; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist.	LOOSE		TOPSOIL
			1.0		CL	SANDY CLAY; low plasticity fines, fine to medium sand, orange-brown, pale yellow-brown, some ferruginous nodules up to 5mm size, dry to moist.	STIFF/ VERY STIFF		ALLUVIUM
			1.2		CL	SANDY CLAY; medium plasticity clay, fine to medium sand, yellow-brown, dry to moist.	STIFF/ VERY STIFF		
			1.4		CL	SANDY CLAY; low plasticity clay, fine to coarse sand, yellow-brown, some sub-angular gravels up to 3mm size, dry.	VERY STIFF/ HARD		RESIDUAL
			3.0			EW DACITE; fine to coarse grained, pale yellow-brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
						EXCAVATION TERMINATED AT 3m DUE TO NEAR AUGER REFUSAL IN HW/MW BEDROCK			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0

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BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

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Excavation Log

Excavation No.	3A
Sheet	1 of 1
Job No.	C8247
Location	See Figure 2
Surface Level	Not Known

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.0–0.3	SM	SILTY SAND/SANDY SILT; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist.	LOOSE		TOPSOIL
			0.3–0.5	SC	CLAYEY SAND; fine to coarse sand, low plasticity fines, red-brown, some silt, dry to moist.	MEDIUM DENSE		ALLUVIUM
			0.5–0.8	CL	SANDY CLAY; medium plasticity clay, fine to coarse sand, red-brown, dry to moist.	VERY STIFF		RESIDUAL
			0.8–1.5		EW DACITE; fine to coarse grained, pale yellow-brown, pale brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.5–1.8		HW/MW DACITE; fine to coarse grained, pale brown, dry.	WEAK TO MEDIUM STRONG ROCK		HW/MW BEDROCK
			1.8		EXCAVATION TERMINATED AT 1.8m DUE TO NEAR AUGER REFUSAL IN HW/MW BEDROCK			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0

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Excavation Log

Excavation No.	4A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.1		SM	SILTY SAND; fine to coarse sand, low plasticity silt, grey-brown, some grass roots, dry to moist.	LOOSE		TOPSOIL
					SC	CLAYEY SAND; fine to coarse sand, low plasticity clay, red-brown, pale yellow-brown, dry to moist.	MEDIUM DENSE/ DENSE		RESIDUAL
			1.0			EW DACITE; fine to coarse grained, pale yellow-brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.9			EXCAVATION TERMINATED AT 1.9m DUE TO AUGER REFUSAL IN HW/MW BEDROCK			
			2.0						
			3.0						
			4.0						
			5.0						

Logged By : AB Date : 18/7/16 Checked By : Date :

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Excavation Log

Excavation No.	5A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.15		SM	SILTY SAND/SANDY SILT; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist.	LOOSE/ SOFT		TOPSOIL
			0.3		ML	SANDY SILT; low plasticity silt, fine to medium sand, pale grey, dry to moist.	SOFT		SLOPEWASH
			1.5		CL	SANDY CLAY; low to medium plasticity clay, fine to coarse sand, orange-brown, some iron staining, dry to moist.	VERY STIFF		ALLUVIUM
						EXCAVATION TERMINATED AT 1.5m DUE TO AUGER REFUSAL IN MW BEDROCK			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0

Logged By : AB	Date : 18/7/16	Checked By :	Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

Excavation Log

Excavation No.	6A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.2		SM/ ML	SILTY SAND/SANDY SILT; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist.	LOOSE/ SOFT		TOPSOIL
			0.3		ML	SANDY SILT; low plasticity silt, fine to medium sand, pale grey, dry to moist.	SOFT		SLOPEWASH
			1.0 1.3		CL/ SC	SANDY CLAY/CLAYEY SAND; low to medium plasticity clay, fine to coarse sand, orange-brown, some iron staining, dry to moist.	VERY STIFF/ DENSE		ALLUVIUM
			1.5			EW DACITE; fine to coarse grained, pale yellow-brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			2.0 3.0 4.0 5.0			EXCAVATION TERMINATED AT 1.5m DUE TO AUGER REFUSAL IN MW BEDROCK			

Logged By : AB	Date : 18/7/16	Checked By :	Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

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Excavation Log

Excavation No.	7A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.1		SM/ML	SILTY SAND/SANDY SILT; fine to coarse sand, low plasticity silt, brown, some grass roots, dry to moist.	LOOSE/ SOFT		TOPSOIL
			0.2		ML	SANDY SILT; low plasticity silt, fine to medium sand, pale grey, dry to moist.	SOFT		SLOPEWASH
			0.7		SC	CLAYEY SAND; fine to coarse sand, low plasticity clay, orange-brown, some ferruginous nodules up to 6mm size, moist.	MEDIUM DENSE/ DENSE		ALLUVIUM
			1.0 1.6		SC	CLAYEY SAND; fine to coarse sand, low to medium plasticity clay, pale brown, dry to moist.	DENSE		RESIDUAL
			2.0 2.5			EW DACITE; fine to coarse grained, pale yellow-brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			2.8			HW DACITE; fine to coarse grained, pale yellow-brown, dry.	WEAK ROCK		HW BEDROCK
			3.0 4.0 5.0			EXCAVATION TERMINATED AT 2.8m DUE TO NEAR AUGER REFUSAL IN HW/MW BEDROCK			

Logged By : AB Date : 18/7/16 Checked By : Date :

Excavation Log

Excavation No.	8A
Sheet	1 of 1
Job No.	C8247
Location	See Figure 2
Surface Level	Not Known

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.1		SM	SILTY SAND; fine to coarse sand, low plasticity silt, dark brown, moist.	LOOSE		TOPSOIL
			1.0 1.1		SC	CLAYEY SAND; fine to coarse sand, low to medium plasticity clay, orange-brown, moist. At 0.4m, becoming yellow-brown, dry to moist.	DENSE		RESIDUAL
			1.3			EW DACITE; fine to coarse grained, yellow-brown, dry to moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.5			HW DACITE; fine to coarse grained, yellow-brown, dry to moist.	WEAK ROCK		HW BEDROCK
			2.0 3.0 4.0 5.0			EXCAVATION TERMINATED AT 1.5m DUE TO AUGER REFUSAL IN MW BEDROCK			

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BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

Excavation Log

Excavation No.	9A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.1		SM	SILTY SAND; fine to coarse sand, low plasticity silt, dark brown, moist.	LOOSE		TOPSOIL
					CL	SANDY CLAY; medium plasticity clay, fine to medium sand, yellow-brown, some orange-brown, moist. At 0.9m, becoming pale brown, some gravels up to 3mm size, dry to moist.	VERY STIFF		ALLUVIUM
			1.0 / 1.4			EW DACITE; fine to coarse grained, pale brown, dry to moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			2.0 3.0 4.0 5.0			EXCAVATION TERMINATED AT 1.4m DUE TO AUGER REFUSAL IN MW BEDROCK			

Logged By : AB Date : 18/7/16 Checked By : Date :

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Excavation Log

Excavation No.	10A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.3		SM	SILTY SAND; fine to coarse sand, low plasticity silt, grey-brown, dry to moist.	LOOSE		TOPSOIL
			0.6		CL	SANDY CLAY; medium plasticity clay, fine to coarse sand, pale yellow-brown, dry to moist.	VERY STIFF		ALLUVIUM
			1.0 1.2		CH	SANDY CLAY; high plasticity clay, fine to coarse sand, pale yellow-brown, dry to moist.	VERY STIFF		
			2.0 3.0 4.0 5.0			EXCAVATION TERMINATED AT 1.2m DUE TO AUGER REFUSAL IN MW BEDROCK			

Logged By : AB Date : 18/7/16 Checked By : Date :

Excavation Log

Excavation No.	11A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.2		ML	SANDY SILT; low plasticity silt, fine to coarse sand, grey-brown, sub-angular gravels up to 10mm size, dry to moist.	LOOSE		TOPSOIL
			0.9		CL-CH/SC	SANDY CLAY/CLAYEY SAND; medium to high plasticity clay, fine to coarse sand, orange-brown, dry to moist.	VERY STIFF/ DENSE		ALLUVIUM
			1.0, 1.2			EW DACITE; fine to coarse grained, yellow-brown, moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.4			EW/HW DACITE; fine to coarse grained, yellow-brown, moist.	VERY WEAK ROCK		EW/HW BEDROCK
			2.0, 3.0, 4.0, 5.0			EXCAVATION TERMINATED AT 1.4m DUE TO AUGER REFUSAL IN MW BEDROCK			

Logged By : AB Date : 18/7/16 Checked By : Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

Excavation Log

Excavation No.	12A
Sheet	1 of 1
Job No.	C8247
Location	See Figure 2
Surface Level	Not Known

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth (Metres)	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.05		SM	SILTY SAND; fine to coarse sand, low plasticity silt, dark brown, moist.	LOOSE		TOPSOIL
			0.6		ML	SANDY SILT; medium plasticity silt, fine to coarse sand, orange-brown, some rounded gravels up to 10mm size, moist.	FIRM/ STIFF		FILL
			1.0		CL/ SC	SANDY CLAY/CLAYEY SAND; medium plasticity fines, fine to coarse sand, orange-brown, some silt, moist.	VERY STIFF/ DENSE		ALLUVIUM
			1.5		CL	SANDY CLAY; medium plasticity fines, fine to coarse sand, grey-brown, pale yellow-brown, some silt, moist.	VERY STIFF		RESIDUAL
			1.9			EW SANDSTONE excavates as CLAYEY SAND; fine to coarse sand, low plasticity clay, yellow-brown, trace ferruginous nodules up to 6mm size, dry to moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			2.0			HW SANDSTONE; fine to coarse grained, yellow, dry to moist.	WEAK ROCK		HW BEDROCK

EXCAVATION TERMINATED AT 2m
DUE TO NEAR AUGER REFUSAL IN HW/MW BEDROCK

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0

Logged By : AB	Date : 18/7/16	Checked By :	Date :

Excavation Log

Excavation No.	13A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.1		ML	SANDY SILT; low plasticity silt, fine to coarse sand, dark grey, brown, some grass roots, dry to moist.	SOFT		TOPSOIL
			0.2		ML	SANDY SILT; low plasticity silt, fine to coarse sand, pale grey-brown, dry to moist.	SOFT		SLOPEWASH
			1.0		SC	CLAYEY SAND; fine to coarse sand, low to medium plasticity clay, brown, moist.	MEDIUM DENSE/ DENSE		ALLUVIUM
			1.1			EW DACITE; fine to coarse grained, pale brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.2			EW/HW & HW DACITE; fine to coarse grained, pale brown, dry.	VERY WEAK & WEAK ROCK		EW/HW & HW BEDROCK
						EXCAVATION TERMINATED AT 1.2m DUE TO AUGER REFUSAL IN MW BEDROCK			
			2.0						
			3.0						
			4.0						
			5.0						

Logged By : AB Date : 18/7/16 Checked By : Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

Excavation Log

Excavation No.	14A
Sheet	1 of 1
Job No.	C8247

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Surface Level : Not Known

Equipment Type : JCB 3CX Backhoe
Excavation Dimensions : 300mm Diameter

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.2		ML	SANDY SILT; low plasticity silt, fine to coarse sand, dark grey, brown, some grass roots, dry to moist.	SOFT		TOPSOIL
			0.3		ML	SANDY SILT; low plasticity silt, fine to coarse sand, pale grey-brown, dry to moist.	SOFT		SLOPEWASH
			1.0 1.3		CL	SANDY CLAY; low to medium plasticity fines, fine to coarse sand, red-brown, some silt, moist.	VERY STIFF		ALLUVIUM
			2.0 2			EW DACITE; fine to coarse grained, brown, dry.	EXTREMELY WEAK ROCK		EW BEDROCK
			2.3			HW DACITE; fine to coarse grained, brown, dry.	WEAK ROCK		HW BEDROCK
			3.0 4.0 5.0			EXCAVATION TERMINATED AT 2.3m DUE TO AUGER REFUSAL IN MW BEDROCK			

Logged By : AB Date : 18/7/16 Checked By : Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

Borehole Log

Borehole No.	BH1
Sheet	1 of 2
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : Gemco 210A Drill Rig
Hole Diameter : 100mm

Location : See Figure 2

Collar Level : ~RL596.8m
Angle From Vertical : 180°
Bearing : N.A.

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.4		SM	SILTY SAND; fine to coarse sand, low plasticity silt, grey-brown, dry to moist.	LOOSE		TOPSOIL
			0.8		CL	SANDY CLAY; medium plasticity clay, fine to coarse sand, pale yellow-brown, grey, dry to moist.	VERY STIFF		ALLUVIUM
			0.85			HW/MW DACITE; fine to coarse grained, grey. CORING COMMENCED AT 0.85m	WEAK TO MEDIUM STRONG ROCK		HW/MW BEDROCK
			1.0						
			2.0						
			3.0						
			4.0						
			5.0						
			6.0						
			7.0						
			8.0						
			9.0						
			10.0						

Logged By : AB/HR Date : 18/7/16 Checked By : Date :

BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

THE DOMA GROUP

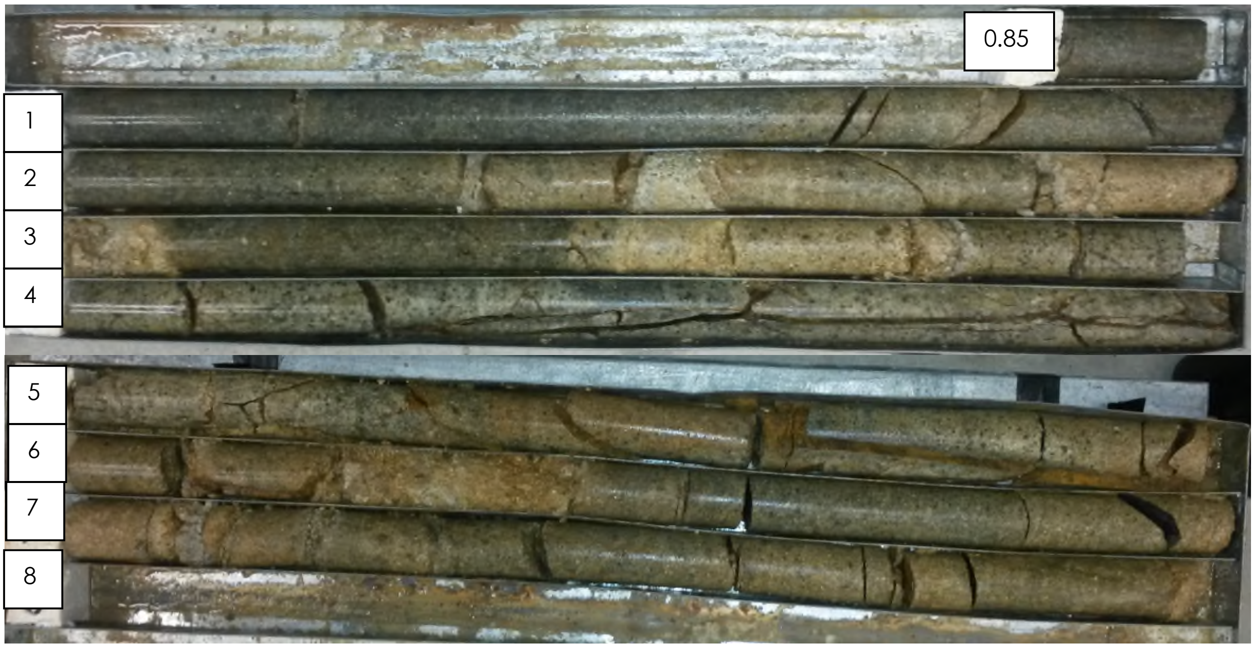
PROPOSED CSIRO REDEVELOPMENT
SECTION 38 CAMPBELL ACT

CORE PHOTOGRAPHS

Geotechnical Engineers ACT
ACT Geotechnical engineers Pty Ltd
Consulting Engineers

Borehole No.: BH1

Depth: 0.85m – 8.0m



Borehole BH1

Cored Borehole Log

Borehole No.	BH1
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Collar Level : ~RL596.8m
Angle From Horizontal : -90°
Bearing : N.A.

Drill Type : Gemco 210A Drill Rig
Barrel Type, Length, Drilling fluid : NMLC, 1.5m, Water

Columns: Method/Casing | R.Q.D./Lift | Water | Depth Metres | Graphic Log | Soil or Rock Substance Description | Degree of Weathering | Estimated Strength Range (EW VW W MS S VS ES) | Is(50) MPa (D = diaxial, A = axial) | Core Length (mm) (30 100 300 1000 3000) | Defects | Defect Description

Water: None Encountered

R.Q.D./Lift: 81% / 100%; 35% / 100%; 8% / 100%; 37% / 100%; 47% / 100%

Soil or Rock Substance Description

- 0.85 – CORING COMMENCED AT 0.85m DEPTH
- DACITE; fine to coarse grained, grey, blue-grey, dry.
- At 1.6m, becoming yellow-grey.
- At 3.8m, becoming pale grey, blue speckled.
- At 5.4m, becoming yellow-grey and yellow-brown.
- 8.0 – BOREHOLE TERMINATED AT 8m

Degree of Weathering (top to bottom): FR, SW/FR, FR, MW/SW, EW, SW/FR, MW, EW, FR, HW/MW, SW, EW, HW, SW, MW, MW/SW

Is(50) MPa: D = 3.7; D = 0.7; D = 0.6; D = 0.7; D = 2.1; D = 2.8; D = 2.7; D = 2.4

Defect Description

- joint, 5°, planar, rough
- joint, 5°, planar, slightly rough, clay infill to 3mm
- 2 joints, 35°, planar, slightly rough, staining
- joint, 40°, planar, slightly rough, clay infill to 1mm
- joint, 45°, planar, slightly rough, staining
- joint, 35°, planar, rough
- joint, 5°, planar, rough, clay infill to 15mm
- joint, 50°, planar, slightly rough, staining
- joint, 15°, sub-planar, rough, staining
- joint, 30°, planar, smooth
- clay seam
- joint, 25°, planar, smooth
- joint, 55°, planar, slightly rough, staining
- joint, 5°, planar, rough
- joint, 40°, planar, slightly rough, clay infill to 10mm
- joint, 30°, planar, slightly rough, clay infill to 10mm
- joint, 45°, planar, rough
- fragmented
- joint, 0°, wavy, slightly rough
- joint, 25°, planar, smooth, clay infill to 1mm
- joint, 10°, planar, slightly rough, clay infill to 20mm
- joint, 15°, planar, slightly rough, clay infill to 10mm
- joint, 10°, planar, slightly rough, clay infill to 5mm
- joint, 5°, sub-planar, rough, clay infill to 2mm
- joint, 40°, sub-planar, slightly rough, staining
- joint, 0°, planar, rough, staining
- joint, 15°, sub-planar, slightly rough, staining
- joint, 20°, sub-planar, slightly rough, staining
- joint, 45°, planar, smooth, staining
- joint, 85°, sub-planar, smooth, staining
- joint, 40°, planar, smooth, staining
- joint, 90°, sub-planar, smooth, staining
- joint, 90°, sub-planar, smooth, staining
- joint, 90°, wavy, smooth, staining
- joint, 40°, planar, rough, staining
- joint, 0°, irregular, rough, staining
- 3 joints, 0°, sub-planar, rough
- joint, 70°, planar, smooth, staining
- joint, 70°, planar, smooth, staining
- joint, 75°, sub-planar, rough, staining
- joint, 60°, planar, slightly rough, staining
- joint, 10°, planar, rough
- joint, 0°, planar, rough, staining
- joint, 60°, planar, smooth, staining
- joint, 85°, planar, smooth, staining
- joint, 10°, planar, slightly rough, staining
- joint, 10°, irregular, rough, staining
- joint, 40°, planar, rough
- fractured and fragmented
- joint, 50°, planar, smooth
- 2 joints, 5°, planar, smooth
- joint, 10°, planar, smooth
- joint, 10°, planar, smooth
- joint, 50°, planar, slightly rough, staining
- joint, 0°, planar, rough
- joint, 10°, planar, rough, clay infill to 20mm
- joint, 15°, planar, slightly rough
- joint, 25°, planar, slightly rough
- joint, 0°, planar, rough
- joint, 15°, planar, rough
- joint, 20°, sub-planar, rough
- joint, 30°, planar, slightly rough
- joint, 5°, sub-planar, slightly rough, staining
- joint, 0°, planar, smooth, staining
- joint, 5°, sub-planar, smooth, staining
- 2 joints, 5°, planar, slightly rough, staining
- joint, 5°, planar, smooth, staining
- joint, 0°, planar, smooth
- joint, 20°, planar, smooth, clay infill to 7mm
- joint, 0°, planar, slightly rough, staining

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Borehole Log

Borehole No.	**BH2**
Sheet	1 of 2
Job No.	C8247

CLIENT:	Doma Group
PROJECT	Proposed CSIRO Redevelopment Section 38 Campbell ACT

Equipment Type : Gemco 210A Drill Rig
Hole Diameter : 100mm

Location : See Figure 2

Collar Level : ~RL598.2m
Angle From Vertical : 180°
Bearing : N.A.

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.0–0.2		SM	SILTY SAND; fine to coarse sand, low plasticity silt, pale brown, some grass roots, moist.	LOOSE		TOPSOIL
			0.2–0.5		CL	SANDY CLAY; medium plasticity clay, fine to coarse sand, brown, moist.	VERY STIFF		ALLUVIUM
			0.5–4.0			EW DACITE; fine to coarse grained, yellow-brown, dry to moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			4.0			CORING COMMENCED AT 4m			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

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BOREHOLE/EXCAVATION LOG C8247.GPJ ACT GEO.GDT 29/7/16

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SECTION 38 CAMPBELL ACT

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Borehole No.: BH2

Depth: 4.0m – 8.05m

Borehole BH2

Cored Borehole Log

Borehole No.	BH2
	2 of 2
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Location : See Figure 2

Collar Level : ~RL598.2m
Angle From Horizontal : -90°
Bearing : N.A.

Drill Type : Gemco 210A Drill Rig
Barrel Type, Length, Drilling fluid : NMLC, 1.5m, Water

Method/Casing	R.Q.D./Lift	Water	Depth Metres	Graphic Log	Soil or Rock Substance Description	Degree of Weathering	Estimated Strength Range (EW VW W MS S VS ES)	Is(50) MPa (D = diaxial, A = axial)	Core Length (mm) (30 100 300 1000 3000)	Defects	Defect Description
			1.0								
			2.0								
			3.0								
			4.0		CORING COMMENCED AT 4m DEPTH						
	38% / 100%	None Encountered	4.0–5.2		DACITE; fine to coarse grained, yellow-brown, dry.	MW		D = 0.3			joint, 30°, planar, smooth 2 joints, 0 & 20°, planar, slightly rough, clay infill to 10mm joint, 60°, wavy, rough joint, 15°, planar, rough joint, 50°, planar, smooth, clay infill to 2mm joint, 75°, sub-planar, rough, staining joint, 70°, planar, rough, staining
			5.0			HW/MW					joint, 30°, irregular, rough joint, 20°, planar, rough, staining
	23% / 100%					HW		D = 0.2			fractured joint, 30°, irregular, rough joint, 45°, planar, smooth, clay infill to 7mm joint, 80°, planar, rough, staining joint, 75°, planar, rough, staining
			6.0			HW/MW		D = 0.3 D = 0.3			joint, 0°, planar, rough, staining joint, 25°, planar, smooth, clay infill to 20mm joint, 30°, wavy, rough, staining joint, 40°, wavy, rough, staining joint, 30°, sub-planar, rough joint, 40°, planar, rough, staining joint, 80°, sub-planar, rough, staining joint, 0°, planar, smooth joint, 40°, planar, rough, staining
	38% / 100%		7.0					D = 0.2			joint, 10°, wavy, rough, clay infill to 20mm joint, 50°, planar, rough, staining joint, 60°, planar, slightly rough, staining joint, 10°, planar, rough joint, 80°, planar, slightly rough, staining joint, 10°, planar, rough joint, 70°, stepped, slightly rough, staining
			8.0 / 8.05			EW/HW					joint, 40°, planar, slightly rough, staining joint, 20°, planar, slightly rough, staining 3 joints, 15°, planar, slightly rough, staining joint, 25°, sub-planar, slightly rough joint, 30°, planar, smooth, quartz infill to 15mm joint, 15°, planar, smooth, clay infill to 20mm joint, 15°, sub-planar, slightly rough joint, 30°, sub-planar, smooth
			8.05		BOREHOLE TERMINATED AT 8.05m						
			9.0								
			10.0								

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Borehole Log

Borehole No.	**BH3**
Sheet	1 of 2
Job No.	C8247

CLIENT: Doma Group

PROJECT Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : Gemco 210A Drill Rig
Hole Diameter : 100mm

Location : See Figure 2

Collar Level : ~RL594m
Angle From Vertical : 180°
Bearing : N.A.

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.3		SM	SILTY SAND; fine to coarse sand, low plasticity silt, pale brown, some grass roots, moist.	LOOSE		TOPSOIL
			1.2		SC	CLAYEY SAND; fine to coarse sand, low plasticity clay, red-brown, moist.	MEDIUM DENSE/ DENSE		ALLUVIUM
						At 0.8m, becoming orange-brown.	DENSE		
			1.4		CL	SANDY CLAY; medium plasticity clay, fine to coarse sand, brown, moist.	VERY STIFF		
			1.65			EW/HW DACITE; fine to coarse grained, yellow-brown, dry to moist.	VERY WEAK ROCK		EW/HW BEDROCK
						CORING COMMENCED AT 1.65m			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

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SECTION 38 CAMPBELL ACT

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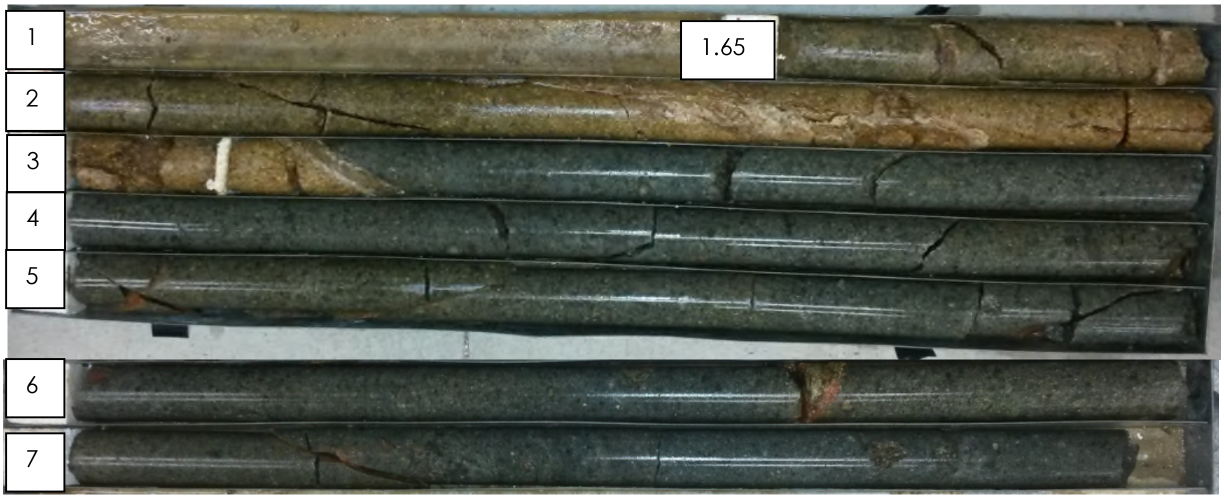
Borehole No.: BH3

Depth: 1.65m – 8.0m



Borehole BH3

Cored Borehole Log

Job No. C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment Section 38 Campbell ACT

Location : See Figure 2

Collar Level : ~RL594m
Angle From Horizontal : -90°
Bearing : N.A.

Drill Type : Gemco 210A Drill Rig
Barrel Type, Length, Drilling fluid : NMLC, 1.5m, Water

Method/Casing	R.Q.D./Lift	Water	Depth Metres	Graphic Log	Soil or Rock Substance Description	Degree of Weathering	Estimated Strength Range (EW VW W MS S VS ES)	Is(50) MPa (D = diaxial, A = axial)	Core Length (mm) (30 100 300 1000 3000)	Defects	Defect Description
			1.0								
			1.65		CORING COMMENCED AT 1.65m DEPTH						
	22% / 100%	None Encountered	2.0		DACITE; fine to coarse grained, green-grey, some yellow-brown, dry.	MW/SW		D = 1.8			joint, 25°, planar, rough, clay infill to 5mm joint, 40°, sub-planar, rough, staining joint, 15°, planar, rough, clay infill to 5mm joint, 20°, sub-planar, rough, staining joint, 15°, sub-planar, rough, clay infill to 5mm joint, 80°, planar, rough
					At 2.5m, becoming yellow-brown.	EW					joint, 25°, sub-planar, rough joint, 85°, wavy, slightly rough fractured
			3.0			MW		D = 0.5			joint, 5°, sub-planar, rough, staining joint, 80°, planar, rough, staining
						HW					joint, 15°, sub-planar, rough 2 joints, 60°, planar, slightly rough, clay infill to 5mm
	86% / 100%				At 3.3m, becoming blue-grey.			D = 5.1			joint, 30°, sub-planar, rough, staining joint, 55°, planar, rough
			4.0								joint, 30°, sub-planar, rough, staining
	55% / 100%										joint, 70°, planar, rough, staining joint, 45°, planar, rough, staining
			5.0					D = 3.9			joint, 45°, planar, rough, staining joint, 60°, planar, slightly rough, staining joint, 75°, planar, rough, staining joint, 70°, planar, rough, staining, clay infill to 1mm joint, 0°, sub-planar, rough
						FR		D = 3.4			joint, 70°, sub-planar, rough, staining joint, 90°, wavy, rough, staining joint, 25°, sub-planar, rough joint, 15°, sub-planar, rough, staining joint, 5°, sub-planar, rough joint, 80°, sub-planar, rough, staining
	84% / 100%		6.0								
			7.0					D = 4.8			
	100% / 100%							D = 5.4			
			8.0		BOREHOLE TERMINATED AT 8m						
			9.0								
			10.0								

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Borehole Log

Borehole No.	BH4
Sheet	1 of 2
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Equipment Type : Gemco 210A Drill Rig
Hole Diameter : 100mm

Location : See Figure 2

Collar Level : ~RL588.5m
Angle From Vertical : 180°
Bearing : N.A.

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.0–0.5		SM	SILTY SAND; fine to coarse sand, low plasticity silt, grey-brown, some grass roots, dry to moist.	LOOSE		TOPSOIL
			0.5–0.8		CL	SANDY CLAY; low to medium plasticity clay, fine to coarse sand, orange-brown, dry to moist.	VERY STIFF		RESIDUAL
			0.8–1.8			EW DACITE; fine to coarse grained, orange-brown, dry to moist.	EXTREMELY WEAK ROCK		EW BEDROCK
			1.8–3.4			EW/HW DACITE; fine to coarse grained, orange-brown, dry to moist.	VERY WEAK ROCK		EW/HW BEDROCK
			3.4			CORING COMMENCED AT 3.4m			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

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SECTION 38 CAMPBELL ACT

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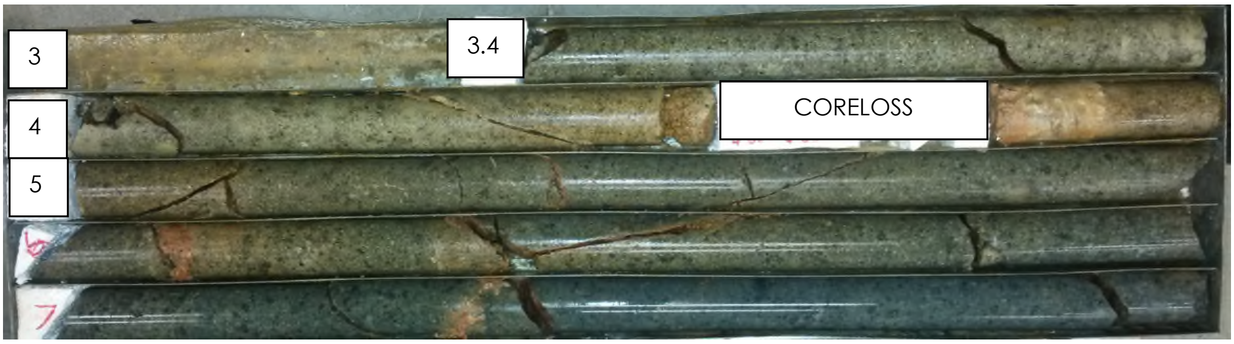
Borehole No.: BH4

Depth: 3.4m – 8.0m



Borehole BH3

Cored Borehole Log

Borehole No.	BH4
	2 of 2
Job No.	C8247

CLIENT: Doma Group

PROJECT: Proposed CSIRO Redevelopment
Section 38 Campbell ACT

Drill Type : Gemco 210A Drill Rig
Barrel Type, Length, Drilling fluid : NMLC, 1.5m, Water

Location : See Figure 2

Collar Level : ~RL588.5m
Angle From Horizontal : -90°
Bearing : N.A.

Method/Casing	R.Q.D./Lift	Water	Depth Metres	Soil or Rock Substance Description	Degree of Weathering	Is(50) MPa (D = diaxial, A = axial)	Defect Description
			3.4	CORING COMMENCED AT 3.4m DEPTH			
	62% 90%	None Encountered	3.4–4.57	DACITE; fine to coarse grained, green-grey, dry.	MW/SW	D = 1.8	joint, 50°, planar, rough, staining joint, 50°, irregular, rough, staining joint, 60°, planar, rough, staining joint, 90°, planar, rough, staining joint, 70°, sub-planar, rough, staining joint, 75°, planar, smooth, staining, clay infill to 2mm
				At 4.4m, becoming yellow-brown.	MW		
			4.57–4.8	CORE LOSS	CORE LOSS		
	58% 94%		4.8–8.0	DACITE; fine to coarse grained, yellow-brown, dry.	EW		clay seam
					MW	D = 1.9	joint, 70°, planar, smooth, staining joint, 0°, sub-planar, rough, staining joint, 25°, planar, rough joint, 25°, planar, rough
				At 5.2m, becoming green-grey.	SW	D = 3.5	joint, 20°, planar, rough joint, 70°, planar, smooth, staining joint, 55°, planar, rough, staining joint, 20°, planar, rough joint, 10°, planar, rough joint, 50°, sub-planar, rough joint, 85°, planar, rough, sand infill to 5mm joint, 0°, sub-planar, rough
	73% 100%			At 6.8m, becoming blue-grey.		D = 3.5	
					FR	D = 7.4	joint, 50°, planar, rough, staining joint, 30°, planar, smooth, clay infill to 3mm joint, 20°, sub-planar, rough, staining joint, 40°, sub-planar, rough
			8.0	BOREHOLE TERMINATED AT 8m			

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

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APPENDIX B

Point-Load Strength Index Tests

Appendix B

Point-Load Strength Index Tests

Borehole	Weathering	Depth (m)	$I_s(50)$ (MPa)	q_u (MPa)	Type of Fracture
BH1	Fr	1.11	3.7	87.6	Joint, 70°, sub-planar, rough
	SW/Fr	2.63	0.7	16.1	20°, sub-planar, rough
	HW/MW	3.65	0.6	13.4	10°, sub-planar, rough
	SW	3.83	0.7	16.3	Joint, 85°, wavy, slightly rough
	SW	4.18	2.1	50.2	10°, irregular, rough
	SW	5.51	2.8	67	0°, irregular, rough
	SW	6.76	2.7	63.6	5°, irregular, rough
	MW/SW	7.64	2.4	57.1	Joint, 45°, planar, rough, staining
BH2	MW	4.61	0.3	7.2	Joint, 60°, planar, rough, staining
	HW	5.62	0.2	4.3	0°, sub-planar, rough
	HW/MW	5.92	0.3	7.2	5°, wavy, rough
	HW/MW	6.4	0.3	6	20° & 30°, planar, rough
	HW/MW	7.09	0.2	5.5	15°, sub-planar, rough
BH3	MW/SW	1.71	1.8	43.4	5°, sub-planar, rough
	MW	2.83	0.5	13	10°, sub-planar, rough
	Fr	3.67	5.1	123.4	0°, sub-planar, rough
	Fr	4.87	3.9	92.6	Joint, 60°, planar, rough, staining
	Fr	5.71	3.4	82.3	Joint, 20°, irregular, rough
	Fr	6.82	4.8	115.4	0°, planar, rough
	Fr	7.72	5.4	129.8	0°, irregular, rough
BH4	MW/SW	3.9	1.8	43.2	0°, irregular, rough
	MW	4.94	1.9	46.6	10°, sub-planar, rough
	SW	5.51	3.5	84.7	25°, planar, rough
	SW	6.88	3.5	83	Joint, 40°, sub-planar, rough, staining
	Fr	7.3	7.4	177.8	20°, sub-planar, rough & 80°, sub-planar, rough

APPENDIX C

Definitions of Geotechnical Engineering Terms

UNIFIED SOIL CLASSIFICATION SYSTEM (METRICATED)
DATA FOR DESCRIPTION IDENTIFICATION AND CLASSIFICATION OF SOILS

Determine approximate percentages of material over 60mm in size, maximum size, shape, surface texture, hardness of material, geological description. Identify on estimated percentage mass of the various fractions.

0.06mm is about the smallest particle visible to the naked eye.

Use the gradation curve of material passing 60 mm for classification of fractions according to the criteria given under "Major Divisions".

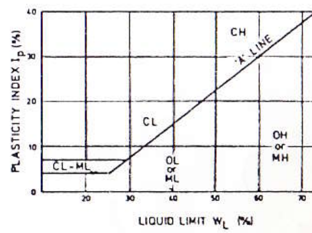
COARSE GRAINED SOILS — More than 50% by dry mass, less than 60mm is greater than 0.06mm (Field identification: More than half of the material less than 60 mm is larger than 0.06mm)

Major Divisions	Group Symbol	Graphic Symbol	Typical Name	Descriptive Data	Gradations		Nature of Fines	Dry Strength	Group Symbol	% [2] < 0.06mm	Plasticity of Fine Fraction	$C_u = \frac{D_{60}}{D_{10}}$	$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$	Notes
GRAVELS: More than 50% of coarse grains are greater than 2.0mm	GW		Well graded gravels and gravel-sand mixtures, little or no fines.	Give typical name, indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition and hardness of the coarse grains, local or geological name and other pertinent descriptive information; symbols in parenthesis.	GOOD	Wide range in grain size	"Clean" materials (not enough fines to bind coarse grains)	None	GW	0-5	-	>4	between 1 and 3	1 Identify fines by the method given for fine grained soils.
	GP		Poorly graded gravels and gravel-sand mixtures, little or no fines.		POOR	Predominantly one size or range of sizes			GP	0-5	-	Fails to comply with above		2 Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols e.g. SP-SM GW-GC
GRAVELLY SOILS	GM		Silty gravels, gravel-sand-silt mixtures.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.	GOOD to FAIR	"Dirty" materials (excess of fines)	Fines are non-plastic (1)	None to medium	GM	12-50	Below 'A' line or $I_p<4$	-	-	
	GC		Clayey gravels gravel-sand-clay mixtures.	EXAMPLE: Silty Sand, gravelly, about 20% hard, angular gravel particles, 10mm maximum size; rounded and sub angular sand grains coarse to fine; about 15% non-plastic fines with low dry strength; well compacted and moist in place; light brown alluvial sand, (SM)			Fines are plastic (1)	Medium to high	GC	12-50	Above 'A' line and $I_p>7$	-	-	
SANDS: More than 50% of coarse grains are less than 2.0mm	SW		Well graded sands and gravelly sands, little or no fines.		GOOD	Wide range in grain size	"Clean" materials (not enough fines to bind coarse grains)	None	SW	0-5	-	>6	between 1 and 3	
	SP		Poorly graded sands and gravelly sands, little or no fines.		POOR	Predominately one size or range of sizes.			SP	0-5	-	Fails to comply with above		
SANDY SOILS	SM		Silty sand, sand-silt mixtures.		GOOD to FAIR	"Dirty" materials (excess of fines)	Fines are non-plastic (1)	None to medium	SM	12-50	Below 'A' line or $I_p<4$	-	-	
	SC		Clayey sands, sand-clay mixtures.				Fines are plastic (1)	Medium to high	SC	12-50	Above 'A' line and $I_p>7$	-	-	

FINE GRAINED SOILS — More than 50% by dry mass, less than 60mm is less than 0.06mm (Field identification: More than half of the material less than 60 mm is smaller than 0.06mm)

SILT AND CLAY FRACTION — Fraction smaller than 0.20mm AS sieve size

Major Divisions	Group Symbol	Graphic Symbol	Typical Name	Descriptive Data	Dry Strength	Dilatancy	Toughness	Group Symbol	More than 50% passing 0.06mm
Liquid Limit less than 50%	ML		Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give: typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains, colour in wet condition, odour if any; local or geological name and other pertinent descriptive information; symbols in parenthesis.	None to low	Quick to slow	None	ML	Below 'A' line
	CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.		Medium to high	None to very slow	Medium	CL	Above 'A' line
	OL		Organic silts and organic silty clays of low plasticity.	For undisturbed soil add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions.	Low to medium	Slow	Low	OL*	Below 'A' line
Liquid Limit more than 50%	MH		Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.	EXAMPLE: Clayey Silt, brown; low plasticity, small percentage of fine sand; numerous vertical root-holes; firm and dry in place, fill, (ML)	Low to medium	Slow to none	Low to medium	MH	Below 'A' line
	CH		Inorganic clays of high plasticity, fat clays.		High to very high	None	High	CH	Above 'A' line
	OH		Organic clays of medium to high plasticity.		Medium to high	None to very slow	Low to medium	OH*	Below 'A' line
	Pt		Peat muck and other highly organic soils.		Readily identified by colour, odour, spongy feel and generally by fibrous texture			Pt*	*Effervesces with H_2O_2



PLASTICITY CHART
FOR CLASSIFICATION
OF FINE GRAINED SOILS

FIELD IDENTIFICATION PROCEDURES FOR FINE GRAIN SOILS OR FRACTIONS

These proceedures are to be performed on the minus 0.6mm size particles. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests

Dilatancy (Reaction to Shaking)

After removing particles larger than 0.6mm size, prepare a pat of moist soil with a volume of about 10 cm³. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assists in identifying the character of the fines in the soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing Characteristics)

After removing particles larger than 0.6 mm size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic of clays in the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength but can be distinguished by feel when powdering the dry specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency Near Plastic Limit)

After removing particles larger than 0.6 mm size, a specimen of soil, about 10 cm³ in size, is moulded to the consistency of putty. If too dry, water must be add and, if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about 3mm diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

Notes

1. The above follows the original Unified Classification System (U.S.B.R. Earth Manual) and ASTM Designation D2487-69 except that it adopts the particle size limits given in AS 1289 and other standards, viz

Gravel	2 - 60mm
Sand	0.06 - 2mm
Silt and Clay	less than 0.06mm

The system excludes the boulder and cobble fractions of the soil and classifies only the material less than 60mm in size.

2. As 60mm, 2mm and 0.06mm sieve sizes are not normally used, the percentages passing these sizes can be obtained from a particle size distribution curve determined from a laboratory test. Alternatively, the percentages passing maybe estimated in the field.
3. Australian Standard Code of Practice for Site Investigation, Appendix D, and ASTM Designation D2488-69, Tables 1 to 4, contain standard terms and manual tests for describing and identifying soils.

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DESCRIPTION AND CLASSIFICATION OF SOILS

The methods of description and classification of soils used in this report are based on Australian Standard 1726 - 1981, the SAA Site Investigation Code. In general, descriptions cover the following properties - soil type, colour, secondary grain size, structure, inclusions, strength or density and geological description.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2.00mm
Gravel	2.00 to 60.00mm

Soils are also classified according to the Unified Soil Classifications System which is included in this Appendix.

Rock types are classified by their geological names.

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The terms are defined as follows:

Classification	Shear Strength kPa
Very soft	less than 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of insitu standard penetration tests as below:

Relative Density	"N" Value blows/300mm
Very loose	less than 5
Loose	5 - 10
Medium dense	10 - 30
Dense	30 - 50
Very dense	greater than 50

SAMPLING

Sampling is carried out during drilling 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 generally taken by one of two methods:

(i) driving or pushing a thinwalled sample tube into the soil and withdrawing with a sample of the soil in a relatively undisturbed state.

(ii) Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in addition to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by insitu penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 "Testing Soils for Engineering Purposes" - Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63 kg hammer having a free fall of 750mm.

The "N" value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test.

Other forms of insitu testing are used under certain conditions and where this occurs, details are given in the report.

DEFINITIONS OF ROCK, SOIL, AND DEGREES OF CHEMICAL WEATHERING

(A) GENERAL DEFINITIONS — ROCK AND SOIL

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Note: Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one.

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System. Three principal classes of soil recognised are:

(a) Residual soils: soils which have been formed insitu by the chemical weathering of parent rock. Residual soil may retain evidence of the original rock texture or fabric or, when mature, the original rock texture may be destroyed.

(b) Transported soils: soils which have been moved from their places of origin and deposited elsewhere. The principal agents of erosion, transport and deposition are water, wind and gravity. Two important types of transported soil in engineering geology and materials investigations are:

(i) Colluvium - a soil, often including angular rock fragments and boulders, which has been transported downslope predominantly under the action of gravity assisted by water. The principal forming process is that of soil creep in which the soil moves after it has been weakened by saturation. It may be water borne for short distances

(ii) Alluvium - a soil which has been transported and deposited by running water. The larger particles (sand and gravel size) are water worn.

(c) Lateritic soils: soils which have formed insitu under the effects of tropical weathering and include all reddish residual and non residual soils which genetically form a chain of material ranging from decomposed rock through clays to sesquioxide rich crusts. The term does not necessarily imply any compositional, textural or morphological definition; all distinctions useful for engineering purposes are based on the differences in geotechnical characteristics.

(B) ROCK WEATHERING DEFINITIONS

Extremely Weathered (EW)
Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.

Highly Weathered (HW)
Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.

Moderately Weathered (MW)
Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.

Slightly Weathered (SW)
Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite, has taken place. The colour and texture of the fresh rock is recognisable.

Fresh (Fr)
Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are weak, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

Fresh drill cores of some rock types, such as basalt and shale may disintegrate after exposure to the atmosphere due to slaking, desiccation, expansion or contraction, stress relief or a combination of any of these factors.

AN ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS

This classification system provides a standardized terminology for the engineering description of the sandstone and shales in the Sydney area, but the terms and definitions may be used elsewhere when applicable. Where other rock types are encountered, such as in dykes, standard geological descriptions are used for rock types and the same descriptions as below are used for strength, fracturing and weathering.

Under this system rocks are classified by Rock Type, Strength, Stratification Spacing, Degree of Fracturing and Degree of Weathering. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc) where these are relevant.

ROCK TYPE DEFINITIONS

ROCK TYPE	DEFINITION
Conglomerate:	More than 50% of the rock consists of gravel sized (greater than 2mm) fragments.
Sandstone:	More than 50% of the rock consists of sand sized (.06 to 2mm) grains.
Siltstone:	More than 50% of the rock consists of silt-sized (less than .06mm) granular particles and the rock is not laminated.
Claystone:	More than 50% of the rock consists of clay or sericitic material and the rock is not laminated.
Shale:	More than 50% of the rock consists of silt or clay sized particles and the rock is laminated.

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

STRATIFICATION SPACING

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

DEGREE OF FRACTURING

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Term	Description
Fragmented:	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter.
Highly Fractured:	Core lengths are generally less than 20mm - 40mm with occasional fragments.
Fractured:	Core lengths are mainly 30mm - 100mm with occasional shorter and longer section.
Slightly Fractured:	Core lengths are generally 300mm - 1000mm with occasional longer sections and occasional sections of 100mm - 300mm.
Unbroken:	The core does not contain any fracture.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	Is(50) MPa	Field Guide	Approx. qu MPa*
Extremely Weak:	0.03	Easily remoulded by hand to a material with soil properties.	0.7
Very Weak:	0.1	May be crumbled in the hand. Sandstone is "sugary" and friable.	2.4
Weak:	0.3	A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	7
Medium Strong:	1	A piece of core 150mm long x 50mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.	24
Strong:	3	A piece of core 150mm long x 50mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.	70
Very Strong	10	A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	240
Extremely Strong:		A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer.	

The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ratio to the point load index of 24:1. This ratio may vary widely.

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