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Report on
Urban Capability Study

Proposed Subdivision
Neighbourhoods 3 - 5, Googong

Prepared for
Spacelab Studio Pty Ltd

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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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Table of Contents

Appendix A:	About this Report
Appendix B:	Site Photographs
Appendix C:	Drawing 1 – Test Location Plan Drawing 2 – Location of Site Photographs
Appendix D:	Explanatory Notes Results of Fieldwork (Pits 1 – 12, 14 – 26)
Appendix E:	Results of Laboratory Testing
Appendix F:	AGS Publication Extract
Appendix G:	CSIRO Publication

Report on Urban Capability Study
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1. Introduction

This report presents the results of an urban capability study undertaken for a proposed subdivision known as Neighbourhoods 3 – 5 (NH 3 – 5), Googong. The investigation was commissioned in an email dated 27 August 2018 from Giselle Ravarian of Spacelab Studio Pty Ltd and was undertaken in accordance with Douglas Partners' proposal CAN180156 dated 5 July 2018.

Assessment and limited subsurface investigation (excavation of 25 test pits and laboratory testing) was carried out to provide preliminary information on geotechnical aspects of the site to assist in conceptual planning of the development and to provide comment on:

- Physical conditions at the site including slope, contours, landform, geology, soils, drainage, erosion, slope stability, rock outcrops and ground water systems;
- Potential geotechnical issues for residential development and/or infrastructure elements;
- Suitability of the site(s) for residential land use;
- Advice on the extent of future subsurface investigations.

A surveyed plan showing the proposed layout of NH 3 – 5 was provided by the client.

This report must be read in conjunction with the notes “About this Report” which are included in Appendix A.

2. Site Description

The site is located to the south and southwest of existing NH1 of the Googong Township and is approximately 9 km south of Queanbeyan, NSW. The NH 3 – 5 development covers a combined area of some 200 hectares with approximate north-south and east-west dimensions of 300 – 500 m and 3,000 m respectively. It is bounded to the north by existing NH1 and Future NH2, to the southeast by undeveloped land that comprises part of the Googong Dam catchment area, to the south and southwest by undeveloped farm land and to the west by Old Cooma Road. Googong Dam is located approximately 500 – 600 m to the east and southeast of the site.

The site is presently being used for grazing and is characterised by a series of ridges and gullies with a number of farm dams constructed within these gullies. It was lightly to moderately grassed with scatterings of mature trees, cleared animal tracks and dirt access tracks that were generally either cut into the landscape or built up. Extensive rock outcropping and/or cobbles/boulders sub-cropping were noted across the majority of the site. Uncontrolled filling was generally limited to farm dam wall construction and built up access tracks, though some stockpiles and scattered debris was noted in other areas.

Site levels fall in variable directions away from a number of ridgelines and hill tops at grades ranging from 1 in 3 to 1 in 60 (V:H) but overall fall is to the north east. An overall difference in level from the highest part of the proposed subdivision site to the lowest has been estimated to be about 100 – 120 m.

3. Assessment Methods

3.1 Information Review

A review of existing geological, soil landscape and hydrogeological maps was undertaken as part of the assessment. The relevant maps reviewed were as follows:

- 1:100 000 Geological Series Sheet for Canberra (Ref 1),
- 1:100 000 Soil Landscape Sheet for Canberra (Ref 2),
- 1:100 000 Hydrogeology of the Australian Capital Territory (Ref 3).

3.2 Site Inspection

A site inspection was undertaken by an experienced geotechnical engineer on 10 and 17 January 2019, which included qualitative assessment of site stability considerations and mapping of site features. A series of photographs illustrating notable site features are presented in Appendix B with the locations of the photographs shown on Drawing 1 in Appendix C.

3.3 Subsurface Investigation

The field investigation comprised the excavation of 25 test pits (Pits 1 – 12 and 14 – 26) to depths of 0.6 – 4.2 m using either a Volvo EC35DL excavator fitted with an 850 mm wide bucket (Pits 1 – 14) or a Volvo EC220DL excavator fitted with an 800 mm wide bucket. The pits were logged onsite by an Experienced Geotechnical Engineer who collected disturbed samples to assist in strata identification and for possible laboratory testing. The approximate location of the test pits are shown on Drawing 2 (Appendix C). The test location coordinates and surface levels relative to AHD are provided on the test pit logs and were interpolated from the survey data provided by the client. The test pit locations were located on site using a handheld GPS unit which is accurate to approximately 3 – 5 m, therefore the survey data must not be relied on.

It is noted that Pit 13 was not excavated due to time constraints.

3.4 Laboratory Testing

Eleven (11) samples collected from the test pits were tested in the laboratory for California bearing ratio (CBR) and/or plasticity properties. The CBR testing was carried out on samples compacted to about 95% modified maximum dry density at close to optimum moisture content. The samples were soaked for four days under surcharge loading of 4.5 kg.

4. Assessment Results

4.1 Geology and Hydrogeology

Reference to the Canberra Geology Sheet (Ref 1) indicates that the site is underlain by three rock units. Figure 1 below is an extract of the geological map showing the approximate site extent and the contained geological units.

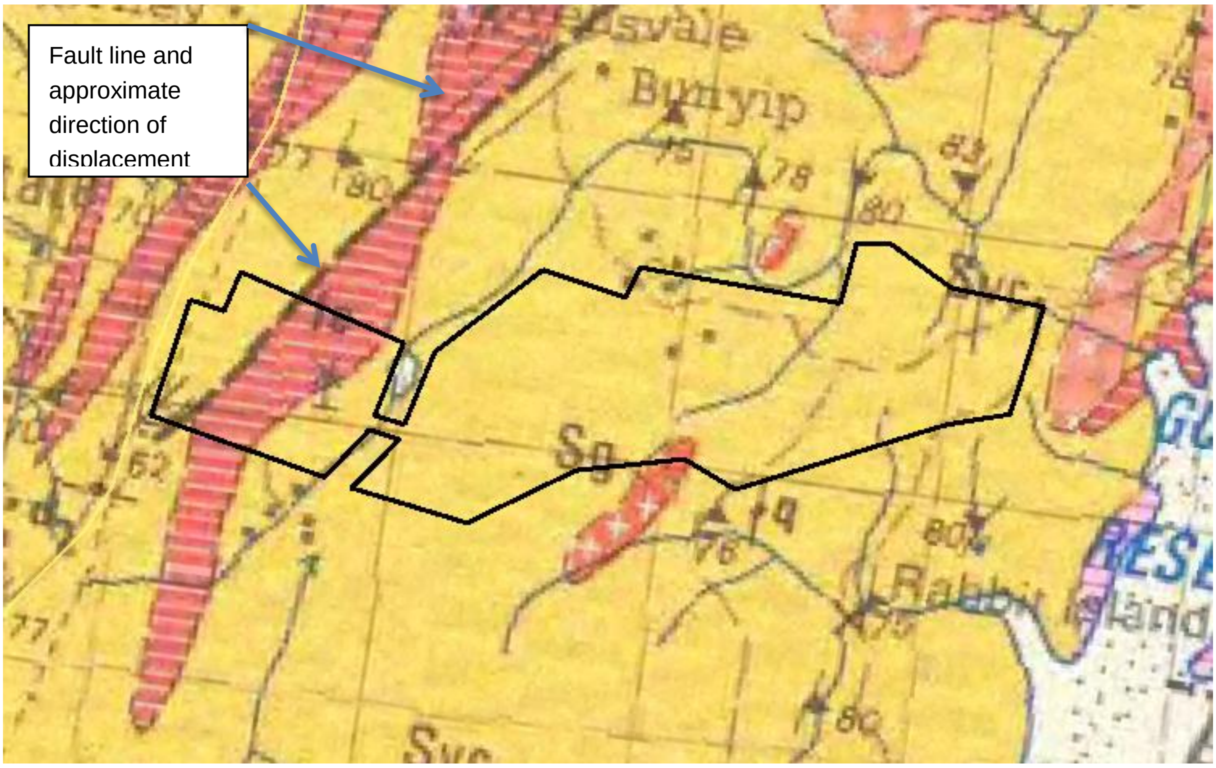


Figure 1: Extract of Geology Map.

The majority of the site is mapped as being underlain by the The Colinton Volcanics of Silurian age which typically comprises limestone and dolomitic limestone or dark green dacitic ignimbrite and minor volcaniclastic sediments. Part of the western end of the site is underlain by an unnamed subgroup of the Colinton Volcanics which typically comprises tuffaceous shale. The small area approximately midway along the southern boundary comprises an unnamed unit of Early Devonian age which typically comprises minor granitoid stocks.

A fault line is shown to cross the western end of the site in a northeast to southwest orientation. The relative displacement of the fault is shown to have moved in this same orientation.

Reference to the Hydrogeology of the Australian Capital Territory and Environs Map (Ref 3) indicates that the site is located on fractured aquifers of late Silurian age. Expected geological units referred on the map include dacitic, rhyodacitic ignimbrite, bedded tuff, minor shale, sandstone, limestone and ashstone.

Based on the hydrogeology map, the yield of aquifers is generally less than 0.5 l/s. Total dissolved solids (TDS) are mapped to be less than 500 mg/L in the south-western corner and over 1,000 mg/L over the majority of the site.

Surface water observations were limited to pooled water in erosion runnels and within farm dams located across the site. Other than the dams, the site is traversed by numerous intermittently flowing water courses and gully lines which run in variable directions but ultimately water flows are from the south west to north east direction.

4.2 Soil Landscape

Reference to the Canberra Soil Landscape Sheet (Ref 2) indicated the majority of the site is underlain by the Burra Soil Group, with a small part in the north-eastern corner underlain by the Celeys Creek Soil Group.

The Burra soil group is characterised by undulating to rolling low hills and alluvial fans on Silurian Volcanics of Canberra Lowlands. Generally, waning and gently to moderately inclined hill slopes, foot slopes and fans. Soils are shallow, well drained earthy sands on crests and upper slopes; moderately deep, moderately well drained red podzolic soils on mid slopes and most lower slopes; and moderately deep slowly to moderately well drained yellow podzolic soils along minor drainage lines and on some lower slopes. The Landscape Sheet lists this soil group as characterised by its strong acidity and low water holding capacity, its low permeability, sheet erosion risk, run-on and localised shallow soil.

The Celeys Creek soil group is characterised by rolling hills on granitic rock with common rock outcrop as large tors on slopes and crests. Soils are shallow, well to rapidly drained Tenosols (earthy soils) and Rudosols (Lithosols) on crests and shallow to moderately deep well drained Tenosols on upper slopes. Shallow to moderately deep, well drained red Chromosols (red Podzolic soils) and moderately well to slow drained yellow Chromosols (yellow podzolic soils) on lower slopes. The Landscape Sheet lists this soil group as characterised by its infertility, shallow depth, non-cohesiveness, high acidity, high permeability, low water holding capability, seasonal waterlogging and localised rock outcrops.

4.3 Site Inspection

The distribution of features noted during the field mapping are shown on Photos A1 – A54 presented in Appendix B. The principal observations are as follows:

- The site generally comprises undulating to steeply undulating grazing land which is variably lightly to heavily grassed;
- Mature trees are scattered across the site with a small area of densely populated pine trees located downstream of a dam midway along the northern boundary;

- Numerous farm dams have been constructed within gully lines across the site. Where visible the dam sides appeared to comprise either weathered rock and/or silty/sandy soils and minor clay;
- The dam embankments were built to around 2 – 5 m in height with the filling material appearing to generally comprise silty gravelly sand with cobbles and boulders;
- The farm dam storage areas range in size from 300 m^2 to 1,500 m^2;
- A dam at the western end of the site had building rubble at its upstream side;
- Another dam towards the south-eastern end of the site had recently placed weathered rock at its abutments;
- A series of contour drains direct flows to the farm dams. The contour drains were generally lushly vegetated with a bright green grass;
- Bull grass was observed over some parts of the site, including near hill tops and on hill sides;
- Outcropping rock was observed across large portions of the site with some surface boulders and cobbles as well. The outcropping rock was generally high to very high strength, slightly weathered and fresh stained in parts. The outcropping rock was often steeply jointed at angles of around 70 – 90° and striking in a north-south or northeast-southwest direction. Some outcropping rock was massive with minimal fracturing evident;
- A burn pit was located at the western end of the site with some building rubble and an old drum visible;
- The site is segmented into a series of small to large paddocks separated by fences and gates;
- Most of the site could be traversed on existing unsealed/unformed access tracks. Outcropping rock or silty sand soils were exposed in many of the tracks. A recently formed track which appears to be raised slightly with filling traversed the eastern part of the site;
- A number of culvert pipes were located under the existing tracks that have been built up, including one traverses the south-western boundary of the site;
- Some high voltage power lines with associated transmission towers were observed dispersing from the western side of the adjacent electrical substation across to the middle part of the site and towards NH1;
- Existing structures (stockyards, warehouses, silo's and sheds) are limited to midway along the northern boundary of the site. An old slab is also located to the east of this area;
- Minor erosion was observed over some parts of the site adjacent to animal tracks, access tracks and on some hill sides. Extensive erosion was observed through the middle parts of the site and adjacent to the dam at the south-eastern end of the site where erosion as great as 0.4 – 0.5 m depth was noted;
- Minimal erosion in areas where the grass/vegetation is intact;
- With the exception of farm dam areas, isolated uncontrolled filling, small stockpiles, some filling/modification to drainage lines and contour drains, and of the existing structures mentioned above, the remainder of the site is generally undisturbed;
- An excavation which is assumed to be an animal burial pit that was full of water was located just south of the site. Potential sheep bodies were observed at one corner and stockpiled soils were located adjacent to the excavation;

- The flanks of the ridgelines and hills are generally moderately to steeply sloping with the foot slopes and gullies gently to moderately sloping in parts;
- No obvious signs of creep movements within near-surface soils were noted, nor any signs or deep-seated instability; and
- No obvious signs of salinity (such as salt deposits and tree die back) were observed within the site.

4.4 Subsurface Conditions

Details of the subsurface conditions encountered are summarised in the test pit logs included in Appendix D, which must be read in conjunction with the accompanied explanatory notes that define classification methods and descriptive terms. The principal succession of strata is summarised below:

- TOPSOIL: sandy silt or silty sand topsoils to depths of 0.1 – 0.2 m;
- SANDY SILT/SILTY SAND: generally hard (occasionally very stiff) or dense, dry to moist sandy silt or silty sand with some gravel in Pits 4 – 7, 9 -1 12, 14 – 18, 20 – 26 to depths of 0.25 – 0.5 m
- SILTY CLAY: generally hard (occasionally stiff or very stiff), dry to moist (occasionally moist), low to high plasticity silty clay with varying amounts of sand and some gravel in Pits 4, 6 – 9, 11, 12, 16, 17, 22, 24 and 26 to depths of 0.4 – 3.4 m.
- ROCK: variably low to very high strength, highly to fresh stained weathered siltstone, dacite, shale and meta-shale below depths of 0.15 – 3.4 m to ripper refusal/slow progress at depths of 0.6 – 4.2 m.

A summary of the rock conditions and test pit depths achieved are summarised in Table 1 below.

Table 1 – Summary of Bedrock & Expected Excavation Depths

Test Pit No	Depth to Bedrock (m)	Bucket Refusal Depth (m)	Ripper Refusal Depth (m)	Test Pit Depth/Reason for Termination (m)
1	0.15	0.9	NE/RSP	2.5 (RSP)
2	0.2	0.8	2.2	2.2 (RR)
3	0.2	0.4	0.6	0.6 (RR)
4	1.4	1.7	NE/RSP	2.3 (RSP)
5	0.25	2.1	NE/RSP	2.7 (RSP)
6	2.3	2.6	2.8	2.8 (RR)
7	3.4	3.7	NE/RSP	3.9 (RSP)
8	2.2	2.4	NE/RSP	2.9 (RSP)
9	0.7	1.2	NE/RSP	2.0 (RSP)
10	0.4	1.1	2.0	2.0 (RSP)

11	0.4	0.6	1.2	1.2 (RSP)
12	0.45	0.8	1.5	1.5 (RR)
14	0.5	0.7	NE/RSP	2.4 (RSP)
15	0.25	0.6	NE/RSP	1.2 (RSP)
16	0.5	1.5	NE/RSP	2.2 (RSP)
17	0.6	2.9	NE/RSP	4.2 (RSP)
18	0.25	0.4	1.2	1.2 (RR)
19	0.2	0.5	0.8	0.8 (RR)
20	0.35	0.7	1.4	1.4 (RR)
21	0.7	1.6	2.6	2.6 (RR)
22	1.1	1.9	NE/RSP	2.5 (RSP)
23	0.2	0.7	NE/RSP	1.2 (RSP)
24	0.8	1.3	1.8	1.8 (RR)
25	0.35	1.5	1.7	1.7 (RR)
26	0.4	1.0	1.5	1.5 (RR)

Where NE = Not Encountered RSP = Ripper Slow Progress RR = Ripper Refusal

No groundwater was observed in the test pits during excavation. It is noted that the test pits were backfilled immediately following excavation precluding longer term monitoring of groundwater levels. Groundwater conditions rarely remain constant and can change seasonally due to variations in rainfall and other factors. It is noted therefore that the moisture condition of the site soils may vary considerably from the time of the investigation compared to at the time of construction.

Historically, though it is noted that during or after extended wet periods, the greater Googong area has experienced a high number of groundwater springs and subsurface seepage flows.

4.5 Laboratory Testing

The detailed laboratory test report sheets are included in Appendix E and the results summarised in Tables 2 and 3 below.

Table 2: Results of Plasticity Testing

Pit No	Depth (m)	W_F (%)	W_L (%)	W_P (%)	PI (%)	LS (%)	Field Description
4	0.6	13.8	52	25	27	7.5	Silty Clay
7	0.6	15.1	42	20	22	5.0	Gravelly Silty Clay

8	0.3 – 0.5	10.5	39	22	17	6.5	Gravelly Silty Clay
9	0.5	44.3	40	21	19	5.5	Silty Sandy Clay
21	0.4	12.0	43	18	25	3.5	Sandy Silty Clay
26	0.3	15.9	68	19	49	5.5	Sandy Silty Clay

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

Table 3: Summary of Compaction & CBR Testing

Pit No	Depth (m)	W_F (%)	OMC (%)	MDD (t/m^3)	CBR (%)	Swell (%)	Field Description
2	0.4 – 0.6	8.9	13.5	1.81	6	1.5	Siltstone
8	0.3 – 0.5	10.7	15.5	1.73	6	2.5	Gravelly Silty Clay
12	0.6 – 0.8	8.4	12.0	1.85	5.0	0.5	Meta-Shale
14	0.7 – 0.9	3.6	7.0	1.91	18	0.0	Meta-Shale
17	1.3 – 1.5	7.0	10.5	2.01	40	0.0	Meta-Shale
24	0.5 – 0.7	14.9	20.5	1.65	3.5	1.5	Sandy Silty Clay

Where: W_F = Field moisture content
OMC = Optimum moisture content
MDD = Maximum dry density
CBR = California bearing ratio

5. Proposed Development

It is understood that the proposed development of the site is for residential subdivision with majority of residential lots, limited multi-unit blocks and open spaces, a village centre in each neighbourhood and associated roadways. No other design details were available at the time of reporting however cut and fill depths up to 5 m would be anticipated.

6. Comments

6.1 General

The following comments are based on the results of site reconnaissance, review of existing information including the current subsurface investigation and our involvement in similar projects including NH1 and NH2.

It is understood that a future residential subdivision is proposed and that further investigations will be undertaken at the appropriate time as the planning and design of the subdivision proceeds. Accordingly, this report and the comments given within must be considered as being preliminary in nature.

6.2 Development Considerations

6.2.1 Site Classification

Classification of residential blocks within the site should comply with the requirements of AS 2870 – 2011 "Residential Slabs and Footings" (Ref 4). Likely block classifications would range from Class A (sand/rock sites), Class S (slightly reactive) to Class M (moderately reactive) or Class H1 (highly reactive), with the final classification dependent on soil reactivity, the presence of filling and rock depth. The topographic slope in various parts of the site ranges from intermediate to steep and accordingly, it is anticipated that some of the blocks will need to consider design and construction techniques that take account of the ground slope and possible Class P conditions. It must be noted that some areas within blocks with steep terrain may not be considered suitable for development. Classifications within these areas would also be dependent on the extent of bulk earthworks proposed.

Class P conditions may arise in low lying areas or areas affected by groundwater springs. Low lying areas have a high risk of adverse moisture conditions however can be treated by drainage and controlled filling methods. Furthermore, Class P conditions may arise on the lots that have highly variable foundation conditions such as pinnacles of rock and soil.

6.2.2 Stability Assessment

The site has been assessed with reference to the Australian Geomechanics Society Sub-Committee on Landslide Risk Management: *"Landslide Risk Management Concepts and Guidelines"* (Ref 5). Based on the observations made during the inspection, an assessment of risk to property has been undertaken for each of four distinct zones as follows:

Zone 1: areas of gently sloping land ie: flatter than 1V:10H (vertical:horizontal) or 5 – 6° (referred to as *"very low risk")*;

Zone 2: areas of moderately sloping land ie: generally between 1V:10H and 1V:5H or 6 – 12° (referred to as *"low risk"*);

Zone 3: areas of moderately to steeply sloping land ie: generally between 1V:5H and 1V:3.3H or 12 – 17° (referred to as *"moderate risk"),*

Zone 4: areas of steeply sloping land ie: steeper than 1V:3.3H or 17° (referred to as high risk).

The results of the assessment for each of these areas are outlined in Tables 4 – 7.

Table 4 – Slope Stability Assessment – Zone 1 (Gently Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Barely credible	Minor	Very Low
Near surface slumping	Barely credible	Medium	Very Low
Active / deep seated slide	Barely credible	Major	Very Low

Table 5 – Slope Stability Assessment – Zone 2 (Moderately Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Unlikely	Minor	Low
Near surface slumping	Unlikely	Medium	Low
Active / deep seated slide	Rare	Major	Low

Table 6 – Slope Stability Assessment – Zone 3 (Moderately to Steeply Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Failure during construction	Possible	Medium	Moderate
Creep of surface soils	Possible	Minor	Moderate
Near surface slumping	Possible	Medium	Moderate
Active / deep seated slide	Rare	Major	Low

Table 7 – Slope Stability Assessment – Zone 4 (Steeply Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Failure during construction	Likely	Medium	High
Creep of surface soils	Likely	Minor	Moderate
Near surface slumping	Likely	Medium	High
Active / deep seated slide	Unlikely	Major	Moderate

In summary, it is considered that most of the site is classified as very low or low risk of damage to property occurring as a result of slope instability. Several areas are considered of moderate or high risk of causing property damage due to the steep ground slopes and possible unsuitable design and construction practice.

Notwithstanding the various risk categories nominated, development of the site for residential purposes is considered feasible in areas of gently and moderately sloping land (very low and low instability risk) with erosion control measures and suitable dwelling design to be addressed. In areas of moderately sloping land, standard practices for hillside development must be incorporated into designs.

Areas designated as moderately to steeply sloping land (moderate risk), could be developed for residential purposes however would have to the subject of site and development specific geotechnical investigations to establish a site model and provide geotechnical limitations and design parameters.

Areas of steeply sloping land (moderately and high risk) are not recommended for residential development at this stage. A detailed site stability assessment including subsurface investigations must be undertaken in these areas to establish an appropriate site model for analysis purposes to assess whether development is feasible in the high risk zones.

It is noted that revisions to the above risk classifications may be necessary following completion of bulk earthworks. It is recommended that if development is proposed within the moderate and high risk areas, further delineation and assessment be undertaken.

6.2.3 Soil Erosion

It is considered that the erosion hazard within the areas proposed for development would be within usually accepted limits and could be managed by good engineering and land management practices which will also be required to address flood hazard and localised waterlogging limitations of soils along gully lines and low lying flat areas. These hazards are considered to impose only a minor constraint to development.

It is anticipated that the treatment of the existing erosion gullies as part of an overall site development would include:

- filling using select materials (i.e. non – dispersive or erodible) placed under controlled conditions;
- provision of temporary surface cover (e.g. pegged matting) during the period of valley floor revegetation;
- channel lining in sections of rapid change in gully floor grade;
- piping of flow where appropriate;
- the re-establishment of a zone of tree or shrub cover along gully banks.

6.2.4 Footings

All footing systems for standard residential dwellings should be designed and constructed in accordance with AS 2870 – 2011 (Ref 4) for the appropriate classification. For hillside lot construction (low risk or greater), reference should be made to the publication by AGS (Ref 5), relevant extracts of which are included in Appendix F.

For preliminary sizing of footings, allowable base bearing pressures for the various strata likely to be encountered including controlled filling are given below:

• Stiff natural soils:	100 kPa
• Controlled Filling:	150 kPa
• Very stiff or medium dense natural soils:	150 kPa
• Very low strength rock:	750 kPa
• Low strength rock:	1000 kPa
• Medium strength rock	2500 kPa (min)

6.3 Site Preparation and Earthworks

6.3.1 Stripping

Site preparation for the construction of roadways and structures should include the removal of vegetation, topsoils, silty sandy soils, existing filling and other deleterious materials from the proposed building areas. Deep excavations (such as in gullies) could occur should localised deeper topsoils or unsuitable materials/filling be encountered, if inclement weather precedes construction or if the contractor adopts inappropriate stripping methods.

Silty sands/sandy silts (beneath the topsoils) were encountered in 20 of the 25 test pits to depths of 0.25 – 0.5 m and should be expected across the majority of the site, potentially to greater depths than that encountered in the limited subsurface investigation. This material is difficult to handle and compact and would require extremely careful moisture control. It is recommended that allowance be made for at least partial stripping of this material (say 0.3 m following topsoil stripping), with inspection undertaken by a suitably qualified geotechnical engineer to assess the depth of removal. Where possible (ie: in deep fill areas) this material could be designated to remain in-situ, provided it is stable under test rolling, however if considered unsuitable would be required to be removed.

Depending on prior weather conditions it may also be necessary to use a geofabric separation layer and/or a rock bridging layer to stabilise the stripped surface.

6.3.2 Excavation Conditions

The limited investigation has indicated subsurface conditions generally comprising silty/sandy topsoils underlain by shallow rock or else silty and clayey soils with some sand and gravel overlying weathered rock.

The topsoil, natural soils and extremely low to low strength bedrock could be expected to be removed using conventional earthmoving plant and as such no difficulties are anticipated with the exception of wet soils should they become exposed to inundation or saturation.

Large excavators fitted with rock hammers, toothed buckets and/or rippers will be needed to remove low to medium strength (or greater) strength rock in trenches and ripping with large dozers will be required for bulk excavations to the level of test pit ripper refusal (encountered at depths of 0.6 – 3.9 m) detailed in this investigation. The excavatability of the rock below test pit ripper refusal depths will be largely dependent on the degree of fracturing and the dip of bedding within the rock mass. Low production rates must be envisaged particularly where shallow refusal was encountered with the likelihood of blasting to loosen the rock in areas of deep cut to assist the excavation.

The extent of groundwater inflow would be dependent on prior weather conditions. Given the extent of gully lines and relatively flat topography over some parts of the site, groundwater seepages should be anticipated, which would increase following rainfall.

6.3.3 Filling Placement

In areas that require filling, the stripped around surfaces must be test rolled in the presence of a geotechnical engineer. Any areas exhibiting deflections under test rolling must be appropriately treated by over-excavation and replacement with suitable non-reactive filling or else tyning and drying, whichever is more appropriate at that time. All filling material must be placed in horizontal layers of maximum 250 mm loose thickness. The material must have a moisture content within the range of ±2% of modified optimum at the time of placement.

All permanent fill batters must be constructed no steeper than 1:3 (vertical:horizontal), appropriately protected against erosion with toe and spoon drains constructed as a means of controlling surface flows on the batters and vegetation of the batter.

6.3.4 Filling Compaction

All filling placed within standard residential construction platforms must be compacted to a minimum 90% modified maximum dry density, except for the upper 1.0 m within pavement areas or within the entirety of commercial lots or lots expected to require higher bearing support from the filling, which must be compacted to a minimum of 95% modified maximum dry density.

To validate future site classifications, field inspections and in-situ testing of future earthworks must be undertaken on any controlled filling placed in residential blocks in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 2007 (Ref 6).

6.3.5 Existing Farm Dams

It is assumed that the farm dams located onsite would be required to be filled to facilitate development. The general procedures outlined above should be adopted for the backfilling of these dams. Prior to bulk earthworks, however, the dams will require draining, removal of the embankment and desilting wet sediment from the base of the reservoir. An assessment of groundwater seepages must then be undertaken (prior to filling) to determine if drainage measures are required. Where possible, roads or open space areas should be planned over existing dam locations.

6.3.6 Drainage

Parts of the site have poor natural subsurface drainage. Infiltrated rainwater can become contained in Parts of the site may encounter groundwater seepage during construction as encountered in previous stages of the Googong development, primarily along and adjacent to gully lines. This is supported by the vegetation type in these areas. The limited investigation was undertaken during a dry period of weather, possibly not reflecting the likely groundwater conditions which could be present during average or above average rainfall periods. Infiltrated rainwater can become contained in the upper semi-pervious silty/sandy stratum and deeper sandy/gravelly layers. Seepage water may be present in fractured bedrock at shallow depth. Seepage water may rise to the ground surface in places as springs.

In order to reduce the downslope seepage flow volume into residential areas, it is recommended that:

- Open lined, contour drains be constructed along the upslope areas of the estate extending to at least 0.5 m depth below the bedrock surface;
- Floodways be constructed along natural drainage lines;
- Deep subsurface gravel drains be installed along the invert of major gullies to be infilled and through any spring areas which has been effectively constructed within the other neighbourhoods;
- Subsurface drains be installed at both sides of roads constructed in cut and/or at about natural grade. Some sections of road subgrades may need to be provided with cross-drains or a drainage blanket to control upward seepages.

Groundwater springs are mostly impossible to detect prior to development and as such, contingencies must be put in place to install drainage measures when springs are encountered.

6.3.7 House Site Maintenance

The developed blocks should be maintained in accordance with the CSIRO publication "Guide to Home Owners on Foundation Maintenance and Footing Performance", a copy of which is included in Appendix G. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits. Surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

6.3.8 Pavements

As only a limited subsurface investigation has been carried out and design of pavements have yet to be undertaken, the pavement advice below should be considered preliminary and subject to further investigation and testing.

Based on the limited testing done and results of testing from the previous neighbourhoods, Table 8 gives indicative design CBR values for the various likely subgrade conditions.

Table 8 – Design CBR Values

Subgrade Material	Design CBR (%)
Clay (high plasticity)	1.0 – 2.0
Sandy/Gravelly Soils	3.0 – 4.0
Recompacted (Sedimentary) Weathered Rock	3.0 – 5.0
Recompacted (Igneous) Weathered Rock & In-situ (Sedimentary) Weathered Rock	5.0 – 7.0
Insitu (Igneous) Weathered Rock	7.0 – 10

There may be construction advantages in undertaking subgrade replacement in those areas where any high plasticity clay subgrades occur. Detailed investigations will be required following finalisation of subdivision layout to confirm and delineate, if possible the variation in subgrade conditions.

Surface and subsurface drainage must be installed and maintained to protect the pavement and subgrade. The subsurface drains should extend a minimum of 0.5 m depth below the subgrade level.

6.4 Development Constraints

The assessment has identified a number of constraints on the development, which are:

- Potential for waterlogging in several areas;
- Potential for erosion in areas once vegetation cover is removed;
- Areas of moderate and high risk of damage to property with respect to slope instability;
- Uncontrolled filling around existing dams, some access tracks and gully lines, and limited stockpiles;
- Outcropping & shallow very high strength bedrock;
- Potential for low soaked CBR values;
- Potential for Class P lots.

Waterlogging: There is evidence of previous wet, soft and/or boggy conditions within several areas identified as potential for waterlogging, mainly in gully and low lying areas. These areas are characterised by slightly greener and lush grass and contain grass species such as bull grass which from Douglas Partners experience indicates previous or current presence of elevated soil/ground water levels.

Erosion: Where the previous vegetation cover has been removed, which was observed adjacent to some access and animal tracks and though a large area in the middle of the site. The erosion observed ranged from slight to severe.

Stability: Several areas have been assessed as having a potential moderate to high risk of damage to property.

Uncontrolled Filling: Removal of uncontrolled fill which was placed as stockpiles or part of dam construction and gully line modification works can be included as part of the site regrading or site clean-up during construction of the development and would only pose a minor constraint to development.

High Strength Bedrock: The presence of extensive outcrops and shallow very high strength bedrock would prove difficult to excavate should design levels require cutting.

Low CBR Values: Either design can be based on low CBR values or replacement with a select weathered rock material could be undertaken. Given the relatively shallow depth to rock in large parts of the site, it would be expected that subgrade replacement where low CBR clays encountered would be the most feasible option.

Class P Lots: Class P lots, as discussed, could arise due to uncontrolled filling or adverse moisture conditions (gully lines, low lying areas and springs). Provided the uncontrolled filling is removed and controlled filling placed, conventional site classifications would be expected for that case. In areas of adverse moisture conditions, drainage measures could be incorporated to control seepages and/or controlled filling placed to raise/modify the surface levels. Class P classifications may still be warranted however with sound engineering design, dwellings could be appropriately proposed/constructed.

After the above constraints are addressed, the site will be considered suitable for the proposed development.

6.5 Remedial Measures/Site Controls

The main activities or methods to enable effective development of the site, from a geotechnical perspective, would be:

- Planning/layout of development areas;
- Extensive drainage measures;
- Erosion management;
- Timing of works;
- Development restrictions from a slope instability perspective; and
- Minimising cut-fill on hillside.

6.5.1 Planning/Layout of Development

Gully lines and possibly low lying areas should be avoided for standard residential construction without engineering modification as these areas would require extensive drainage works and/or bulk earthworks. Roads should be positioned over the top of gully lines to enable the construction of subsurface drainage lines. If development of the low lying areas is being considered, controlled filling would be required to raise surface levels to assist in drainage design. Should residential areas be proposed over drainage areas, Class P site classifications would be warranted with special advice required on foundation design and construction as not to interfere with the drainage measures.

6.5.2 Drainage Measures

Engineered drainage both to divert overland flow and intercept subsurface flow combined with bulk earthworks to raise surface levels and/or contour the surface level to improve drainage will be required if permanent structures are to be constructed in gully and/or low lying areas.

A network of drainage lines would be required across the site to intercept and provide a controlled transportation pathway for groundwater flows. Main drainage lines would be located at the base of gullies and within the low lying areas with interceptor drainage lines constructed as and where required across the site feeding into the main drainage lines. The drainage lines could either be subsurface or surface (floodway) type structures depending on surface levels.

6.5.3 Erosion Management

One of the existing limitations to development of the site is considered to be areas of gully erosion. Soil and water management is an integral part of the development process and should adopt a preventative rather than a reactive approach to the site limitations, such that the work can proceed without undue pollution of receiving streams.

Once consent is given, a detailed soil and water management plan (SWMP) will be required and should be incorporated into the engineering design of the development methods for:

- Minimising water pollution due to erosion of soils or the development of saline conditions;
- Reducing or managing salinity to provide acceptable conditions for building and revegetation Works;
- Minimisation of soil erosion during and after construction; and
- Maximising the re-use of materials on site.

6.5.4 Timing of Works

Timing of the site works could also be a critical aspect that will require careful consideration. Bulk earthworks activities are suggested to be undertaken in the warmer months of the year and not the winter months when ground moisture is higher due to the negative evapotranspiration effect experienced in winter. If moist or wet soils are encountered and require drying to enable reuse in controlled filling areas, the warmer months would allow more expedited processing negating the potential for several weeks of drying time expected during winter.

6.5.5 Development Restrictions

Development within areas of medium risk of instability is technically feasible though would be required to be undertaken with geotechnical guidance. Site specific and development specific geotechnical investigation and advice would be required for individual structures.

At this stage without subsurface investigations, development within the high risk areas are not recommended. A comprehensive site stability assessment will be required if development in those areas are proposed.

6.5.6 Cut and Fill Minimisation

It is standard hillside development practice to minimise the depths of cutting and filling. All proposed modification of the ground slop in hillside areas must be subject to geotechnical review and comment.

6.5.7 Subsurface Investigation

Additional subsurface investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include but not necessarily be limited to:

- Preliminary geotechnical investigations across the areas of gently to moderately sloping land and the areas of moderately to steeply sloping land to determine the subsurface profiles and the properties of the site soils including dispersion/erosion properties and/or acidity/aggressiveness,
- Detailed geotechnical investigation and assessment of areas of steeply sloping land should development be desired in these areas, and
- Detailed geotechnical investigation on a stage by stage basis as development proceeds to determine excavation conditions, road subgrade CBR values and confirm site classifications for each block.

6.6 Summary

The site assessment undertaken as described above has indicated that the majority of the site is suitable from a geotechnical perspective for residential development. Comments have been given on the various geotechnical aspects of the proposed development and the identified development constraints and subsequent remedial and control measures.

Conceptual comments on design and construction aspects are also given in the report. Further testing and assessment will be required as the design of the subdivision proceeds and as such, this report must be considered as being preliminary in nature.

7. References

1. Geology of Canberra 1:100 000 Geological Series Sheet 8727, Bureau of Mineral Resources, (1992).
2. Soil Landscape of Canberra 1:100 000 Soil Landscape Series Sheet 8727, NSW Dept of Land and Water Conservation, (2000).
3. Bureau of Mineral Resources, Geology and Geophysics (1984): ‘Hydrogeology of the Australian Capital Territory and Environs’ 1:100,000 scale map.
4. Australian Standard AS 2870 – 2011 Residential Slabs and Footings.

5. AGS – Landslide Risk Management Concepts and Guidelines, Australian Geomechanics Society, Sub-committee on Landslide Risk Management, 2007.
6. Australian Standard AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.

8. Limitations

Douglas Partners (DP) has prepared this report for a proposed subdivision known as Neighbourhoods 3 – 5 (NH 3 – 5), Googong in accordance with DP's proposal CAN180156 dated 5 July 2018 and acceptance received from Giselle Ravarian of Spacelab Studio Pty Ltd dated 27 August 2018. The work was carried out under an amended Spacelab Studio Pty Ltd Conditions of Engagement. This report is provided for the exclusive use of Spacelab Studio Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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

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

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

Douglas Partners Pty Ltd

Appendix A

About This Report

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

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

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

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

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

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

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

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Appendix B

Site Photographs

Photo A1 – Lush grass vegetated contour drain. Refer Drawing 2 for locality and direction

Photo A2 – Culvert under access track. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A1
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A3 – Broad gully. Refer Drawing 2 for locality and direction

Photo A4 – Outcropping rock and stockpile. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A2
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A5 – Undulating landscape. Refer Drawing 2 for locality and direction

Photo A6 – Outcropping rock. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A3
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A7 – Refer Drawing 2 for locality and direction

Photo A8 –Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A4
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A9 – Bull grass and outcropping rock. Refer Drawing 2 for locality and direction

Photo A10 – Bull grass on hill side. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A5
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A11 – Gully. Refer Drawing 2 for locality and direction

Photo A12 – Vibrant grass around contour drain and outcropping rock. Refer Drawing 2 for locality and direction

Photo A13 – Building rubble and outcropping rock adjacent to dam. Refer Drawing 2 for locality and direction

Photo A14 – Dam embankment and outcropping rock. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A7
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A15 – Burn pit with building rubble and old drum. Refer Drawing 2 for locality and direction

Photo A16 – Minor erosion. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A8
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A17 – Dam. Refer Drawing 2 for locality and direction

Photo A18 – Lush grass upslope of dam. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A9
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A19 – Bull grass over flat area. Refer Drawing 2 for locality and direction

Photo A20 – Outcropping rock. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT: PLATE No: REV:	46285.44 A10 1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A21 – Some outcropping rock in track. Refer Drawing 2 for locality and direction

Photo A22 – Some outcropping rock. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A11
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A23 – Some outcropping rock and mature trees. Refer Drawing 2 for locality and direction

Photo A24 – Erosion. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A12
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A25 – Erosion. Refer Drawing 2 for locality and direction

Photo A26 – Dense pine trees and outcropping rock. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A13
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A27 – broad gully between pine trees. Refer Drawing 2 for locality and direction

Photo A28 – Silo’s. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A14
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A29 – Water tank and discarded fridge. Refer Drawing 2 for locality and direction

Photo A30 – Boulders in dam embankment filling. Refer Drawing 2 for locality and direction

Photo A31 – Lush grass upstream of dam. Refer Drawing 2 for locality and direction

Photo A32 – Old concrete slan. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A16
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A33 – Access track and outcropping rock on hill side. Refer Drawing 2 for locality and direction

Photo A34 – Erosion on hill side. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A17
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A35 – Lush grass vegetated contour drain. Refer Drawing 2 for locality and direction

Photo A36 – Geofabric lined swale drain with boulders. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A18
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A37 – Erosion in access track and hill side. Refer Drawing 2 for locality and direction

Photo A38 – Vegetated contour drain. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A19
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A39 – Erosion in dam wall. Refer Drawing 2 for locality and direction

Photo A40 – Lush grass adjacent to culvert outlet. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A20
	Neighbourhoods 3 – 5, Googong	REV:	01
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A41 – Outcropping rock. Refer Drawing 2 for locality and direction

Photo A42 – Blackberry bushes downstream of dam. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A21
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A43 – Lush grass vegetated contour drain. Refer Drawing 2 for locality and direction

Photo A44 – Erosion. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A22
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A45 – Outcropping rock. Refer Drawing 2 for locality and direction

Photo A46 – Wide gully with bull grass. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A23
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A47 – Recently built up access track. Refer Drawing 2 for locality and direction

Photo A48 – Erosion. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A24
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A49 – Recently placed weathered rock at dam abutments. Refer Drawing 2 for locality and direction

Photo A50 – Culvert pipe under track and lush grass. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **Neighbourhoods 3 – 5, Googong**	PROJECT:	46285.44
		PLATE No:	A25
		REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A51 – Erosion. Refer Drawing 2 for locality and direction

Photo A52 – Tree branches in potential contour drain or old dam. Refer Drawing 2 for locality and direction

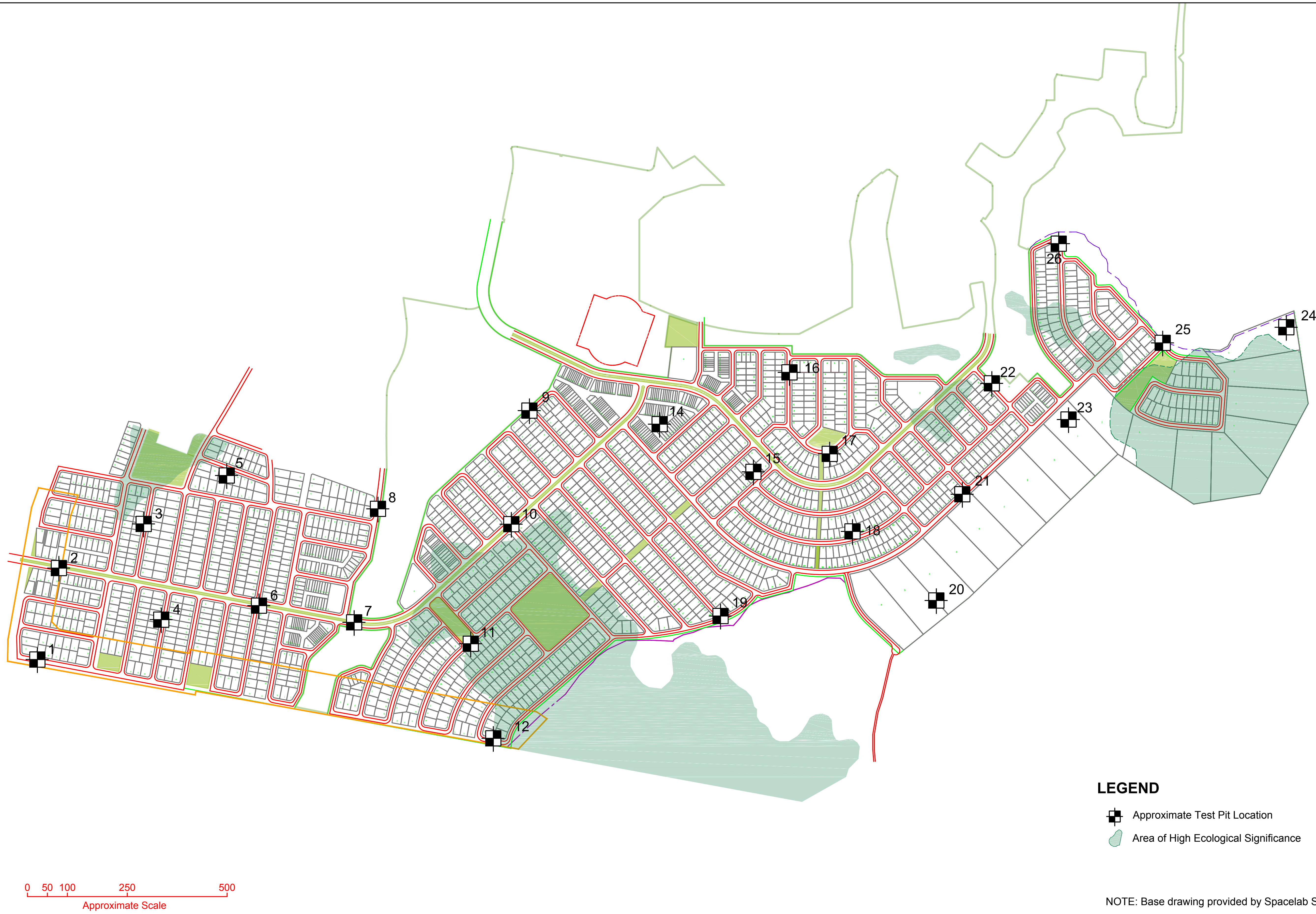
Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A26
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Photo A53 – Contour drain. Refer Drawing 2 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	46285.44
	Urban Capability Study	PLATE No:	A27
	Neighbourhoods 3 – 5, Googong	REV:	1
	CLIENT: Spacelab Studio Pty Ltd	DATE:	17/06/2019

Appendix C

Drawing 1 – Location of Site Photographs
Drawing 2 – Test Location Plan



LEGEND

▣ Approximate Test Pit Location

🟩 Area of High Ecological Significance

NOTE: Base drawing provided by Spacelab Studios

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: Spacelab Studio Pty Ltd

OFFICE: Canberra
DRAWN BY: AZR

SCALE: As shown
DATE: 17-06-2019

TITLE: **Test Location Plan**
Urban Capability Study
Neighbourhoods 3 - 5, Googong

MAG
ISG
MGA
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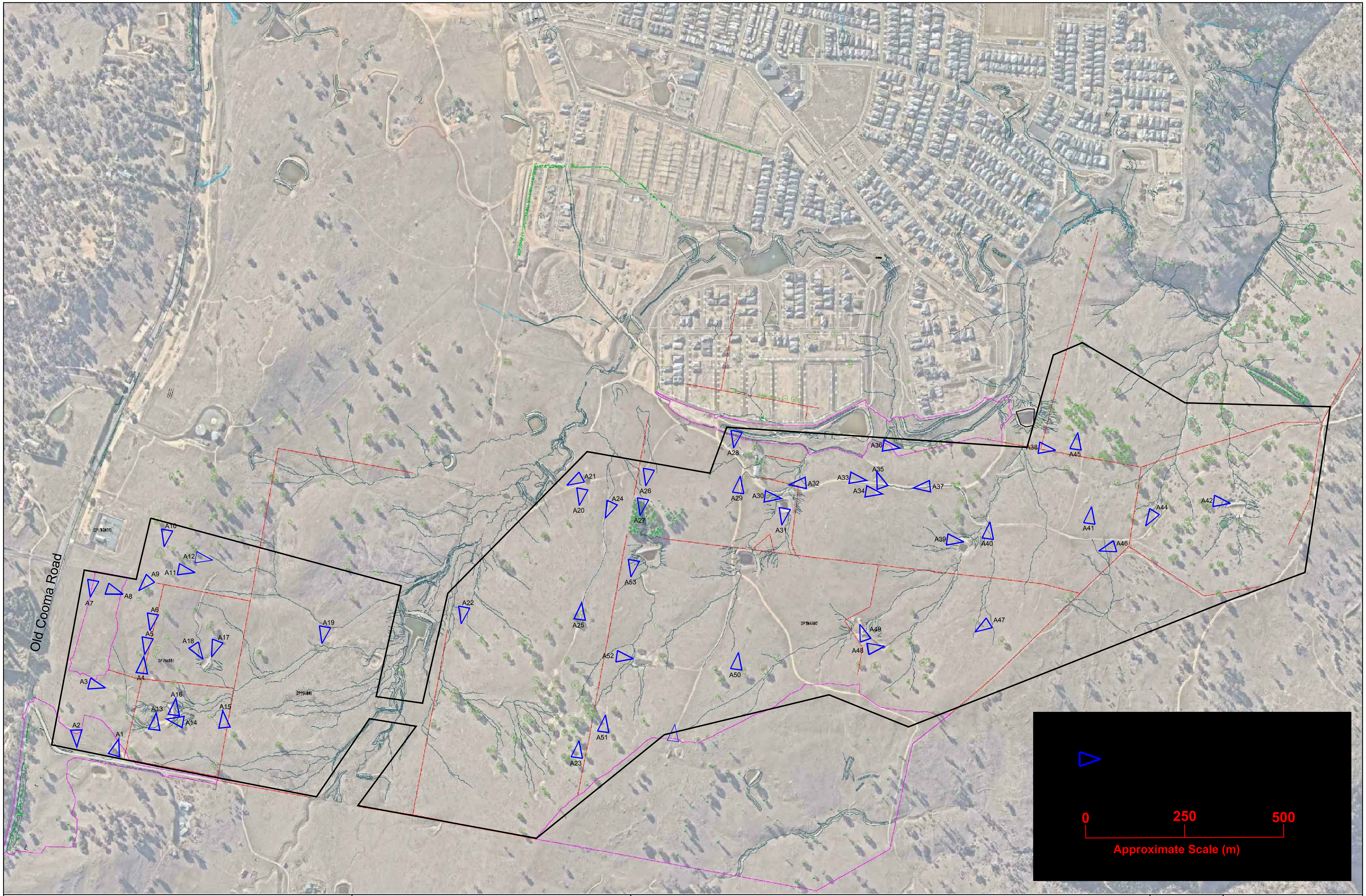
PROJECT No: 46285.44
DRAWING No: 2
REVISION: 1



Douglas Partners
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CLIENT: Spacelab Studio Pty Ltd	
OFFICE: Canberra	DRAWN BY: AZR
SCALE: As Shown	DATE: 17.06.2019

TITLE:
Location of Site Photographs
Urban Capability Study
Neighbourhoods 3 - 5, Googong

PROJECT No:	46285.44
DRAWING No:	1
REVISION:	1

Appendix D

Explanatory Notes
Results of Fieldwork (Pits 1 – 12, 14 – 26)

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

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726-1993, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Rock Descriptions

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 2007. The terms used to describe rock strength are as follows:

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

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$. It should be noted that the UCS to $Is_{(50)}$ ratio varies significantly for different rock types and specific ratios should be determined for each site.

Degree of Weathering

The degree of weathering of rock is classified as follows:

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

Degree of Fracturing

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

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

Rock Descriptions

Rock Quality Designation

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

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

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

Stratification Spacing

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

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

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

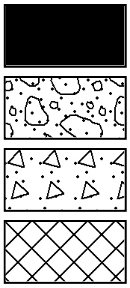
Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

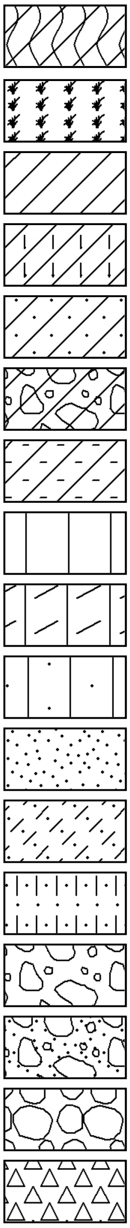
Graphic Symbols for Soil and Rock

General



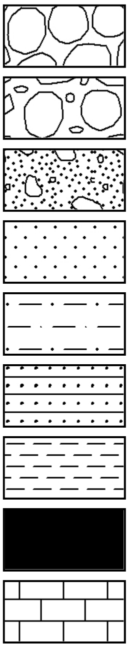
- Asphalt
- Road base
- Concrete
- Filling

Soils



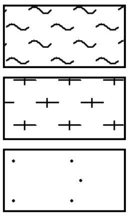
- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks



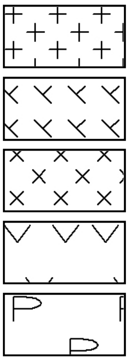
- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks



- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks



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

May 2017

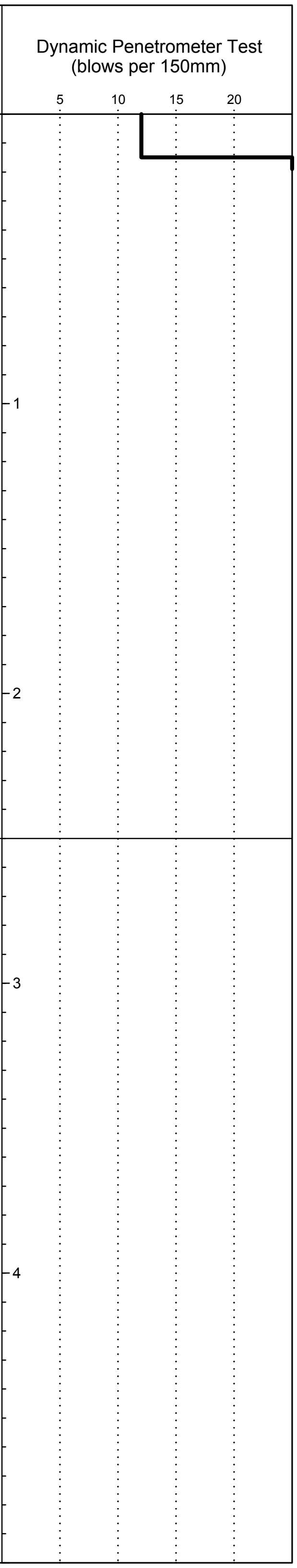
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 790 AHD
EASTING: 701232
NORTHING: 6076112

PIT No: 1
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
790		TOPSOIL-dry to moist, light brown clayey sandy silt with some rootlets						
	0.15	SILTSTONE-low to medium strength, highly to moderately weathered, yellow light brown grey siltstone, highly fractured		D	0.4			
		-from 0.7m, medium to high strength, moderately to slightly weathered, yellow grey						
		-from 0.9m, bucket refusal, ripper used						
789	1							
788	2							
	2.5	Pit discontinued at 2.5m -slow progress						
787	3							
786	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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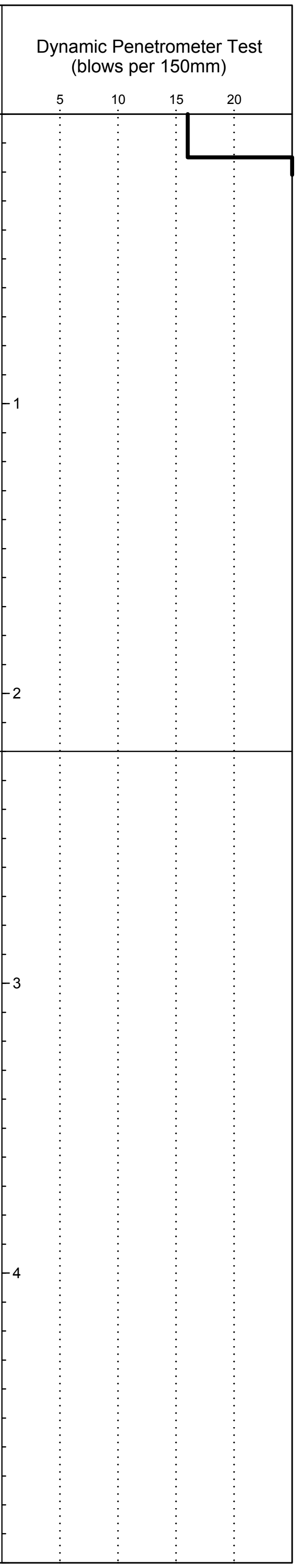
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 783 AHD
EASTING: 701292
NORTHING: 6076338

PIT No: 2
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
783		TOPSOIL-dry to moist, light brown sandy silt with some rootlets						
	0.2	SILTSTONE-high strength, slightly weathered to fresh stained, grey siltstone, highly fractured		B	0.4 0.6			
		-from 0.8m, bucket refusal, ripper used						
782	1							
781	2							
	2.2	Pit discontinued at 2.2m -ripper refusal						
780	3							
779	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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Geotechnics / Environment / Groundwater

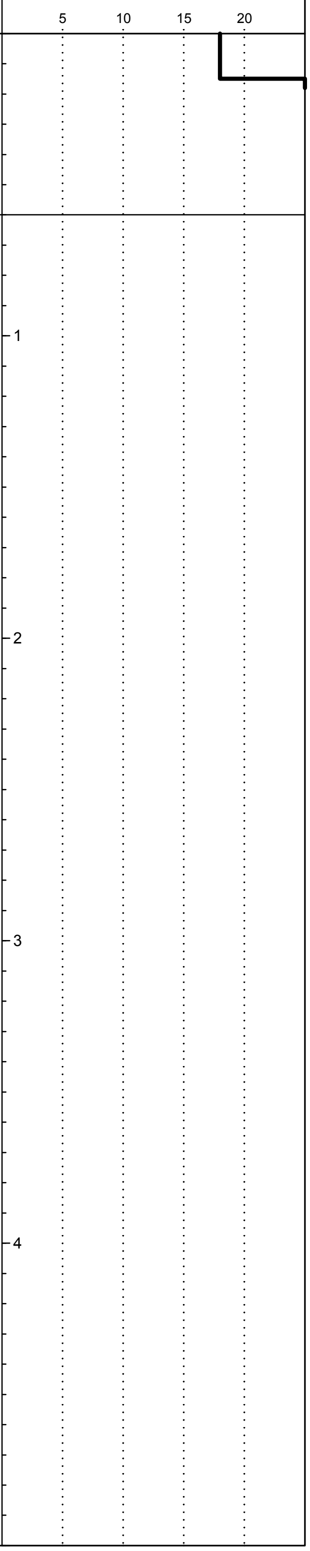
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 791 AHD
EASTING: 701504
NORTHING: 6076450

PIT No: 3
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
791		TOPSOIL-dry to moist, light brown grey sandy silt with some rootlets							
	0.2	DACITE-high to very high strength, fresh stained, grey dacite, fractured -from 0.4m, bucket refusal, ripper used							
	0.6	Pit discontinued at 0.6m -ripper refusal							
790	1								
789	2								
788	3								
787	4								



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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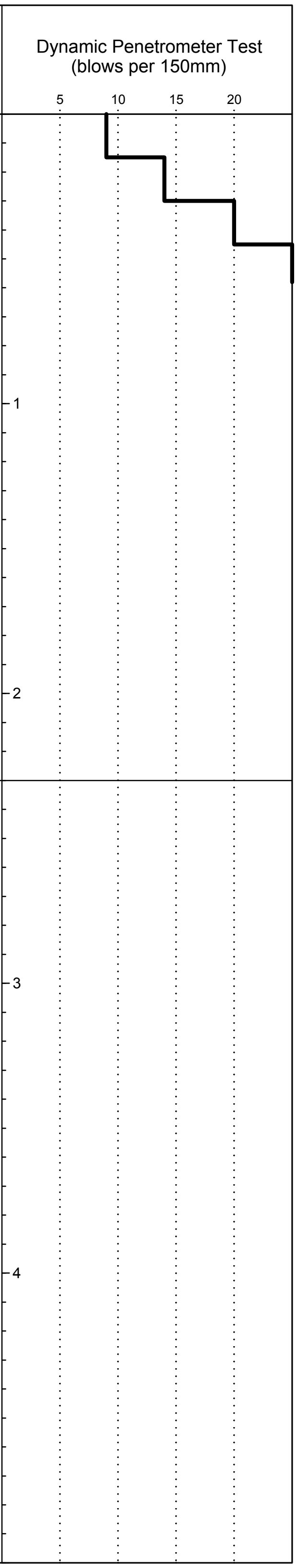
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 770 AHD
EASTING: 701548
NORTHING: 6076209

PIT No: 4
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
770	0.1	TOPSOIL-dry to moist, light brown, low plasticity sandy silt with some rootlets						
	0.45	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
769	1 1.4	SILTY CLAY-hard, dry to moist, light orange yellow brown, low to medium plasticity silty clay		D	0.6			
768	2 2.3	SILTSTONE/SHALE-high strength, slightly weathered, grey brown siltstone/shale, highly fractured -from 1.7m, bucket refusal, ripper used		D	1.8			
767	3	Pit discontinued at 2.3m -slow progress						
766	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper

LOGGED: APH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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Geotechnics / Environment / Groundwater

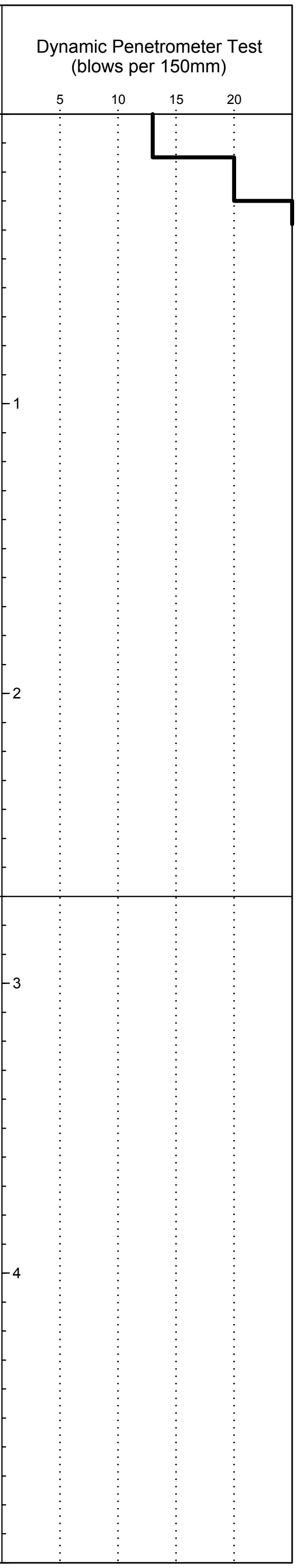
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 773 AHD
EASTING: 701712
NORTHING: 6076568

PIT No: 5
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
773		TOPSOIL-dry to moist, light brown brown sandy silt with some rootlets					
	0.15	GRAVELLY SILT-hard, dry to moist, light brown grey, low plasticity gravelly silt					
	0.25	META SHALE-medium to high strength, moderately to slightly weathered, grey orange meta shale, fractured to highly fractured					
772	1						
			D	1.5			
771	2	-from 2.1m, bucket refusal, ripper used					
	2.7	Pit discontinued at 2.7m -slow progress					
770	3						
769	4						



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

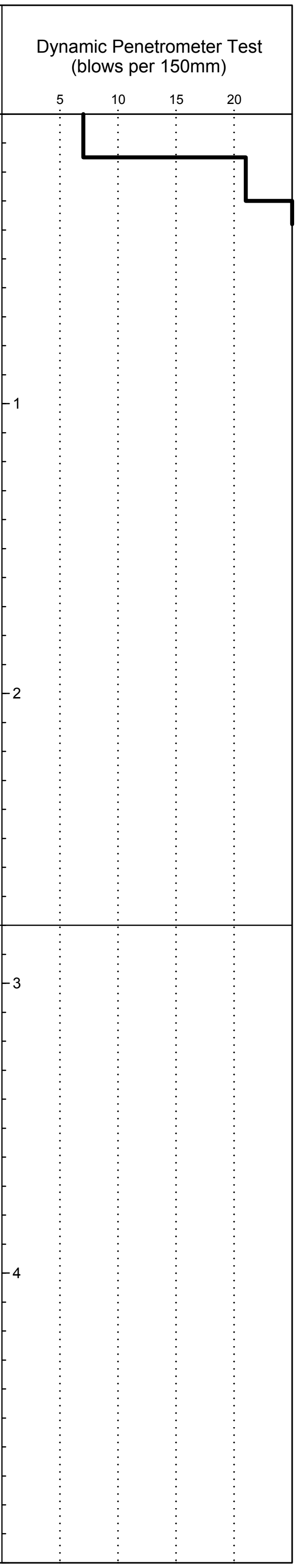
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 763 AHD
EASTING: 701793
NORTHING: 6076244

PIT No: 6
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
763		TOPSOIL-dry to moist, light brown sandy silt with some rootlets						
	0.1	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
	0.4	GRAVELLY SILTY CLAY-hard, dry to moist, orange yellow brown, medium plasticity gravelly silty clay with some siltstone gravel		D	0.7			
762	1 / 1.0	SILTY SANDY CLAY-hard, dry to moist, orange brown, low to medium plasticity silty sandy clay with some ironstone nodules						
761	2							
	2.3	DACITE-high strength, slightly weathered to fresh stained, grey dacite, slightly fractured -from 2.6m, bucket refusal, ripper used						
	2.8	Pit discontinued at 2.8m -ripper refusal						
760	3							
759	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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Geotechnics / Environment / Groundwater

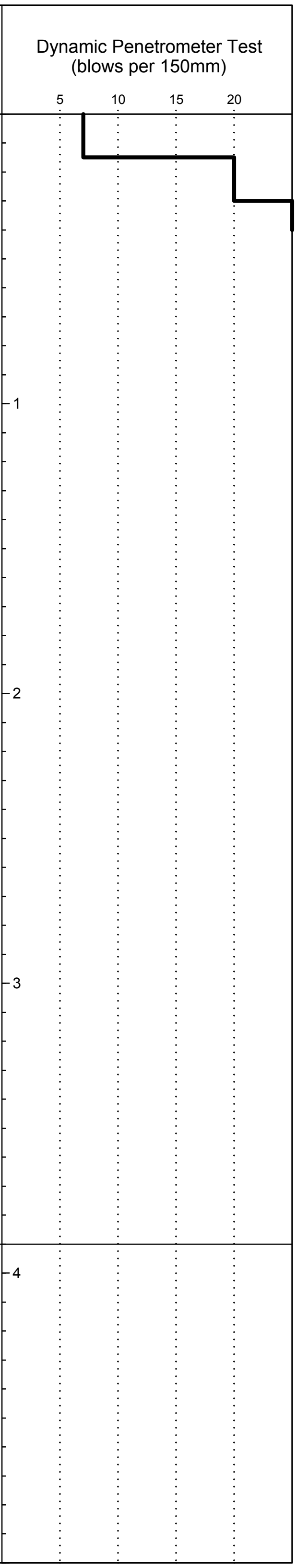
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 758 AHD
EASTING: 702032
NORTHING: 6076201

PIT No: 7
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
758		TOPSOIL-dry to moist, light brown silty sand with some rootlets						
	0.1	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
	0.25	GRAVELLY SILTY CLAY-hard, dry to moist, orange yellow grey, medium to high plasticity gravelly silty clay		D	0.6			
	0.8	SANDY SILTY CLAY-hard, dry to moist, orange yellow brown, medium plasticity sandy silty clay						
757	1							
	1.5	SILTY CLAY-hard, dry to moist, yellow brown grey, medium plasticity silty clay						
756	2			D	2.0			
755	3							
	3.4	DACITE-medium to high strength, moderately to slightly weathered, yellow grey brown, fine to coarse grained dacite, highly fractured -from 3.7m, bucket refusal, ripper used						
	3.9	Pit discontinued at 3.9m -slow progress						
754	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

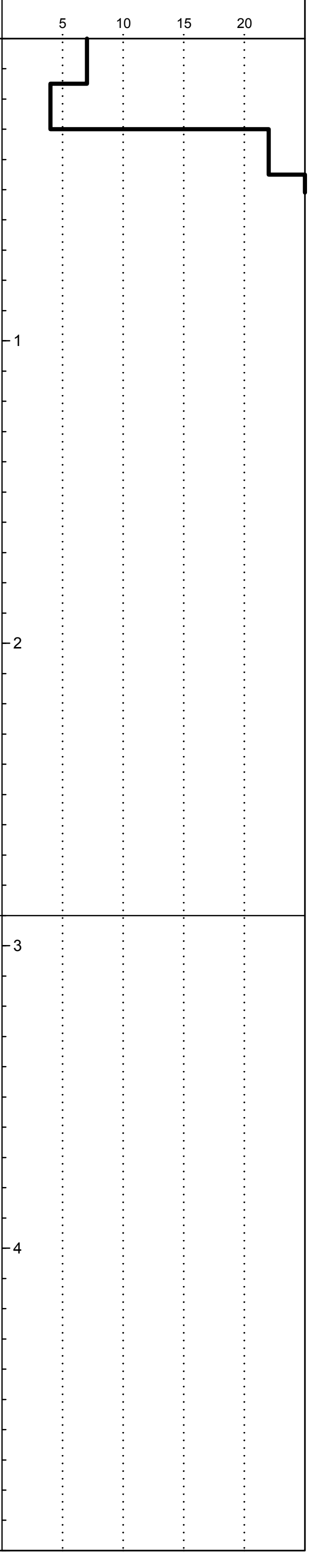
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 755 AHD
EASTING: 702091
NORTHING: 6076490

PIT No: 8
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments
755		TOPSOIL-dry to moist, brown silty sand with some rootlets				
	0.15	GRAVELLY SILTY CLAY-stiff, moist, light orange brown, medium plasticity gravelly silty clay -from 0.3m, hard, dry to moist	B	0.3 0.5		
	0.5	SANDY SILTY CLAY-hard, dry to moist, brown, low to medium plasticity sandy silty clay				
754	1					
	1.3	GRAVELLY SANDY CLAY-hard, dry to moist, orange brown, medium plasticity gravelly sandy clay	D	1.6		
753	2					
	2.2	DACITE-medium to high strength, moderately to slightly weathered, grey brown yellow, fine to coarse grained dacite, fractured -from 2.4m, bucket refusal, ripper used				
	2.9	Pit discontinued at 2.9m -slow progress				
752	3					
751	4					

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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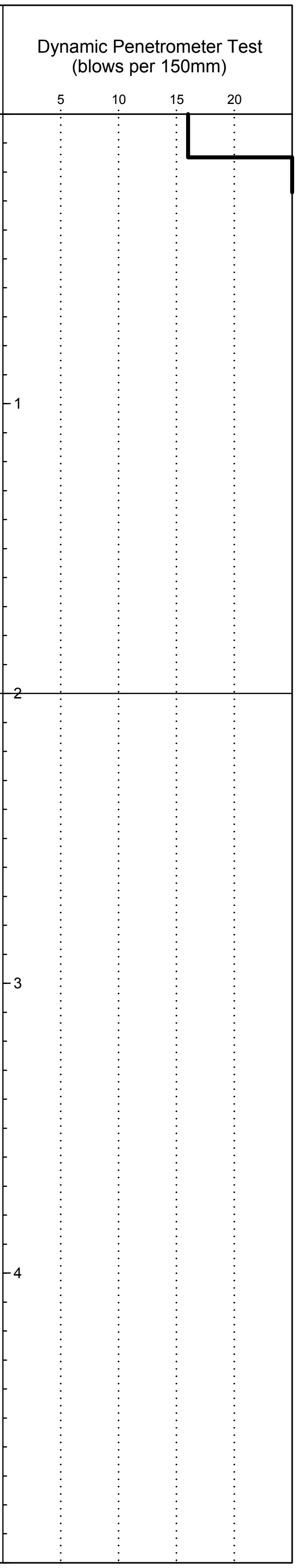
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 748 AHD
EASTING: 702471
NORTHING: 6076730

PIT No: 9
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
748	0.1	TOPSOIL-dry to moist, light brown brown silty sand with some rootlets					
	0.3	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt					
	0.7	SILTY SANDY CLAY-hard, dry to moist, orange brown, medium plasticity silty sandy clay	D	0.5			
747	1	DACITE-high strength, slightly weathered, brown grey, fine to coarse grained dacite, fractured -from 1.2m, bucket refusal, ripper used					
746	2 2.0	Pit discontinued at 2.0m -slow progress					
745	3						
744	4						



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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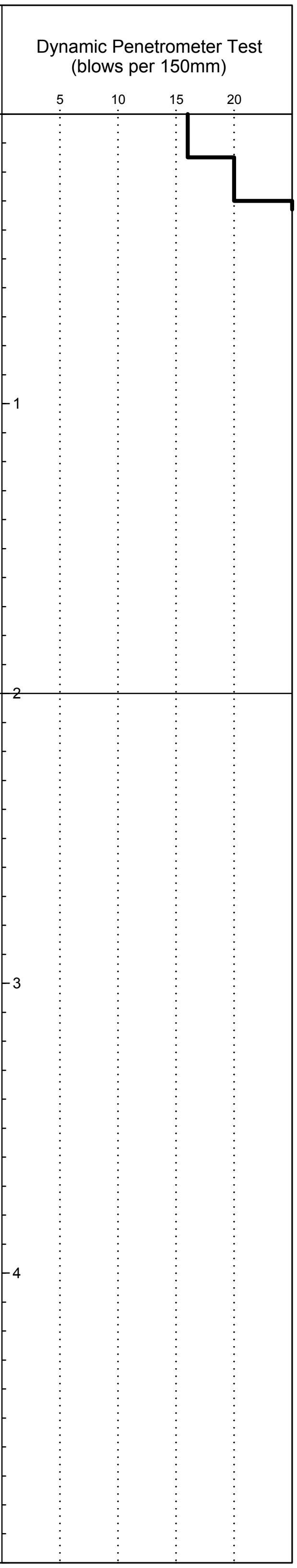
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 764 AHD
EASTING: 702424
NORTHING: 6076449

PIT No: 10
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
764	0.1	TOPSOIL-moist to dry, brown silty sand with some rootlets					
	0.4	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt with some gravel					
		DACITE-high strength, slightly weathered, yellow grey, fine to coarse grained dacite, fractured					
763	1	-from 1.1m, bucket refusal, ripper used	B	1.0 1.2			
762	2 2.0	Pit discontinued at 2.0m -ripper refusal					
761	3						
760	4						



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

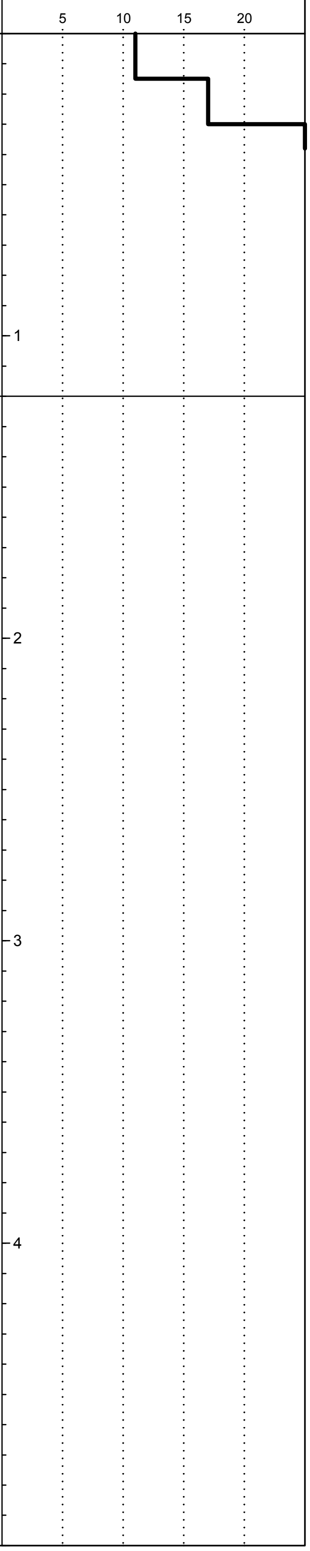
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 767 AHD
EASTING: 702341
NORTHING: 6076169

PIT No: 11
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
767		TOPSOIL-dry to moist, light brown brown silty sand with some rootlets						
	0.1	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
	0.2	SILTY CLAY-hard, dry to moist, yellow orange grey, medium to high plasticity silty clay		D	0.3			
	0.4	META SHALE-high strength, slightly weathered, yellow grey, fine to coarse grained meta shale, fractured -from 0.6m, bucket refusal, ripper used						
766	1							
	1.2	Pit discontinued at 1.2m -ripper refusal						
765	2							
764	3							
763	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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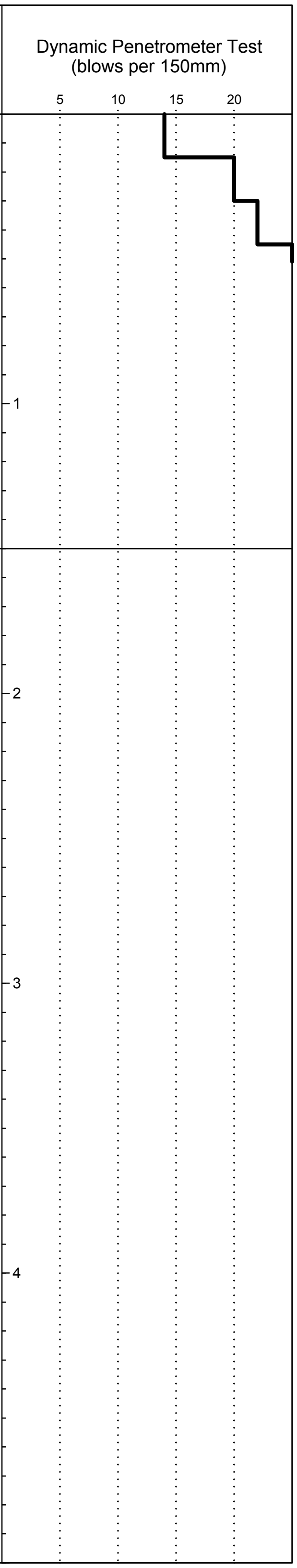
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 789 AHD
EASTING: 702410
NORTHING: 6075914

PIT No: 12
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
789		TOPSOIL-dry to moist, light brown brown silty sand with some rootlets						
	0.1	GRAVELLY SANDY SILT-hard, dry to moist, light grey, low plasticity gravelly sandy silt						
	0.3	SILTY SANDY CLAY-hard, dry to moist, orange brown, medium plasticity silty sandy clay						
	0.45	META SHALE-high strength, slightly weathered, yellow grey meta shale, fractured -from 0.8m, bucket refusal, ripper use		B	0.6 0.8			
788	1							
	1.5	Pit discontinued at 1.5m -ripper refusal						
787	2							
786	3							
785	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper

LOGGED: APH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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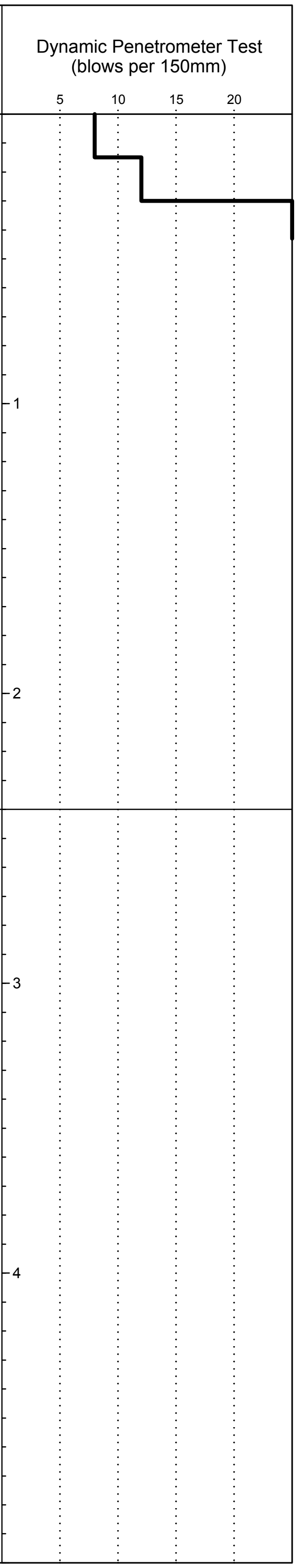
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 758 AHD
EASTING: 702813
NORTHING: 6076699

PIT No: 14
PROJECT No: 46285.44
DATE: 30/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
758		TOPSOIL-moist to dry, brown silty sand with some rootlets						
	0.1	SANDY SILT-very stiff, dry to moist, light grey, low plasticity sandy silt with some gravel						
	0.5	META SHALE-high strength, slightly weathered, yellow grey, fine to coarse grained meta shale, fractured -from 0.7m, bucket refusal, riper used		B	0.7 0.9			
757	1							
756	2							
	2.4	Pit discontinued at 2.4m -slow progress						
755	3							
754	4							



RIG: Volvo EC350DL excavator, 850mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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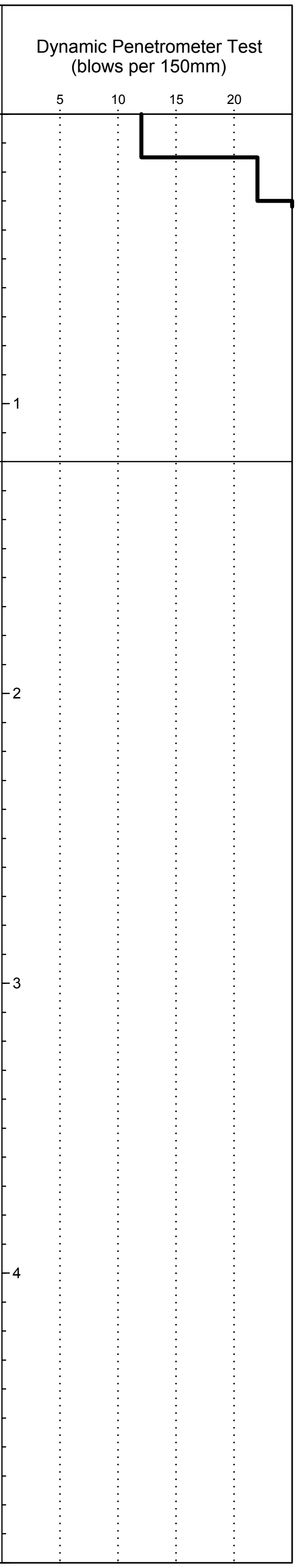
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 749 AHD
EASTING: 703033
NORTHING: 6076578

PIT No: 15
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
749	0.1	TOPSOIL-dry to moist, light brown grey sandy silt with some rootlets and cobbles						
	0.25	GRAVELLY SANDY SILT-hard, dry to moist, light grey, low plasticity gravelly sandy silt						
		SHALE-medium strength, moderately weathered, yellow grey, highly fractured shale -from 0.5m, high strength, slightly weathered, grey -bucket refusal at 0.6m, ripper used		D	0.6			
748	1							
	1.2	Pit discontinued at 1.2m -slow progress						
747	2							
746	3							
745	4							



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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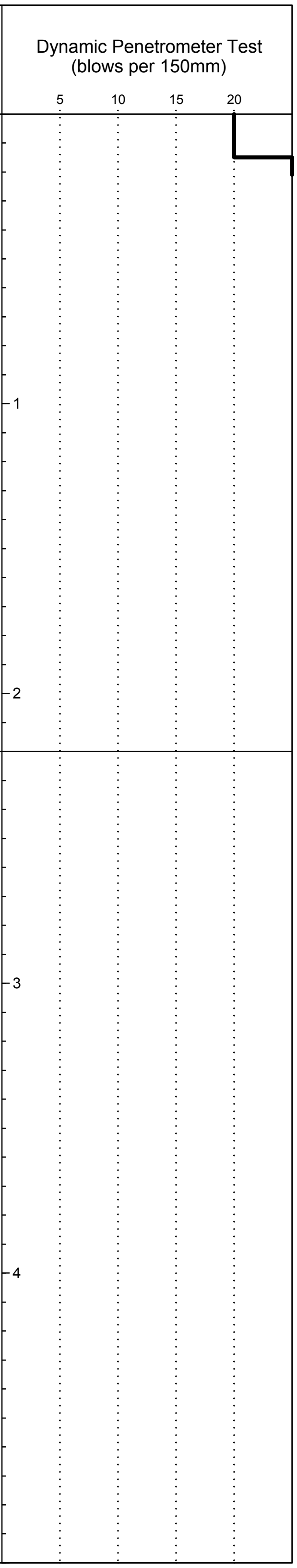
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 739 AHD
EASTING: 703123
NORTHING: 6076829

PIT No: 16
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
739	0.15	TOPSOIL-dry to moist, light brown sandy silt with some rootlets						
	0.35	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
	0.5	SANDY SILTY CLAY-hard, dry to moist, red orange brown, medium plasticity sandy silty clay						
738 737	1 2 2.2	META SHALE-medium to high strength, moderately to slightly weathered, yellow grey, fine to coarse grained meta shale, slightly fractured -from 1.3m, high strength, slightly weathered -bucket refusal at 1.5m, ripper used		D	0.8			
736 735	3 4	Pit discontinued at 2.2m -slow progress						



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper

LOGGED: APH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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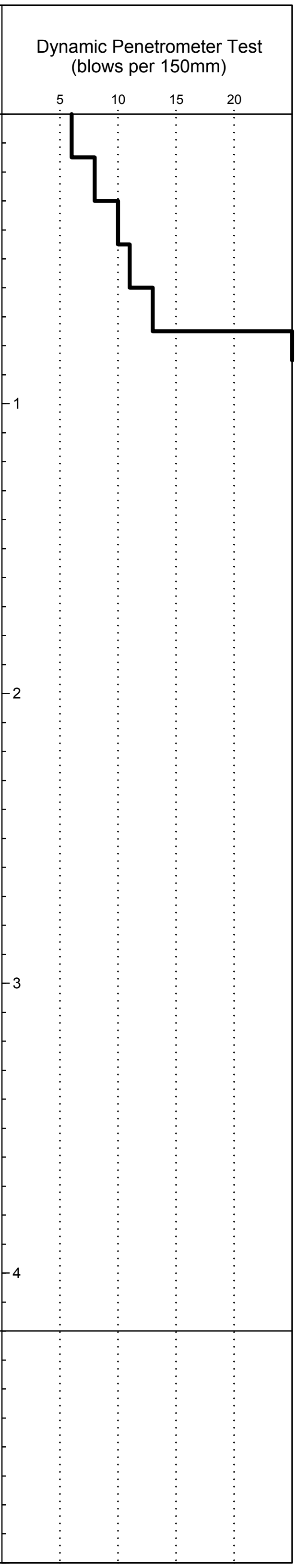
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 752 AHD
EASTING: 703224
NORTHING: 6076624

PIT No: 17
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
752	0.1	TOPSOIL-moist to dry, brown silty sand with some rootlets					
	0.3	SANDY SILT-very stiff, dry to moist, light grey, low plasticity sandy silt					
	0.6	GRAVELLY SILTY CLAY-hard, dry to moist, light brown orange, medium plasticity gravelly silty clay	D	0.5			
751	1	META SHALE-medium strength, moderately weathered, yellow orange brown, fine to coarse grained meta shale, highly fractured	B	1.3 1.5			
750	2	-from 2.0m, low to medium strength, highly to moderately weathered, yellow orange brown					
		-from 2.4m, low strength, highly weathered, brown orange					
749	3	-from 2.9m, medium strength, moderately weathered, yellow grey brown, bucket refusal, ripper attached					
748	4						
	4.2	Pit discontinued at 4.2m -slow progress					



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

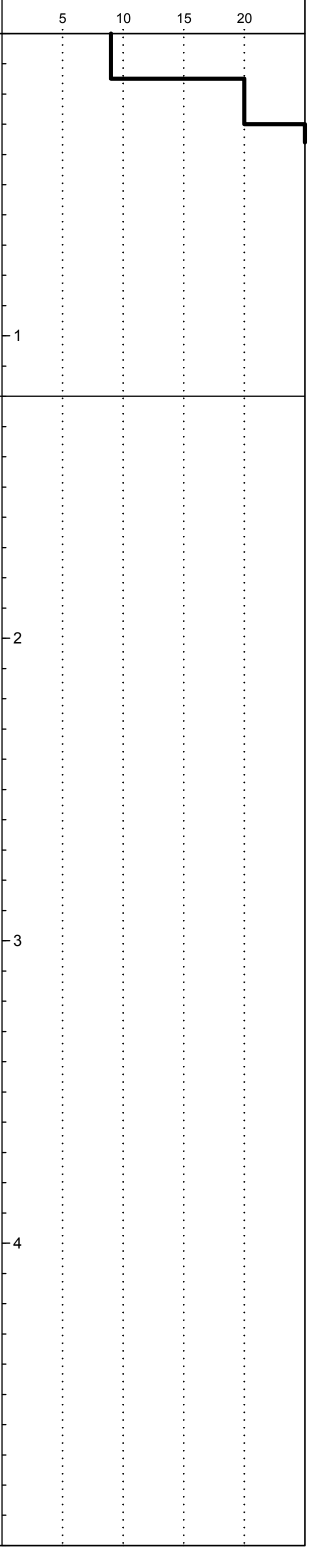
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 740 AHD
EASTING: 703282
NORTHING: 6076430

PIT No: 18
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
740	0.1	TOPSOIL-dry to moist, light brown grey clayey silty sand with some rootlets						
	0.25	SANDY SILT-hard, dry to moist, light grey brown, low plasticity sandy silt						
739	1	META SHALE-medium to high strength, moderately to slightly weathered, grey brown meta shale, slightly fractured -bucket refusal at 0.4m, ripper used						
	1.2	Pit discontinued at 1.2m -ripper refusal						
738	2							
737	3							
736	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

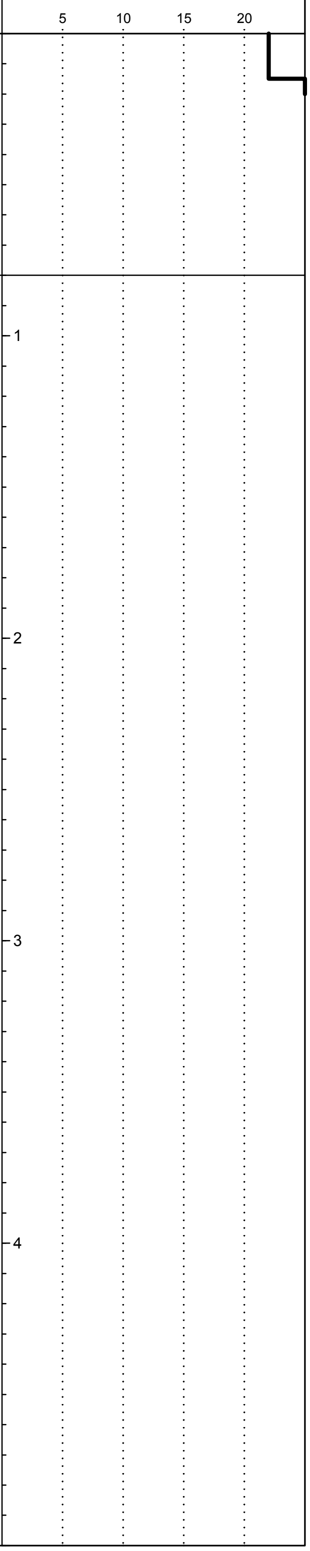
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 762 AHD
EASTING: 702951
NORTHING: 6076218

PIT No: 19
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
762		TOPSOIL-dry to moist, light brown brown gravelly sandy silt with some rootlets						
	0.2	META SHALE-medium to high strength, moderately to slightly weathered, yellow grey, fine to coarse grained meta shale, slightly fractured -bucket refusal at 0.5m, ripper attached		D	0.3			
	0.8	Pit discontinued at 0.8m -ripper refusal						
761	1							
760	2							
759	3							
758	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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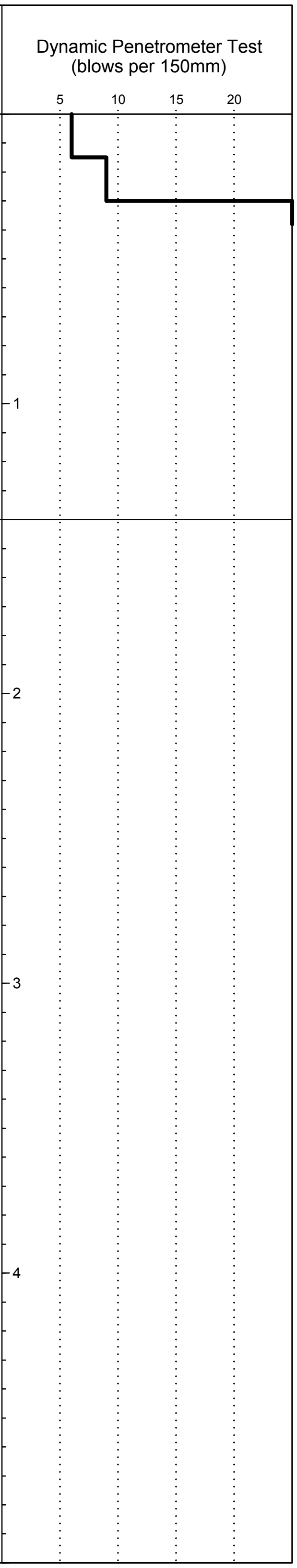
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 746 AHD
EASTING: 703491
NORTHING: 6076256

PIT No: 20
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
746	0.1	TOPSOIL-dry to moist, light orange brown clayey sandy silt with some rootlets						
	0.35	GRAVELLY SANDY SILT-very stiff, dry to moist, light grey, low plasticity gravelly sandy silt						
745	1.4	META SHALE-medium to high strength, moderately to slightly weathered, grey meta shale, some low to medium plasticity clay seams, slightly fractured -bucket refusal at 0.7m, ripper used		D	0.8			
		Pit discontinued at 1.4m -ripper refusal						
744	2							
743	3							
742	4							



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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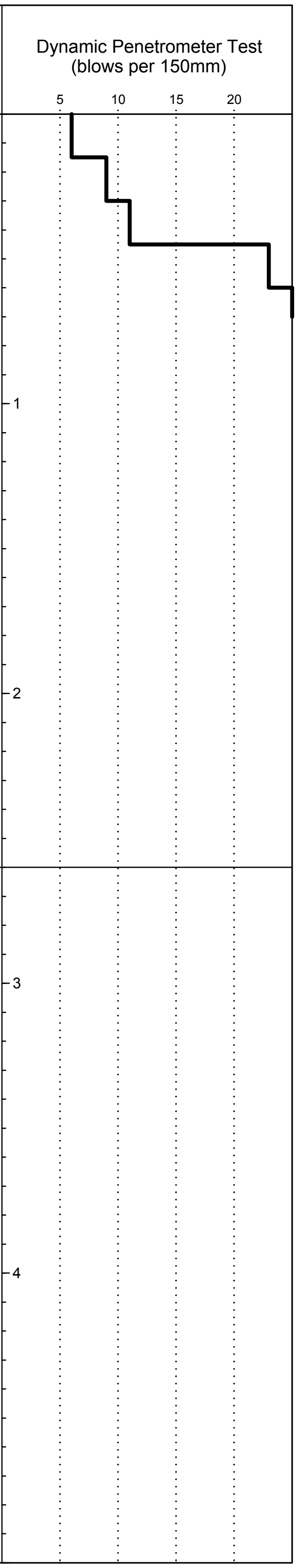
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 731 AHD
EASTING: 703556
NORTHING: 6076524

PIT No: 21
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
731		TOPSOIL-dry to moist, light brown silty sand with some rootlets						
	0.1	SANDY SILT-very stiff, dry to moist, light grey, low plasticity sandy silt with some gravel						
	0.3	SANDY SILTY CLAY-very stiff, dry to moist, orange grey, medium plasticity sandy silty clay (residual)		D	0.4			
	0.7	META SHALE-low to medium strength, highly to moderately weathered, brown grey, fine to medium grained meta shale, highly fractured						
730	1			D	1.0			
		-from 1.4m, high strength, slightly weathered, grey						
		-bucket refusal at 1.6m, ripper used						
729	2							
	2.6	Pit discontinued at 2.6m -ripper refusal						
728	3							
727	4							



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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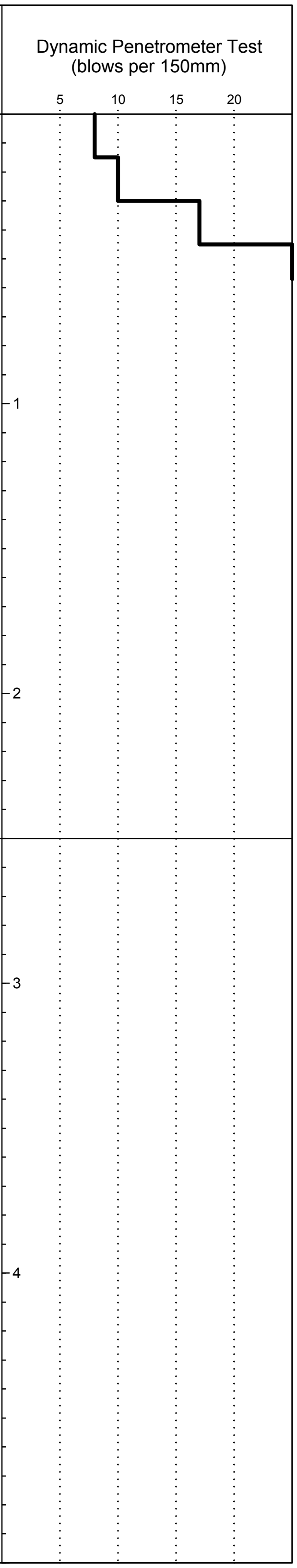
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 720 AHD
EASTING: 703629
NORTHING: 6076801

PIT No: 22
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
720	0.15	TOPSOIL-dry to moist, light brown brown clayey silty sand with some rootlets					
	0.5	SANDY SILT-very stiff, dry to moist, light grey, low plasticity sandy silt -from 0.3m, hard, dry to moist					
	1.1	SANDY SILTY CLAY-hard, dry to moist, yellow brown grey, medium plasticity sandy silty clay	D	0.7			
719	1						
	2.5	META SHALE-medium to high strength, moderately to slightly weathered, yellow grey, fine to coarse grained meta shale, highly fractured -bucket refusal at 1.9m, ripper attached -from 2.2m, high strength, slightly weathered, grey					
718	2						
		Pit discontinued at 2.5m -slow progress					
717	3						
716	4						



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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Geotechnics / Environment / Groundwater

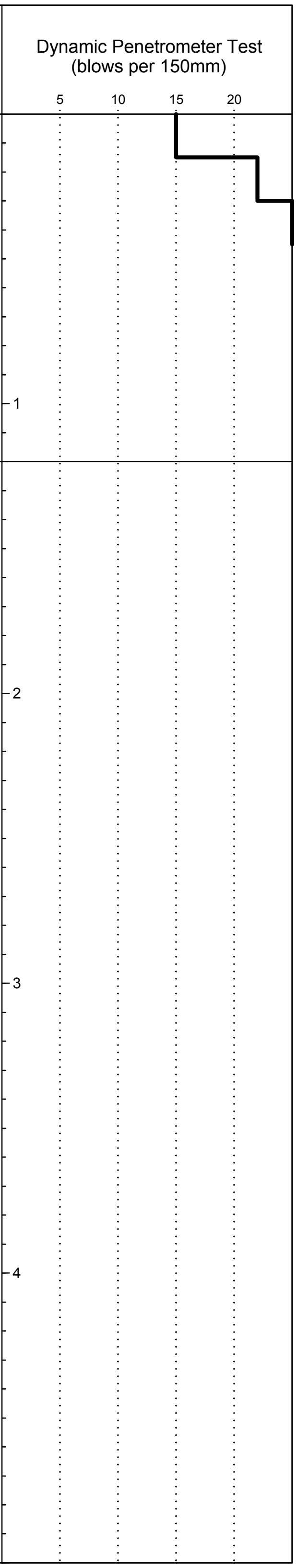
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 728 AHD
EASTING: 703822
NORTHING: 6076711

PIT No: 23
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
728		TOPSOIL-moist to dry, brown clayey sand with some rootlets						
	0.1	SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt with some gravel						
	0.2	SHALE-high strength, slightly weathered, grey shale, highly fractured -bucket refusal at 0.7m, ripper used		D	0.5			
727	1							
	1.2	Pit discontinued at 1.2m -slow progress						
726	2							
725	3							
724	4							



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

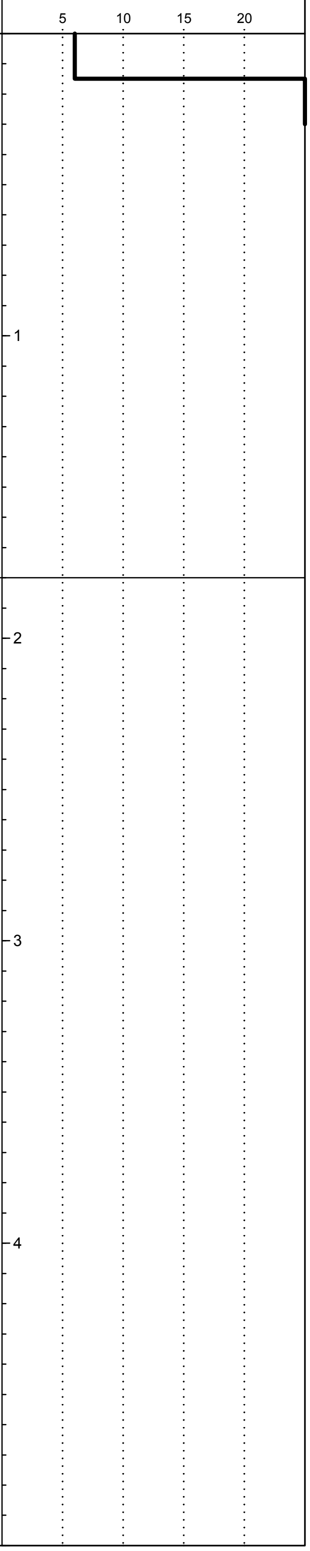
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 718 AHD
EASTING: 703805
NORTHING: 6077122

PIT No: 24
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
718		TOPSOIL-dry to moist, brown sandy gravelly silt with some rootlets						
	0.1	GRAVELLY SANDY SILT-hard, dry to moist, light grey, low plasticity sandy silt						
	0.4	SANDY SILTY CLAY-hard, dry to moist, orange red brown, medium plasticity sandy silty clay		B	0.5 0.7			
	0.8	META SHALE-high strength, slightly weathered, grey meta shale, slightly fractured						
717	1							
		-bucket refusal at 1.3m, ripper attached						
	1.8	Pit discontinued at 1.8m -ripper refusal						
716	2							
715	3							
714	4							

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper
LOGGED: APH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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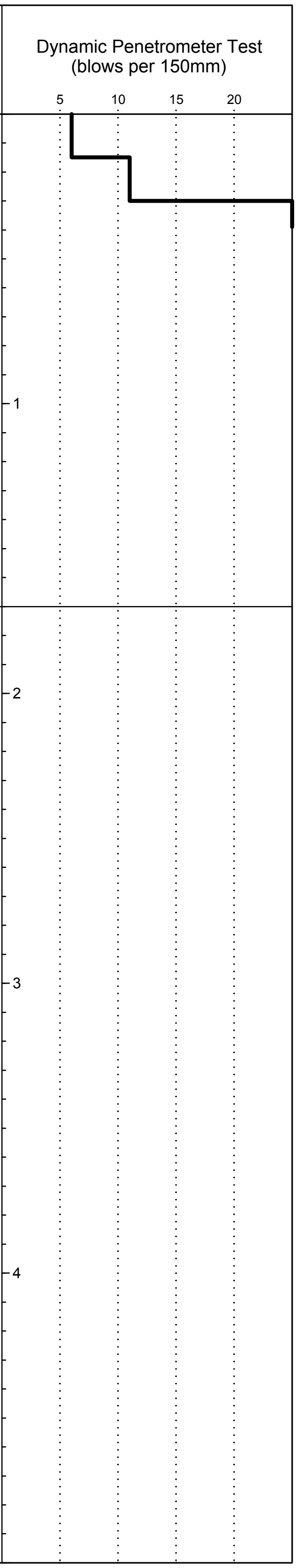
TEST PIT LOG

CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 705 AHD
EASTING: 704056
NORTHING: 6076903

PIT No: 25
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
705	0.1	TOPSOIL-dry to moist, light brown clayey sandy silt with some rootlets						
	0.35	SANDY SILT-very stiff, dry to moist, light grey, low plasticity sandy silt -from 0.3m, hard, dry to moist						
704	1	META SHALE-low to medium strength, highly to moderately weathered, yellow orange, fine to coarse grained meta shale, fractured -from 1.3m, high strength, slightly weathered, yellow grey -bucket refusal at 1.5m, ripper used						
	1.7	Pit discontinued at 1.7m -ripper refusal						
703	2							
702	3							
701	4							



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper

LOGGED: APH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

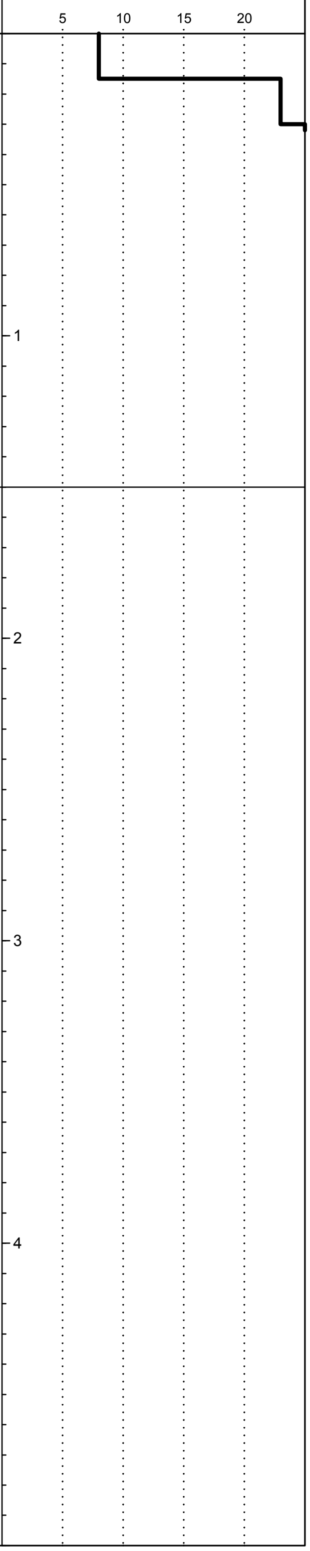
CLIENT: Spacelab Studio Pty Ltd
PROJECT: Urban Capability Study
LOCATION: Neighbourhood 3-5, Googong

SURFACE LEVEL: 713 AHD
EASTING: 704353
NORTHING: 6076834

PIT No: 26
PROJECT No: 46285.44
DATE: 31/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
713	0.1	TOPSOIL-dry to moist, brown silty sand with some rootlets					
	0.3	SANDY SILT-dry to moist, light brown grey, low plasticity sandy silt with some tree roots					
	0.4	SANDY SILTY CLAY-hard, dry to moist, yellow grey, high plasticity sandy silty clay	D	0.35			
		META SHALE-high strength, slightly weathered, grey meta shale, fractured					
712	1	-bucket refusal at 1.0m, ripper used					
	1.5	Pit discontinued at 1.5m -ripper refusal					
711	2						
710	3						
709	4						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Volvo EC220R excavator, 800mm bucket or single tyne ripper **LOGGED:** APH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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Appendix E

Results of Laboratory Testing

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Goulburn Laboratory
1 Farquhar Street Goulburn NSW 2580
Phone: 02 4822 8395
Email: peter.gaunt@douglaspartners.com.au

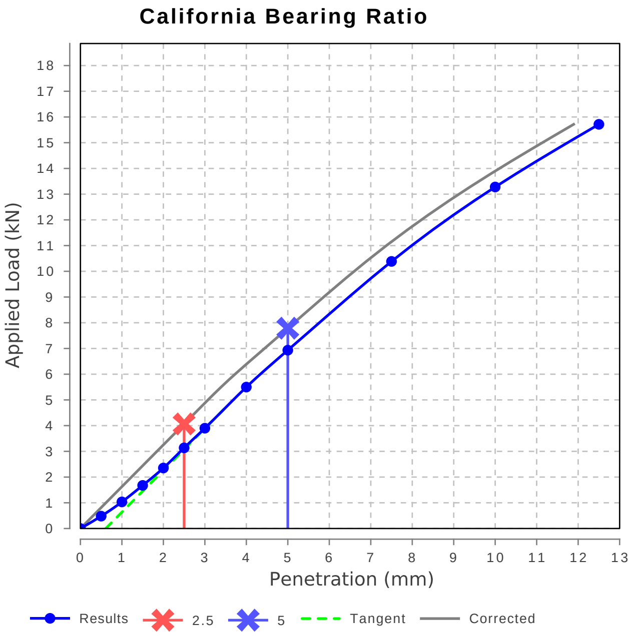
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Peter Gaunt
Laboratory Manager
NATA Accredited Laboratory Number: 828

Report Number:	**46285.44-1**
Issue Number:	4 - *This version supersedes all previous issues*
Date Issued:	18/03/2019
Client:	Spacelab Studio Pty Ltd 5/97 Northbourne Avenue, Turner ACT 2612
Contact:	Giselle Ravarian
Project Number:	46285.44
Project Name:	Urban Capability Study
Project Location:	NH 3-5, Googong
Work Request:	1863
Sample Number:	19-1863A
Date Sampled:	08/02/2019
Dates Tested:	08/02/2019 - 19/02/2019
Sampling Method:	Sampled by Engineering Department
Sample Location:	**Pit 17 (1.3-1.5m)**
Material:	Meta Shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**40**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	2.01		
Optimum Moisture Content (%)	10.5		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	96.5		
Dry Density after Soaking (t/m^3)	2.02		
Field Moisture Content (%)	7.0		
Moisture Content at Placement (%)	10.3		
Moisture Content Top 30mm (%)	11.5		
Moisture Content Rest of Sample (%)	11.0		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	50.5		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	12.2		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	7.0



Material Test Report

Douglas Partners Pty Ltd
Goulburn Laboratory
1 Farquhar Street Goulburn NSW 2580
Phone: 02 4822 8395
Email: peter.gaunt@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Peter Gaunt
Laboratory Manager
NATA Accredited Laboratory Number: 828

Report Number:	**46285.44-1**
Issue Number:	4 - *This version supersedes all previous issues*
Date Issued:	18/03/2019
Client:	Spacelab Studio Pty Ltd 5/97 Northbourne Avenue, Turner ACT 2612
Contact:	Giselle Ravarian
Project Number:	46285.44
Project Name:	Urban Capability Study
Project Location:	NH 3-5, Googong
Work Request:	1863
Sample Number:	19-1863B
Date Sampled:	08/02/2019
Dates Tested:	08/02/2019 - 13/02/2019
Sampling Method:	Sampled by Engineering Department
Sample Location:	**Pit 21 (0.4m)**
Material:	Sandy Silty Clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	43		
Plastic Limit (%)	18		
Plasticity Index (%)	**25**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	3.5		
Cracking Crumbling Curling	Cracking & Curling		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	12.0

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Goulburn Laboratory
1 Farquhar Street Goulburn NSW 2580
Phone: 02 4822 8395
Email: peter.gaunt@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Peter Gaunt
Laboratory Manager
NATA Accredited Laboratory Number: 828

Report Number: **46285.44-1**
Issue Number: 4 - *This version supersedes all previous issues*
Date Issued: 18/03/2019
Client: Spacelab Studio Pty Ltd
5/97 Northbourne Avenue, Turner ACT 2612
Contact: Giselle Ravarian
Project Number: 46285.44
Project Name: Urban Capability Study
Project Location: NH 3-5, Googong
Work Request: 1863
Sample Number: 19-1863C
Date Sampled: 08/02/2019
Dates Tested: 08/02/2019 - 14/02/2019
Sampling Method: Sampled by Engineering Department
Sample Location: **Pit 26 (0.3m)**
Material: Sandy Silty Clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	68		
Plastic Limit (%)	19		
Plasticity Index (%)	**49**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	5.5		
Cracking Crumbling Curling	Cracking & Curling		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	15.9

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Goulburn Laboratory
1 Farquhar Street Goulburn NSW 2580
Phone: 02 4822 8395
Email: peter.gaunt@douglaspartners.com.au

Report Number: **46285.44-1**
Issue Number: 4 - *This version supersedes all previous issues*
Date Issued: 18/03/2019
Client: Spacelab Studio Pty Ltd
5/97 Northbourne Avenue, Turner ACT 2612
Contact: Giselle Ravarian
Project Number: 46285.44
Project Name: Urban Capability Study
Project Location: NH 3-5, Googong
Work Request: 1863
Sample Number: 19-1863D
Date Sampled: 08/02/2019
Dates Tested: 08/02/2019 - 19/02/2019
Sampling Method: Sampled by Engineering Department
Sample Location: **Pit 24 (0.5-0.7)**
Material: Sandy Silty Clay

NATA
WORLD RECOGNISED ACCREDITATION

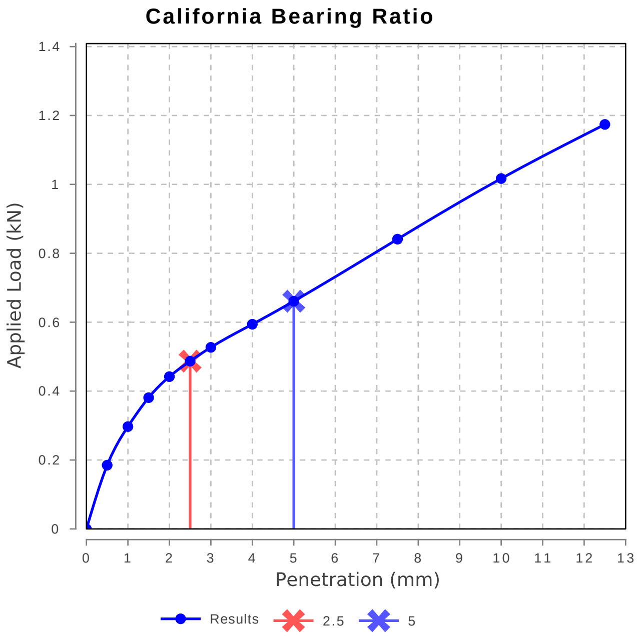
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Peter Gaunt
Laboratory Manager

NATA Accredited Laboratory Number: 828

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**3.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.65		
Optimum Moisture Content (%)	20.5		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	98.5		
Dry Density after Soaking (t/m^3)	1.63		
Field Moisture Content (%)	14.9		
Moisture Content at Placement (%)	20.1		
Moisture Content Top 30mm (%)	29.0		
Moisture Content Rest of Sample (%)	21.0		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	119		
Swell (%)	1.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	14.9



Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Goulburn Laboratory
1 Farquhar Street Goulburn NSW 2580
Phone: 02 4822 8395
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Accredited for compliance with ISO/IEC 17025 - Testing

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Approved Signatory: Peter Gaunt
Laboratory Manager
NATA Accredited Laboratory Number: 828

Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content	Material
19-1863A	Pit 17 (1.3-1.5m)	7.0 %	Meta Shale
19-1863B	Pit 21 (0.4m)	12.0 %	Sandy Silty Clay
19-1863C	Pit 26 (0.3m)	15.9 %	Sandy Silty Clay
19-1863D	Pit 24 (0.5-0.7)	14.9 %	Sandy Silty Clay

TESTCRETE
LABORATORIES PTY LIMITED

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ABN: 35 102 659 754

Job No.
TCBR 018

California Bearing Ratio Test Certificate

Client: .... Douglas Partners Pty Ltd, HUME ACT   Date of test: **11/02/19**
Principal: .... Douglas Partners Pty Ltd
Project: .... Urban Capability Study Neighbourhoods 3 - 5, Project # 46285.44
Location: .... GOOGONG NSW

Test procedure: .... AS1289 6.1.1 for C.B.R.   Sampled by Client Submitted 01/02/19

Laboratory compaction method: ..... AS1289 5.1.1 for M.D.D. *Blows per Layer (3 Layers) with Standard Hammer for C.B.R.

Sample No.		**TCBR 018/ S17**	**TCBR 018/ S18**	**TCBR 018/ S19**	**TCBR 018/ S20**
Depth		0.4 m - 0.6 m	0.3 m - 0.5 m	0.6 m - 0.8 m	0.7 m - 0.9 m
Location		Client ID: Pit 2	Client ID: Pit 8	Client ID: Pit 12	Client ID: Pit 14
Date sampled		Sampled by Client	Sampled by Client	Sampled by Client	Sampled by Client
Description of sample		(Client Material Description: Silt Stone) Yellow Brown	(Client Material Description: Gravely Silty Clay) Yellow Brown	(Client Material Description: Meta - Shale) Red Yellow Brown / Yellow Brown Mottled	(Client Material Description: Meta - Shale) Yellow Brown
Max dry density	t/m^3	1.81	1.73	1.85	1.91
Optimum moisture content	%	13.5	15.5	12.0	7.0
Material Retained 19.0mm A.S. Sieve	%	0	0	0	0
Field moisture content	%	8.9	10.7	8.4	3.6
CBR Test: Dry density t/m^3	Before soaking	1.81	1.74	1.84	1.89
	After soaking	1.78	1.70	1.83	1.89
Density ratio %	Before soaking	100.0	101.0	99.0	99.0
	After soaking	98.0	98.0	99.0	99.0
Moisture content %	Before soaking	12.5	14.5	12.3	6.8
	After soaking	15.8	19.8	15.0	11.0
Laboratory Moisture Ratio %	Before soaking	94	93	103	97
Number of days soaked		4	4	4	4
Surcharge	kg	4.5	4.5	4.5	4.5
Moisture content after test %	Top 30mm	21.3	22.9	17.3	10.9
	Whole sample	15.8	19.8	15.0	11.0
Swell after soaking	%	1.5	2.5	0.5	0.0
C.B.R. value	%	**6 @ 5.0 mm**	**6 @ 5.0 mm**	**5.0 @ 2.5 mm**	**18 @ 2.5 mm**
*Number of Blows per Layer		53* Blows	53* Blows	53* Blows	53* Blows

Remarks: **CBR Value Reported @ Determined Penetration Depth**

Authorised Signatory
G.W.Collins

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Date of Issue: 12/02/2019

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ABN: 35 102 659 754

Job No.

TPSD 018

Particle Size Distribution / Atterberg Limits

Client: .... Douglas Partners Pty Ltd, HUME ACT

Date Tested.... 12/02/19

Principal: .... Douglas Partners Pty Ltd

Project: .... Urban Capability Study Neighbourhoods 3 - 5, Project # 46285.44

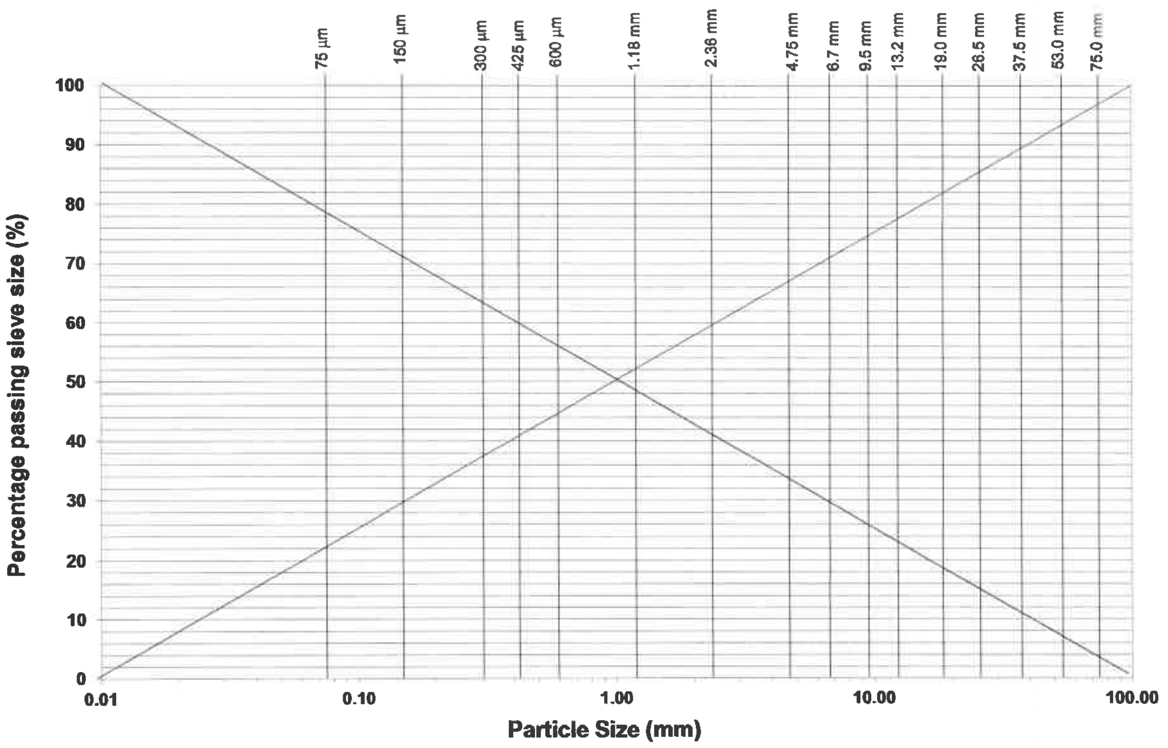
Location: .... GOOGONG NSW

Sample Identification: **TPSD 018/S30** Client ID: Pit 4, Depth: 0.6 m

Test Procedure: -

Sampled by the Client and Submitted 04/02/19 (Tested as Received)

AS Sieve size	150 mm	75 mm	53 mm	37.5 mm	26.5 mm	19.0 mm	13.2 mm	9.5 mm	6.7 mm	4.75 mm	2.36 mm	1.18 mm	600 um	425 um	300 um	150 um	75 um	13.2 um	0.02 um						
Percent Passing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						



Atterberg Limits (Test procedure)	Liquid Limit AS 1289 3.1.1	52 %	Plastic Limit AS 1289 3.2.1	25 %	Plasticity Index AS 1289 3.3.1	27 %
	Linear Shrinkage AS 1289 3.4.1	7.5 %	**AS1289 2.1.1, Moisture Content: 13.8 %**			

Remarks: Unless otherwise stated Atterberg Limits have been oven dried & dry sieved.
Linear Shrinkage moisture condition determined by AS1289 3.1.1

Authorised Signatory

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Date of Issue: 27/02/2019

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Job No.
TPSD 018

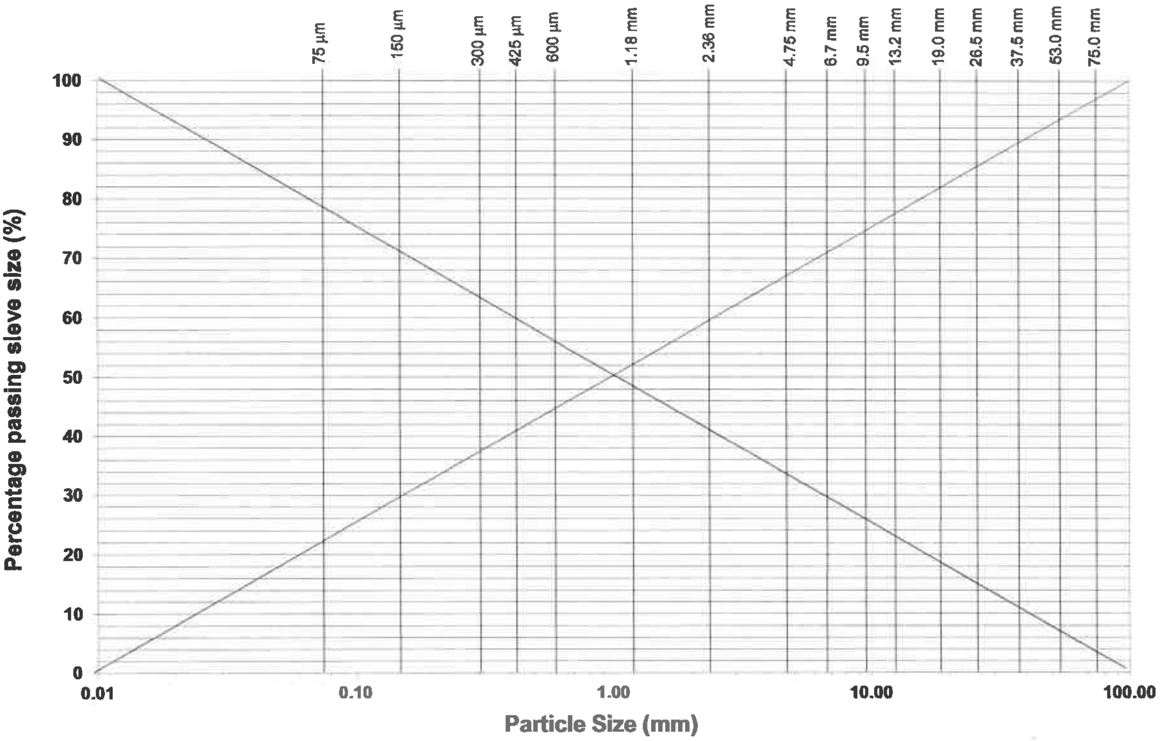
Particle Size Distribution / Atterberg Limits

Client: .... Douglas Partners Pty Ltd, HUME ACT
Date Tested.... 13/02/19
Principal: .... Douglas Partners Pty Ltd
Project: .... Urban Capability Study Neighbourhoods 3 - 5, Project # 46285.44
Location: .... GOOGONG NSW

Sample Identification: **TPSD 018/S31**
Client ID: Pit 7, Depth: 0.6 m

Test Procedure: -
Sampled by the Client and Submitted 04/02/19 (Tested as Received)

AS Sieve size	150 mm	75 mm	53 mm	37.5 mm	26.5 mm	19.0 mm	13.2 mm	9.5 mm	6.7 mm	4.75 mm	2.36 mm	1.18 mm	600 um	425 um	300 um	150 um	75 um	13.2 um	0.02 um						
Percent Passing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						



Atterberg Limits (Test procedure)	Liquid Limit AS 1289 3.1.1	42 %	Plastic Limit AS 1289 3.2.1	20 %	Plasticity Index AS 1289 3.3.1	22 %
	Linear Shrinkage AS 1289 3.4.1	5.0 %	**AS1289 2.1.1, Moisture Content: 15.1 %**			

Remarks: Unless otherwise stated Atterberg Limits have been oven dried & dry sieved.
Linear Shrinkage moisture condition determined by AS1289 3.1.1

Form No 6. R1289 3.6.1 Issued 10.09.2013

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Page 1 of 1
Issue # 1

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ABN: 35 102 659 754

Job No.
TPSD 018

Particle Size Distribution / Atterberg Limits

Client: .... Douglas Partners Pty Ltd, HUME ACT

Date Tested.... 12/02/19

Principal: .... Douglas Partners Pty Ltd

Project: .... Urban Capability Study Neighbourhoods 3 - 5, Project # 46285.44

Location: .... GOOGONG NSW

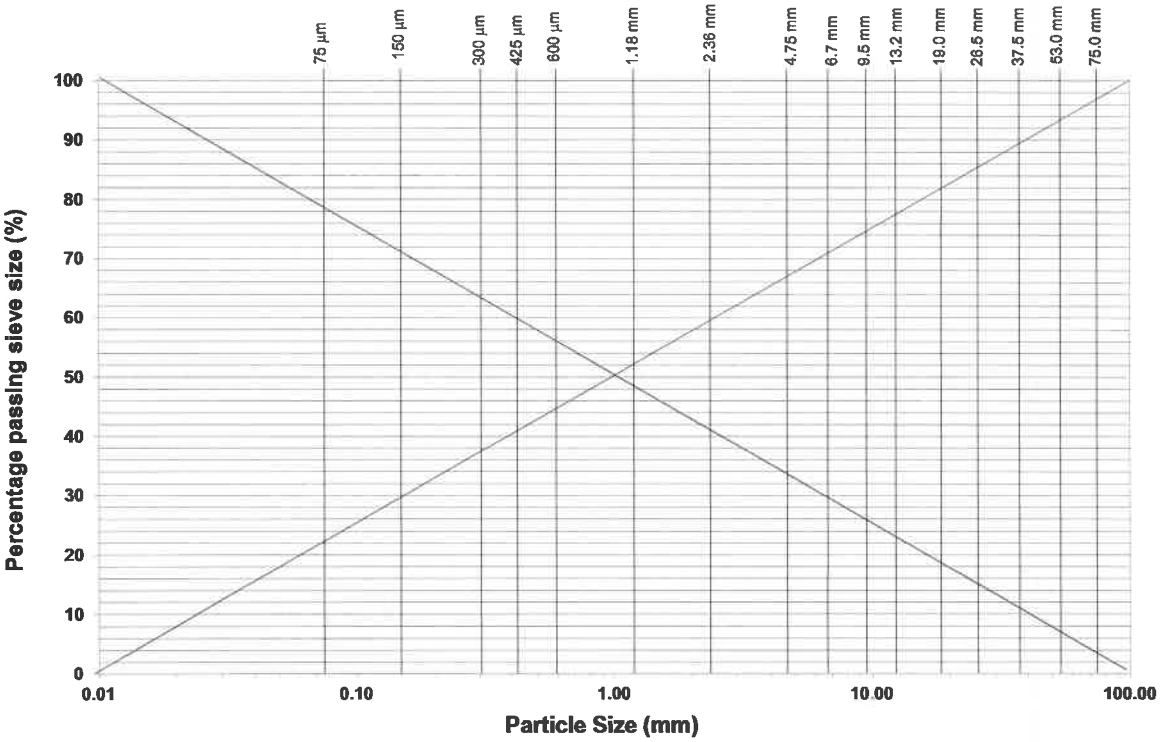
Sample Identification: **TPSD 018/S32**

Client ID: Pit 8, Depth: 0.3 m - 0.5 m

Test Procedure: -

Sampled by the Client and Submitted 04/02/19 (Tested as Received)

AS Sieve size	150 mm	75 mm	53 mm	37.5 mm	26.5 mm	19.0 mm	13.2 mm	9.5 mm	6.7 mm	4.75 mm	2.36 mm	1.18 mm	600 um	425 um	300 um	150 um	75 um	13.2 um	0.02 um						
Percent Passing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						



Atterberg Limits (Test procedure)	Liquid Limit AS 1289 3.1.1	39	%	Plastic Limit AS 1289 3.2.1	22	%	Plasticity Index AS 1289 3.3.1	17 %
	Linear Shrinkage AS 1289 3.4.1	6.5	%	**AS1289 2.1.1, Moisture Content: 10.5 %**				

Remarks: Unless otherwise stated Atterberg Limits have been oven dried & dry sieved.
Linear Shrinkage moisture condition determined by AS1289 3.1.1

Form No 6. R1289 3.6.1 Issued 10.09.2013

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Page 1 of 1
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ABN: 35 102 659 754

Job No.
TPSD 018

Particle Size Distribution / Atterberg Limits

Client: .... Douglas Partners Pty Ltd, HUME ACT

Date Tested.... 12/02/19

Principal: .... Douglas Partners Pty Ltd

Project: .... Urban Capability Study Neighbourhoods 3 - 5, Project # 46285.44

Location: .... GOOGONG NSW

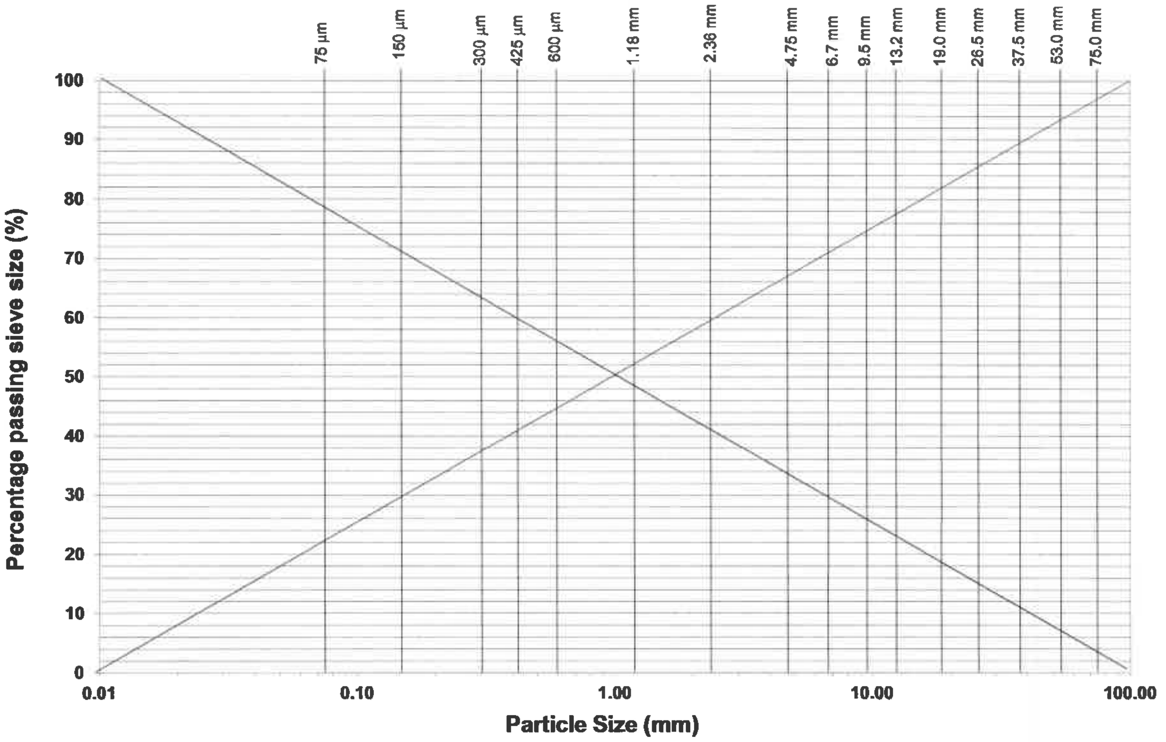
Sample Identification: **TPSD 018/S33**

Client ID: Pit 9, Depth: 0.5 m

Test Procedure: -

Sampled by the Client and Submitted 04/02/19 (Tested as Received)

AS Sieve size	150 mm	75 mm	53 mm	37.5 mm	26.5 mm	19.0 mm	13.2 mm	9.5 mm	6.7 mm	4.75 mm	2.36 mm	1.18 mm	600 um	425 um	300 um	150 um	75 um	13.2 um	0.02 um						
Percent Passing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						



Atterberg Limits (Test procedure)	Liquid Limit AS 1289 3.1.1	40	%	Plastic Limit AS 1289 3.2.1	21	%	Plasticity Index AS 1289 3.3.1	19 %
	Linear Shrinkage AS 1289 3.4.1	5.5	%	**AS1289 2.1.1, Moisture Content: 44.3 %**				

Remarks: Unless otherwise stated Atterberg Limits have been oven dried & dry sieved.
Linear Shrinkage moisture condition determined by AS1289 3.1.1

Form No 6. R1289 3.6.1 Issued 10.09.2013

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Page 1 of 1
Issue # 1

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Date of Issue: 27/02/2019

Appendix F

AGS Publication Extracts

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	5x10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5x10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5x10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5x10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5x10^{-6}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		**CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)**				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

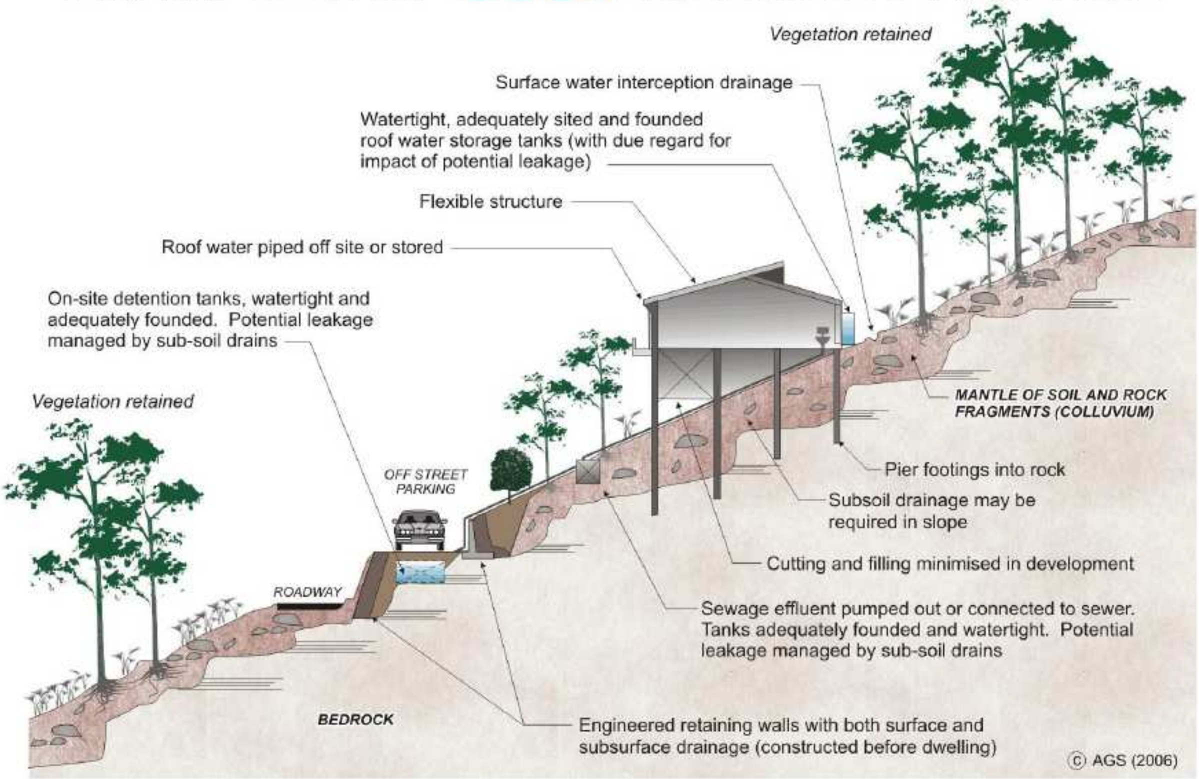
Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

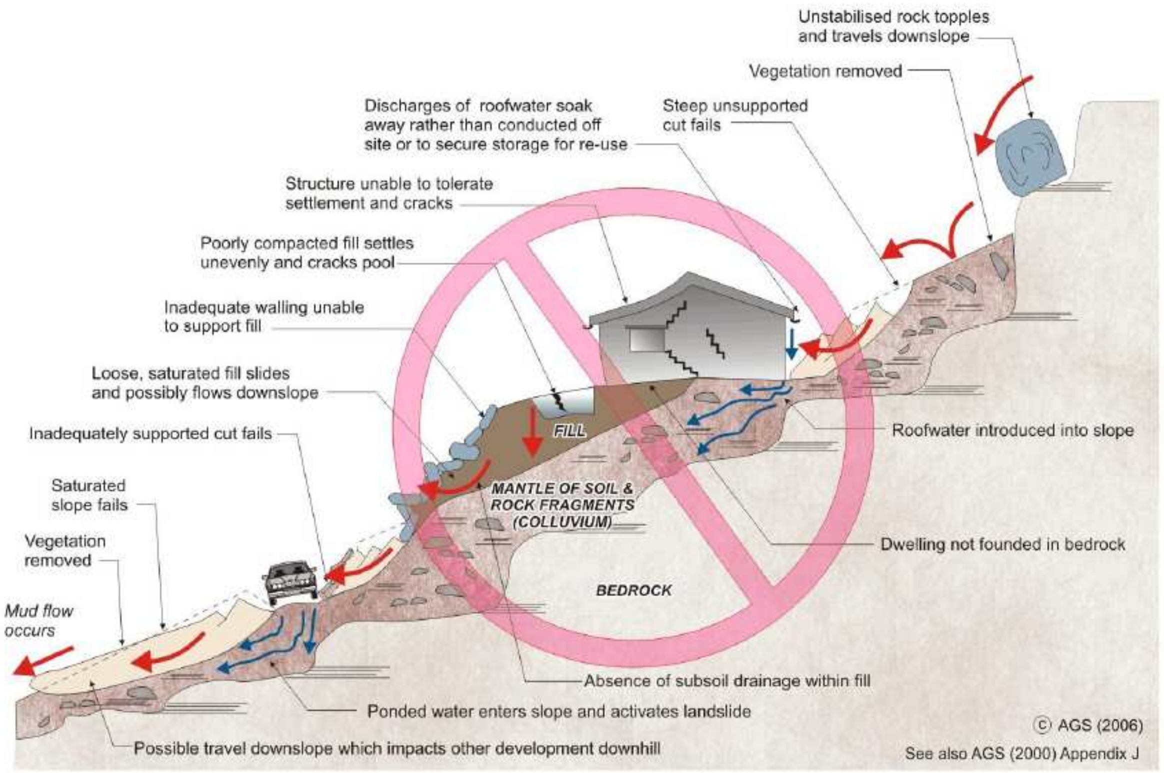
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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

EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



Appendix G

CSIRO Publication

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

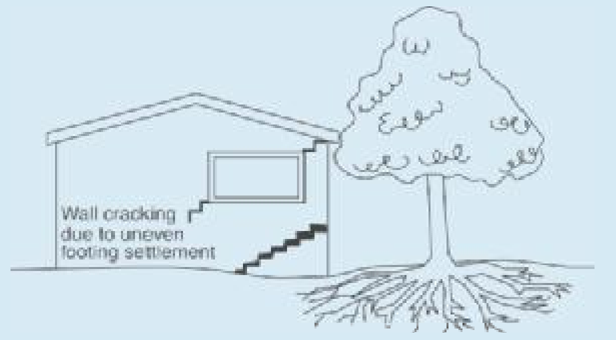
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

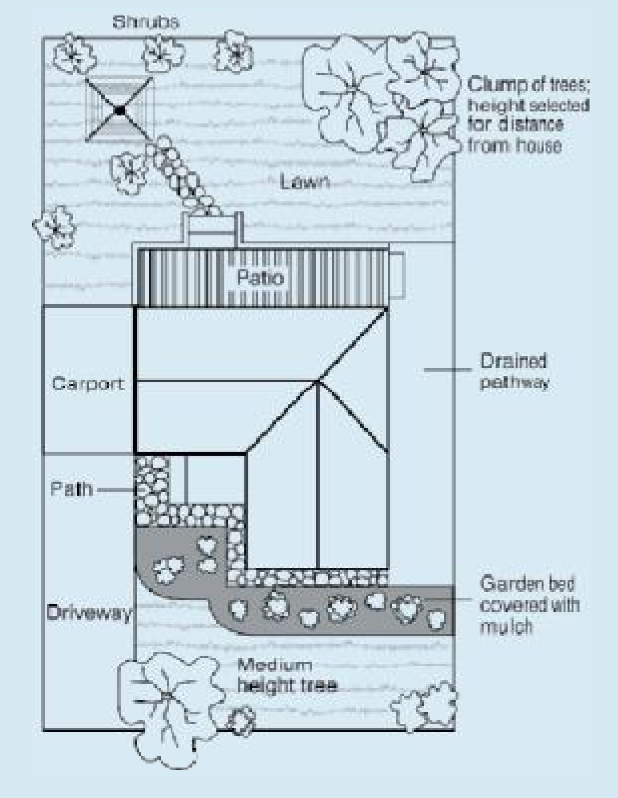
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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