



Geotechnical Investigation Report

Client: Dubbo Regional Council

Site Address: “Keswick Estate Stage 7, 8 and 9” Dubbo NSW

16 August 2024

Our Reference: 44935-GR01_A

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The accuracy of the advice provided in this report may be limited by unobserved variations in ground conditions across the site in areas between and beyond test locations and by any restrictions in the sampling and testing which was able to be carried out, as well as by the amount of data that could be collected given the project and site constraints. These factors may lead to the possibility that actual ground conditions and materials behaviour observed at the test locations may differ from those which may be encountered elsewhere on the site. If the sub-surface conditions are found to differ from those described in this report, we should be informed immediately to evaluate whether recommendations should be reviewed and amended if necessary.

Project Name:	"Keswick Estate Stage 7, 8 and 9" Dubbo NSW	
Client:	Dubbo Regional Council	
Project Number:	44935	
Report Reference:	44935-GR01_B	
Date:	16.08.2024	
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1. INTRODUCTION

The following is a report on the geotechnical assessment of a site in accordance with AS1726-2017 “Geotechnical Site Investigations”. General notes and abbreviations are outlined in **Appendix A**.

The site investigation was carried out by Barnson Pty Ltd, on behalf of Dubbo Regional Council.



Plate 1 – Area of Investigation – Nearmap 2024

Dubbo Regional Council is proposing to construct three new stages of Keswick Estate in Dubbo NSW. The proposed site features that are covered by this investigation are as follows;

- Proposed new stages of residential subdivision

The investigation comprised forty-three (43) boreholes together with field mapping near the site. Details of the field work and laboratory testing are given in the report together with comments relevant to design and construction practice. The borehole locations are presented in **Appendix B**.

1.1. Terminology

The methods used in this report to describe the soil profiles, including visual classification of material types encountered, are in accordance with Australian standard AS1726-2017 “Geotechnical Site Investigations”.

1.2. Limitations

The geotechnical section of Barnson Pty Ltd has conducted this investigation and prepared this report in response to specific instructions from the client to whom this report is addressed. This report is intended for the sole use of the client, and only for the purpose which it is prepared. Any third party who relies on the report or any representation contained in it does so at their own risk.

1.3. Geotechnical Testing

Representative samples from the site were subjected to the following range of tests in accordance with relevant method of Australian Standard AS1289:

- Linear Shrinkage
- Liquid Limit

NATA endorsed reports are attached in **Appendix C**.

Dynamic cone penetrometer (DCP) testing was conducted at representative locations. The DCP results are included in the borelogs.

2. GENERAL DESCRIPTION OF SITE

The site is situated in a residential area on the southeast of Dubbo NSW.

The site has light to moderate scattered grass and weed cover, with mature trees scattered over the site.

The site is generally sloping to the southwest. There are existing schools, residential dwellings and commercial buildings surrounding the area.



Plate 2 – General view of site facing west.



Plate 3 – General view of site facing northwest.



Plate 4 – General view of site facing east.



Plate 5 – General view of site facing southwest.



Plate 6 – General view of site facing east.

3. SITE HISTORY

A review of Google Earth imagery indicates the site is in similar condition as to when the image was taken in 2006. The site is therefore assumed to have no recent tree removal. Images exist back to 1985, yet the image is not clear enough to determine site features. See 2006 aerial image below:



Plate 7 – Aerial Image 2006, Courtesy Google Earth.

4. METHOD OF INVESTIGATION

On the 23rd and 24th of July 2024, a geotechnical investigation was carried out at the site of the above-mentioned development. The field drilling was carried out by a geotechnical technician who logged the boreholes on site and undertook geological mapping of the nearby area.

A drilling rig with a 90mm auger and tungsten tip was used to excavate thirty-seven (37) boreholes to target depths of 3.0m in proposed subdivision areas. These are identified as boreholes 1 through 37. Six (6) boreholes were drilled to target depths of 4.5m in proposed deep excavation areas. These are identified as boreholes 38 through 43.

4.1. GPS Co-Ordinates

The boreholes were drilled at representative locations. GPS Co-ordinates of these were recorded on site to enable plotting of the borehole locations. The following Table 1 shows these co-ordinates.

Table 1: GPS Co-Ordinates of Boreholes

Location	Longitude	Latitude
Borehole 1	148.643132	-32.264402
Borehole 2	148.643533	-32.266642
Borehole 3	148.641564	-32.266351
Borehole 4	148.638851	-32.266099
Borehole 5	148.637372	-32.266328
Borehole 6	148.638642	-32.266832
Borehole 7	148.640073	-32.266592
Borehole 8	148.640993	-32.266973
Borehole 9	148.642463	-32.267140
Borehole 10	148.644177	-32.267390
Borehole 11	148.643926	-32.268375
Borehole 12	148.643057	-32.268302
Borehole 13	148.642327	-32.267875
Borehole 14	148.641446	-32.267934
Borehole 15	148.640665	-32.267728
Borehole 16	148.638216	-32.267595
Borehole 17	148.636436	-32.267437
Borehole 18	148.636080	-32.268359
Borehole 19	148.638672	-32.268226
Borehole 20	148.640382	-32.269220
Borehole 21	148.643046	-32.269231
Borehole 22	148.642372	-32.269874

Location	Longitude	Latitude
Borehole 23	148.641059	-32.270052
Borehole 24	148.639430	-32.269823
Borehole 25	148.638456	-32.269888
Borehole 26	148.637823	-32.269307
Borehole 27	148.636753	-32.269203
Borehole 28	148.635795	-32.269577
Borehole 29	148.634136	-32.269041
Borehole 30	148.633694	-32.270118
Borehole 31	148.633627	-32.270846
Borehole 32	148.637405	-32.270934
Borehole 33	148.642521	-32.270565
Borehole 34	148.643105	-32.271420
Borehole 35	148.642589	-32.272063
Borehole 36	148.641315	-32.271154
Borehole 37	148.640846	-32.271817
Borehole 38	148.639602	-32.270880
Borehole 39	148.639288	-32.271436
Borehole 40	148.638298	-32.271365
Borehole 41	148.638421	-32.270883
Borehole 42	148.640722	-32.265608
Borehole 43	148.643965	-32.266050

The boreholes were recorded on site with a Garmin Oregon 550 handheld GPS, using GDA94 Datum. The co-ordinates have an accuracy of +/- 5m. These locations are also shown on site plan in **Appendix B**. The borehole logs of sub-surface profiles are attached in **Appendix C**

5. GENERAL SUB-SURFACE CONDITIONS

From the bore logs attached it can be seen that the soil encountered to the test end point was as follows:

5.1. Topsoil

A 0.1m-0.4m thick layer of topsoil was encountered at boreholes 1-28, 31-34, 36-38 and 40-43. The topsoil generally consisted of clayey sandy silts as shown in the borehole logs attached **Appendix C**.

5.2. Fill

Fill material was encountered at boreholes 30 and 39. The fill encountered was clays with gravel and gravels to the depths as shown in the borehole logs attached in **Appendix C**.

5.3. Sub-Soils

Alluvial soils were encountered throughout the boreholes. These comprised slightly moist silts and clays to the depths as shown in **Appendix C**. The clays were noted to be of a medium to high plasticity, which was confirmed with laboratory testing.

Drill refusal on rock occurred in some boreholes as noted on the borelogs.

5.4. Regional Geology

Reference to the Dubbo 1:250,000 Geological Map indicates the surrounding area consists of “Tholeiite, alkali basalt, basanite, nephelinite, limburgite, trachyte, rare obsidian.”.

Our investigation encountered alluvial soils overlying high strength igneous rock.

5.5. Igneous Rock

Igneous rock (drill refusal) was encountered at the below borehole locations shown in Table 2. The igneous rock was noted to be of a high strength. T.C Bit refusal and bouncing was encountered on the below boreholes at varying depths of 0.2m-2.3m. Borelogs of the sub-surface profiles are attached in **Appendix C** providing all details of the profiles encountered. The target depth was reached for the boreholes not listed in Table 2.

Table 2: Boreholes with Rock Encountered

Borehole No.	Depth (m) Rock Encountered
Borehole 1	0.45
Borehole 2	0.75
Borehole 3	0.85
Borehole 7	0.25
Borehole 9	1.3
Borehole 10	0.8
Borehole 11	0.2
Borehole 12	0.5
Borehole 13	0.45
Borehole 15	0.85
Borehole 17	0.2
Borehole 20	1.1
Borehole 22	2.3
Borehole 23	1.5
Borehole 25	1.1
Borehole 29	0.2
Borehole 30	1.0
Borehole 31	1.5
Borehole 33	1.1
Borehole 34	0.4
Borehole 36	1.7
Borehole 42	0.5
Borehole 43	1.8

6. NATA LABORATORY TESTING

Disturbed samples were taken during the field investigation. Laboratory testing was carried out on selected samples of all different material types, with details of the sampling and testing shown below:

Soil Index Properties testing was carried out on samples to aid in classification of the soils encountered and to assist in determining design parameters. This testing results are presented in **Appendix D** and indicated below:

6.1. Linear Shrinkage Testing (L.S)

Table 3: Linear Shrinkage Results

Borehole No.	Depth (m)	Linear Shrinkage (%)
Borehole 1	0.4	8.0
Borehole 2	0.7	16.5
Borehole 3	0.8	13.0
Borehole 4	1.0	16.0
Borehole 5	2.0	20.0
Borehole 6	3.0	16.0
Borehole 7	0.2	7.0
Borehole 8	2.0	20.0
Borehole 9	1.3	14.5
Borehole 10	0.8	17.0
Borehole 11	0.2	5.0
Borehole 12	0.5	3.5
Borehole 13	0.4	6.5
Borehole 14	2.0	21.0
Borehole 15	0.8	14.0
Borehole 16	1.0	19.0
Borehole 17	0.2	8.0

Borehole No.	Depth (m)	Linear Shrinkage (%)
Borehole 18	3.0	19.5
Borehole 19	1.0	17.0
Borehole 21	0.4	5.5
Borehole 22	1.0	13.5
Borehole 23	1.5	13.0
Borehole 24	3.0	22.0
Borehole 25	1.0	12.0
Borehole 26	2.0	14.5
Borehole 27	3.0	19.0
Borehole 28	1.0	13.0
Borehole 30	0.9	15.0
Borehole 31	1.0	5.0
Borehole 32	2.0	18.5
Borehole 33	1.0	15.0
Borehole 35	2.0	16.5
Borehole 36	1.7	18.5
Borehole 37	1.0	15.0
Borehole 38	2.0	17.0
Borehole 39	3.0	17.0
Borehole 40	4.0	17.5
Borehole 41	1.0	9.0
Borehole 42	0.5	9.0
Borehole 43	1.8	18.5

The above test results confirm the material as highly variable ranging from low to very high plasticity.

6.2. Seasonal Surface Movement

The soil profiles, depths and linear shrinkage laboratory results are variable.

The estimated seasonal ground surface movement (Y_s) across the subdivision is expected to be highly variable and dependant on the soil reactivity, shrink swell properties and soil profile.

Site classification geotechnical assessments will be required for individual Lots to assist in residential dwelling structural design.

7. SITE EARTHWORKS RECOMMENDATIONS

7.1. Excavations

Excavations within the natural silt and clay will be achievable using conventional earthmoving equipment. Excavations into the high strength igneous rock may require larger equipment and ripping or hammering.

The civil contractor should be responsible for selecting excavation equipment based on the proposed excavation depths and equipment capabilities.

7.2. General Construction Filling

All earthworks performed on site must be undertaken in a controlled manner, in accordance with a suitable earthwork's specification. Filling should be placed, compacted, inspected and tested in accordance with the Level 2 requirements of AS3798-2007.

7.3. General Bulk Fill Material

All general fill materials used shall be approved clean, hard material, deposited and compacted in the locations specified. Unless notified otherwise, general fill shall be sourced from excavations within the project area. The following conditions should also be satisfied:

- General filling must be compacted to a minimum dry density ratio of 98-100% relative to standard compaction at a moisture content of -2% to +2% of standard optimum moisture content.
- Filling should proceed in layers of 300mm maximum loose thicknesses.
- Layers of filling should be horizontal or benched to suit the surrounding topography.
- The existing subgrade should NOT be used as bulk fill, due to high plasticity.

7.4. Temporary Batter Slopes

Temporary batter slopes in soil should be graded no steeper than 2 Horizontal (H) in 1 Vertical (V), and protected from erosion by re-directing any surface water flows from the batter face, revegetating etc.

7.5. Permanent Batter Slopes

Permanent Batter slopes in clay should be no steeper than 3 Horizontal (H) in 1 Vertical (V) and protected from erosion. Alternatively, fill embankments may be retained with properly designed and constructed retaining walls.

8. CONCLUSION

The testing methods adopted are indicative of the site's sub-surface conditions to the depths excavated and to specific sampling and/or testing locations in this investigation, and only at the time the work was carried out.

The accuracy of geotechnical engineering advice provided in this report may be limited by unobserved variations in ground conditions across the site in areas between and beyond test locations and by any restrictions in the sampling and testing which was able to be carried out, as well as by the amount of data that could be collected given the project and site constraints.

These factors may lead to the possibility that actual ground conditions and materials behaviour observed at the test locations may differ from those which may be encountered elsewhere on the site.

If the sub-surface conditions are found to differ from those described in this report, we should be informed immediately to evaluate whether recommendations should be reviewed and amended if necessary.

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APPENDIX A

General Notes

GEOTECHNICAL INVESTIGATION GENERAL NOTES

This report contains the results of a geotechnical investigation conducted for a specific purpose and client. The results should not be used by other parties, or for other purposes, as they may contain neither adequate nor appropriate information. In particular, the investigation does not cover contamination issues unless specifically required to do so by the client.

TEST HOLE LOGGING

The information on the test hole logs (boreholes, test pits, exposures etc.) is based on a visual and tactile assessment, except at the discrete locations where the test information is available (field and/or laboratory results). The borehole logs include both factual data and inferred information. Reference should be made to the relevant sheets for the explanation of logging procedures (Soil and Rock Descriptions, Core Log Sheet Notes etc).

GROUNDWATER

Unless otherwise indicated, the water levels presented on the borehole logs are the levels of free water or seepage in the bore hole recorded at the given time of measuring. The actual groundwater level may differ from this recorded level depending on material permeability's (i.e. depending on response time of the measuring instrument). Further, variations of this level could occur with time due to such effects as seasonal, environmental and tidal fluctuations or construction activities. Confirmation of groundwater levels, phreatic surfaces or piezometric pressures can only be made by appropriate instrumentation techniques and monitoring programmes.

INTERPRETATION OF RESULTS

The discussion or recommendations contained within this report normally are based on a site evaluation from discrete borehole area. Generalised, idealised or inferred subsurface conditions (including any geotechnical cross-sections) have been assumed or prepared by interpolation and/or extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in the generalised ground conditions do occur in the natural environment, particularly between discrete borehole locations. Additionally, certain design or construction procedures may have been assumed in assessing the soil-structure interaction behaviour of the site. Furthermore, conditions may change at the site from those encountered at the time of the geotechnical investigation through construction activities and constantly changing natural forces.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed or reported should be referred to this firm for appropriate assessment and comment.

GEOTECHNICAL VERIFICATION

Verification of the geotechnical assumptions and/or model is an integral part of the design process – investigation, construction verification and performance monitoring. Variability is a feature of the natural environment and, in many instances, verification of soil or rock quality, or foundation levels are required. There may be a requirement to extend foundation depths to modify a foundation system or to conduct monitoring as a result of this natural variability. Allowance for verification by geotechnical personnel accordingly should be recognised and programmed during construction.

FOUNDATIONS

Where referred to in the report, the soil or rock quality, or the recommendation depth of any foundation (piles, caissons footings etc.) is an engineering estimate. The estimate is influenced and perhaps limited, by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The material quality and/or foundation depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications should provide for variations in the final depth, depending upon the ground conditions at each point of support, and allow for geotechnical verification.

REPRODUCTION OF REPORTS

Where it is desired to reproduce the information contained in our geotechnical report, or other technical information, for the inclusion in contract documents or engineering specification of the subject development, such reproductions should include at least all of the relevant test hole and test data, together with the appropriate standard description sheets and remarks made in the written report of a factual or descriptive nature.

Reports are the subject of copyright and shall not be reproduced either totally or in part without the express permission of this firm.

ROCK

Rock Strength

Rock strength is a scale of strength, based on point load index testing, or field testing.

Term	Letter Symbol	Point load index (MPa) Is (50)	Field guide to strength
Extremely low	EL	< 0.03	Easily remoulded by hand to a material with soil properties.
Very low	VL	0.03 – 0.1	Material crumbles under firm blows with sharp end of pick.
Low	L	0.1 – 0.3	Easily scored by knife, has dull sound under hammer.
Medium	M	0.3 – 1.0	Readily scored with knife, core pieces broken by hand with difficulty
High	H	1 – 3	Rock rings under hammer, core piece broken by pick only.
Very high	VH	3 – 10	Hand specimen breaks with pick after more than one blow.
Extremely high	EH	> 10	Hand specimen breaks with pick after several than one blow.

Rock Weathering

Rock weathering is the degree of rock weathering, determined in the field.

Term	Letter Symbol	Definition
Residual soil	RS	Soil developed on extremely weathered rock.
Extremely weathered rock	XW	Soil is weathered to such an extent that it has soil properties, i.e. it disintegrates or can be remoulded in water.
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be discoloured, usually by iron staining, porosity is increased.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

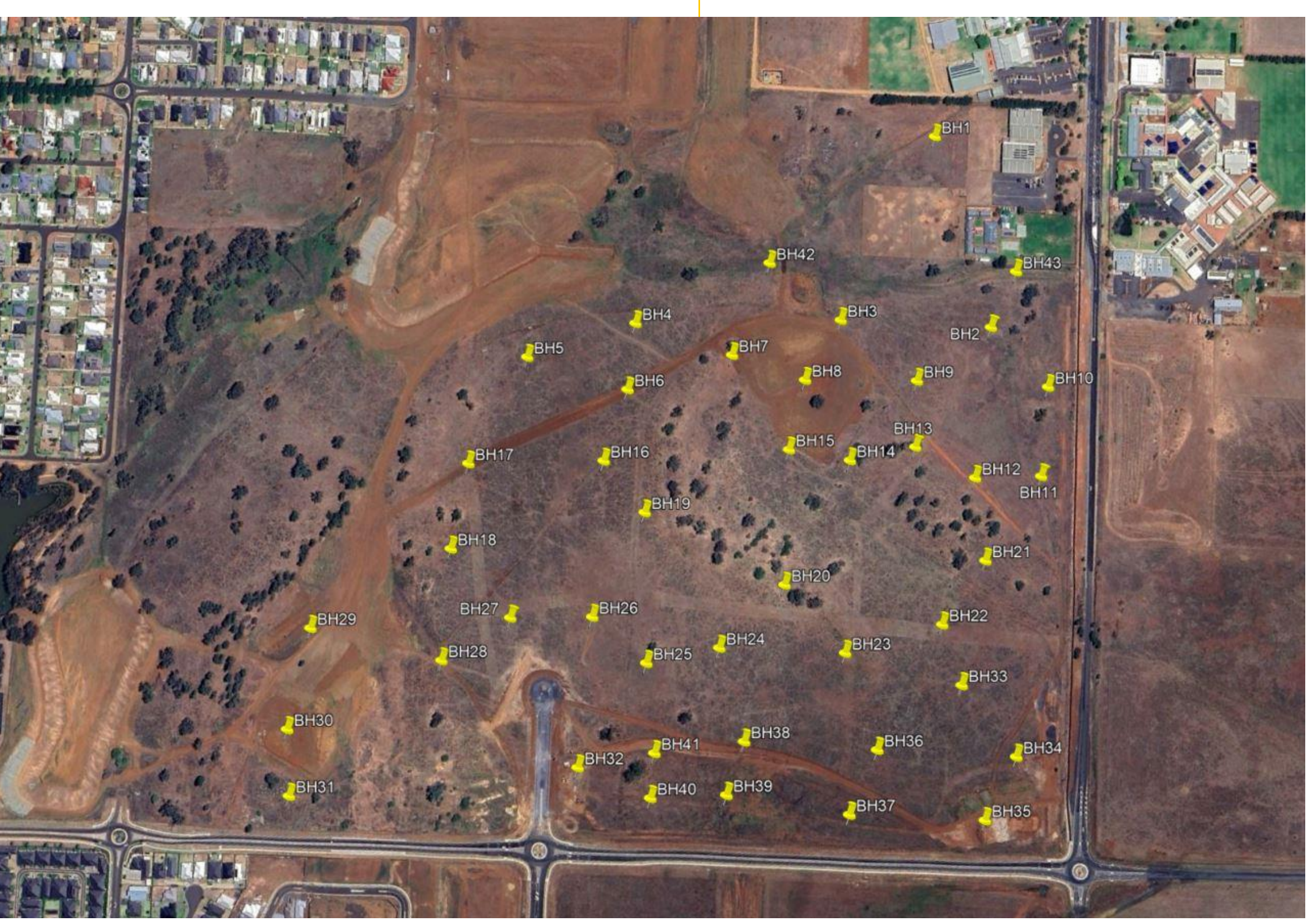
GRAPHIC SYMBOLS FOR SOIL & ROCK

<u>SOIL</u>		<u>SEDIMENTARY ROCK</u>	
	BITUMINOUS CONCRETE		BOULDER CONGLOMERATE
	CONCRETE		CONGLOMERATE
	TOPSOIL		CONGLOMERATIC SANDSTONE
	FILLING		SANDSTONE FINE GRAINED
	PEAT		SANDSTONE COARSE GRAINED
	CLAY		SILTSTONE
	SILTY CLAY		LAMINITE
	SANDY CLAY		MUDSTONE, CLAYSTONE, SHALE
	GRAVELLY CLAY		COAL
	SHALY CLAY		LIMESTONE
	SILT		
	CLAYEY SILT		
	SANDY SILT		
	SAND		
	CLAYEY SAND		
	SILTY SAND		
	GRAVEL		
	SANDY GRAVEL		
	COBBLES/BOULDERS		
	TALUS		
<u>SEAMS</u>		<u>METAMORPHIC ROCK</u>	
	SEAM >10mm		SLATE, PHYLLITE, SCHIST
	SEAM <10mm		GNEISS
			QUARTZITE
		<u>IGNEOUS ROCK</u>	
			GRANITE
			DOLERITE, BASALT
			TUFF
			PORPHYRY



APPENDIX B

Site Plan & Borehole Locations



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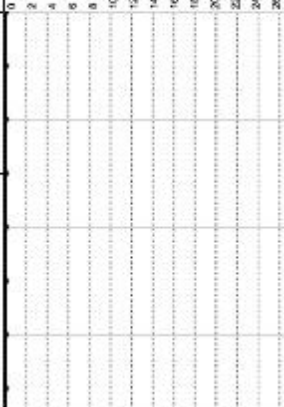
APPENDIX C

Borehole Logs

Latitude : -32.266642
Longitude : 148.643533
Total Depth : 0.75 m

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Logged By : GW
Date : 23/07/2024

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
	0.3		TS	Topsoil Sandy SILT soft, low plasticity, brown, fine grained sand, w > pl.			
			CH	Alluvial Silty to sandy CLAY stiff, high plasticity, brown, fine grained sand, w > pl.			
				LS = 16.5%			
				Borehole 2 refusal at 0.75m (refusal on igneous rock)			
	1						
	2						

Latitude : -32.266351

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.641564

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.85 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.3	TS	TS	Topsoil Sandy SILT soft, low plasticity, brown, fine grained sand, w > pl.			
		Cl-CH	Cl-CH	Alluvial Sandy to silty CLAY stiff, medium to high plasticity, brown, fine grained sand, w > pl.		L.S. = 13.0%	
				Borehole 3 refusal at 0.85m (Refusal on Igneous Rock)			
	1						
	2						

Latitude : -32.266099

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.638851

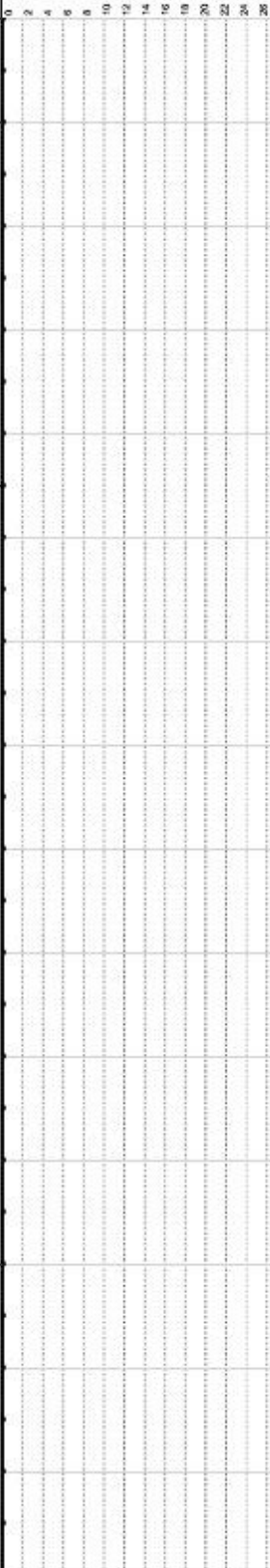
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples		Remarks
						Disturbed sample		
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w = pl.				
			CI-CH	Alluvial Sandy to silty CLAY stiff, medium to high plasticity, brown-red, fine grained sand, trace fine sized gravel, w = pl.				
	0.9							
	1		CH	Alluvial Sandy to silty CLAY hard, high plasticity, brown, fine grained sand, trace fine sized gravel, w < pl.		LS = 16.0%		
			SM	Alluvial Sandy SILT hard, low plasticity, pale brown, fine to medium grained sand, trace fine sized gravel, trace low to medium plasticity clay, w < pl.				
Borehole 4 Terminated at 3m								

Project : Geotechnical Investigation

Borehole 5 Terminated at 3m

Latitude : -32.266832

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.638642

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w = pl to w > pl.			
	0.2		CS-CH	Alluvial Sandy to silty CLAY stiff to very stiff, medium to high plasticity, brown, fine grained sand, w < pl to w = pl.			
	2.2		CH	Alluvial Sandy CLAY hard, high plasticity, pale brown-yellow, medium grained sand, trace fine sized gravel, w < pl.			
Borehole 6 Terminated at 3m						LS = 16.0%	

Latitude : -32.266592

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.640073

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.25 m

Date : 23/07/2024

Project : Geotechnical Investigation

Borehole Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC		TS	TS	Topsoil Clayey to sandy SILT firm, low to medium plasticity, brown, fine grained sand, with medium to coarse sized gravel, w > pl.	0 2 4 6 8 10 12 14 16 18 20 22 24 26 28	LS = 7.0%	
				Borehole 7 refusal at 0.25m (Refusal on Igneous Rock)			
	1						
	2						

Latitude : -32.266973

Location : "Kerwick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.640993

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, brown, fine grained sand, trace medium sized gravel, w > pl.			
	0.8		Cl-CH	Alluvial Sandy to silty CLAY stiff to very stiff, medium to high plasticity, brown-red, fine grained sand, w = pl.			
	1.3		CH	Alluvial Silty to sandy CLAY hard, high plasticity, brown-red, fine grained sand, w = pl.			
	2.1		ML	Alluvial Clayey to sandy SILT hard, low to medium plasticity, yellow-grey, fine grained sand, w < pl.			
	2.1					LS = 20.0%	
Borehole 8 Terminated at 3m							

Latitude : -32.267140

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.642463

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1.3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.1		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w ≈ pl.			
			Cl-SH	Alluvial Sandy to silty CLAY stiff, medium to high plasticity, brown-red, fine grained sand, w ≈ pl.			
	0.9		Cl-SH	Alluvial Silty to sandy CLAY hard, medium to high plasticity, brown, fine grained sand, with medium sized gravel, w < pl.			
	1					LS - 14.5%	
				Borehole 9 refusal at 1.3m (Refusal on Igneous Rock)			
	2						

Latitude : -32.267390

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.644177

Logged By : GW

Client : Dubbo Regional Council

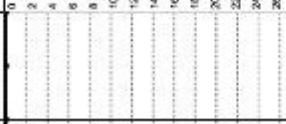
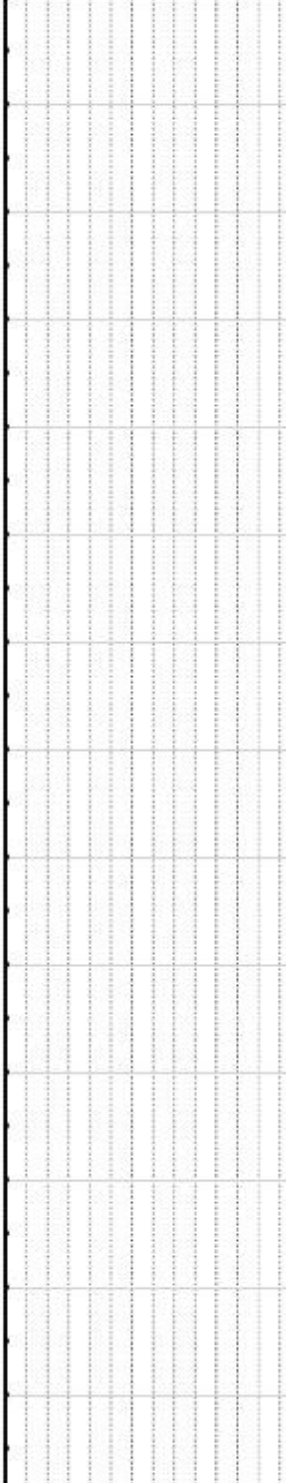
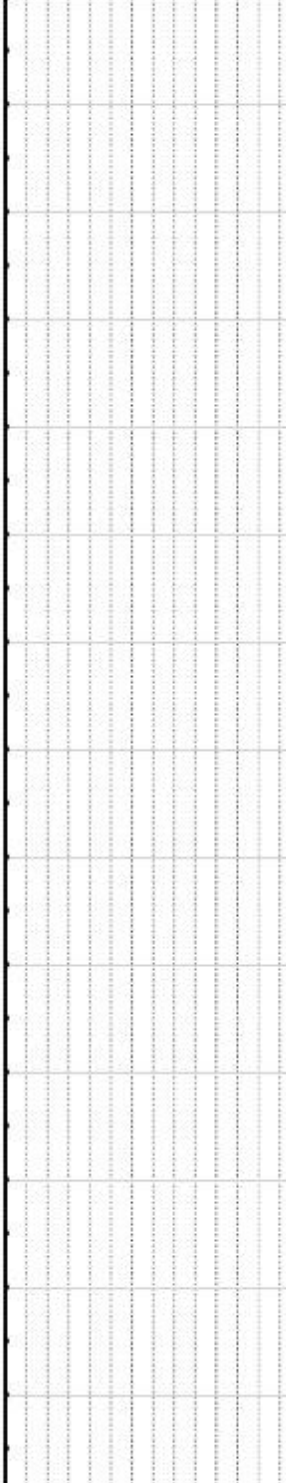
Total Depth : 0.8 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
					0 2 4 6 8 10 12 14 16 18 20 22 24 26 28	Disturbed sample	
Auger drill with TC bit	0.3		TS	Topsoil Sandy SILT soft, low plasticity, brown, fine grained sand, w > pl.			
			CI-CH	Alluvial Sandy to silty CLAY stiff, medium to high plasticity, brown, fine grained sand, w > pl.			
						LS = 17.0%	
				Borehole 10 refusal at 0.8m (Refusal on Igneous Rock)			
	1						
	2						

Latitude : -32.268375 Location : "Kerwick Estate Stage 7, 8 and 9" Dubbo NSW Job Number : 44935
Longitude : 148.643926 Logged By : GW Client : Dubbo Regional Council
Total Depth : 0.2 m Date : 23/07/2024 Project : Geotechnical Investigation

Borehole Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC			TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, red, fine grained sand, with coarse sized gravel, w = pl.			
						LS = 5.0%	
Auger drill with TC	1			Borehole 11 refusal at 0.2m (Refusal on Igneous Rock)			
Auger drill with TC	2			Borehole 11 refusal at 0.2m (Refusal on Igneous Rock)			

Latitude : -32.268302

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.643057

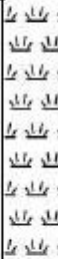
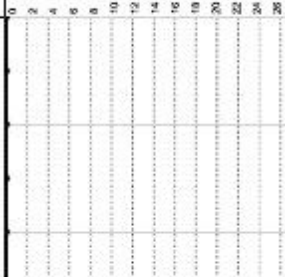
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.5 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit			TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, red, fine grained sand, with coarse sized gravel, w = pl.			
						LS = 3.5%	
				Borehole 12 refusal at 0.5m (Refusal on Igneous Rock)			

Latitude : -32.267875

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.642327

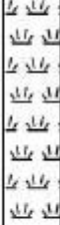
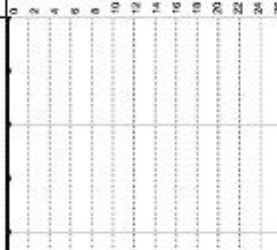
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.45 m

Date : 23/07/2024

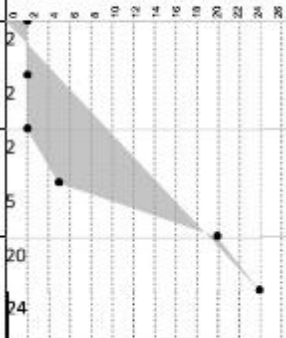
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit			TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, red, fine grained sand, with coarse sized gravel, w = pl.			
				Borehole 13 refusal at 0.45m (Refusal on Igneous Rock)			

Latitude : -32.267934
 Longitude : 148.641446
 Total Depth : 3 m

 Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
 Logged By : GW
 Date : 23/07/2024

 Job Number : 44935
 Client : Dubbo Regional Council
 Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w = pl.			
	0.4		CI	Alluvial Sandy to silty CLAY stiff to very stiff, medium plasticity, brown, fine grained sand, trace medium sized gravel, w = pl.			
	1.0		CI	Alluvial Silty to sandy CLAY hard, medium plasticity, brown, fine grained sand, trace medium sized gravel, w = pl.			
	1.3		CI	Alluvial Sandy to silty CLAY hard, medium plasticity, grey, fine to medium grained sand, with fine to medium sized gravel, w < pl.			
	2.0		CH	Alluvial Silty to sandy CLAY hard, high plasticity, yellow, fine grained sand, w < pl.			
						LS = 21.0%	
Borehole 14 Terminated at 3m							

Latitude : -32.267728

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.640665

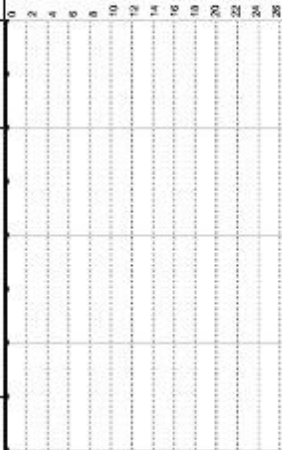
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.85 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w = pl.			
	0.7		Cl-CH	Alluvial Sandy to silty CLAY stiff, medium to high plasticity, brown, fine grained sand, trace medium sized gravel, w = pl.			
			Cl-CH	Alluvial Silty to sandy CLAY hard, medium to high plasticity, grey, fine grained sand, with medium sized gravel, w < pl.		LS = 14.0%	
	1			Borehole 15 refusal at 0.85m (Refusal on Igneous Rock)			
	2						

Latitude : -32.267595

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.638216

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w = pl.			
	1.1		CH	Alluvial Silty to sandy CLAY stiff, high plasticity, brown-dark brown, fine grained sand, w = pl.			
	2.3		CI	Alluvial Silty to sandy CLAY hard, medium plasticity, brown, fine grained sand, trace fine sized gravel, w < pl.			
			SM	Alluvial Sandy SILT hard, low plasticity, pale brown, fine grained sand, trace low to medium plasticity clay, w < pl.			
Borehole 16 Terminated at 3m							

LS = 19.0%

Latitude : -32.267437

Location : "Kerwick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.636436

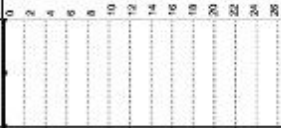
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.2 m

Date : 23/07/2024

Project : Geotechnical Investigation

Boring Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC			TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, red, fine grained sand, with coarse sized gravel, w = pl.			
						LS = 8.0%	
Auger drill with TC	1			Borehole 17 refusal at 0.2m (Refusal on Igneous Rock)			
	2						

Latitude : -32.268359

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.636080

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.4		TS	Topsoil Sandy SILT soft to firm, low plasticity, brown, fine grained sand, w > pl.			
	0.8		CI	Alluvial Silty to sandy CLAY firm, medium plasticity, brown, fine grained sand, w < pl to w = pl.			
	1		CI	Alluvial Silty to sandy CLAY very stiff to hard, medium plasticity, brown, fine grained sand, w < pl to w = pl.			
	2.5		CH	Alluvial Silty to sandy CLAY hard, high plasticity, grey, fine grained sand, trace fine sized gravel, w < pl.			
Borehole 18 Terminated at 3m						LS = 19.5%	

Project : Geotechnical Investigation

Borehole 19 Terminated at 3m

Latitude : -32.269220
Longitude : 148.640382
Total Depth : 1.1 m

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
 Logged By : GW
 Date : 23/07/2024

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
Auger drill with TC bit	0.3		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w ≈ pl.			
	1		SM	Alluvial Sandy SILT very stiff to hard, low plasticity, brown, fine grained sand, with medium to coarse sized gravel, w < pl.			
	2			Borehole 20 refusal at 1.1m (Refusal on Igneous Rock)			

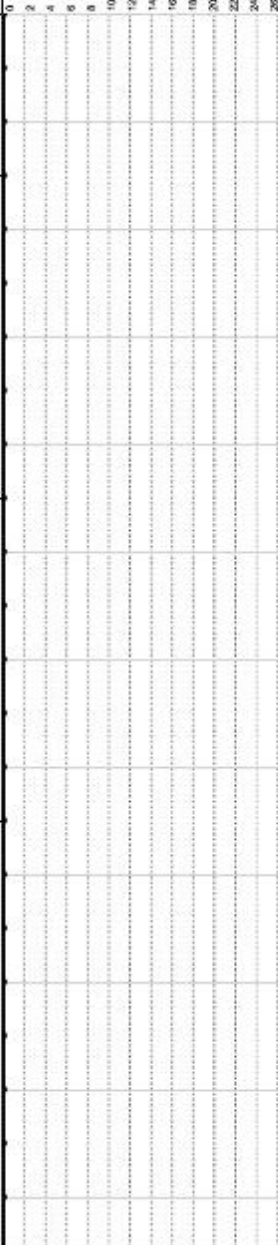
Project : Geotechnical Investigation

Borehole 21 Terminated at 3m

Latitude : -32.269874
Longitude : 148.642372
Total Depth : 2.3 m

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Logged By : GW
Date : 23/07/2024

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.3		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w ≈ pl.			
	0.9		CI	Alluvial Sandy to silty CLAY stiff to very stiff, medium plasticity, brown-red, fine grained sand, w < pl.			
	1		CI-CH	Alluvial Silty to sandy CLAY very stiff to hard, medium to high plasticity, brown, fine grained sand, trace medium sized gravel, w < pl.		LS = 13.5%	
	1.5		SM	Alluvial Sandy SILT hard, low plasticity, grey, fine grained sand, trace fine sized gravel, trace low plasticity clay, w < pl.			
	2						
				Borehole 22 refusal at 2.3m (Refusal on Igneous Rock)			

Latitude : -32.270052

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.641059

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1.5 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples		Remarks
						Disturbed sample		
Auger drill with TC bit	0.3		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w = pl to w < pl.				
	0.7		CL	Alluvial Sandy to silty CLAY stiff to very stiff, low plasticity, brown, fine grained sand, w < pl.				
	1		CI	Alluvial Sandy to silty CLAY hard, medium plasticity, grey-brown, fine grained sand, with fine to medium sized gravel, w < pl.				
						LS = 13.0%		
	2			Borehole 23 refusal at 1.5m (Refusal on Igneous Rock)				

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Borehole 24 Terminated at 3m

Latitude : -32.269888
Longitude : 148.638456
Total Depth : 1.1 m

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Logged By : GW
Date : 23/07/2024

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

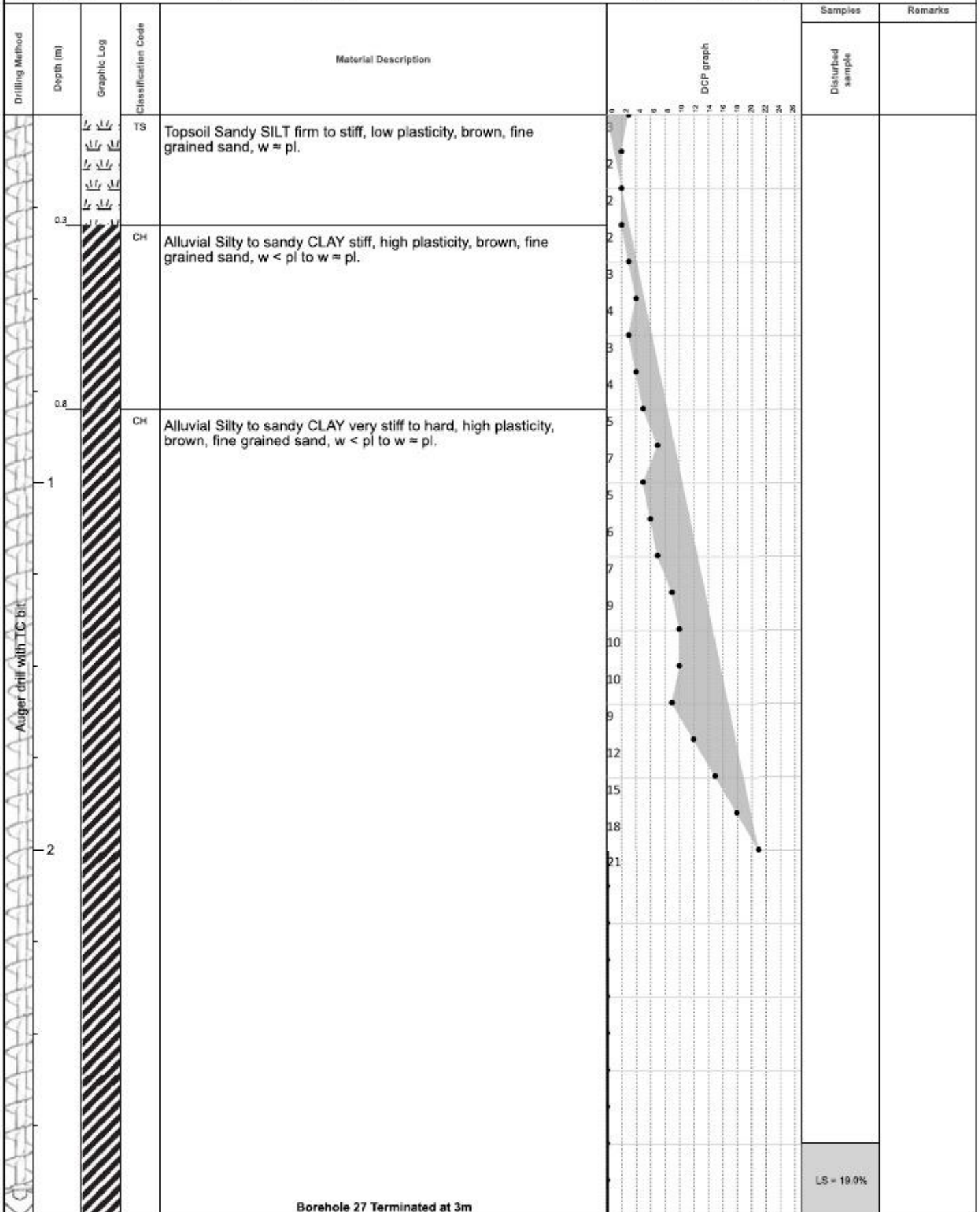
Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.1		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w ≈ pl.			
	CI		Alluvial Sandy to silty CLAY very stiff to hard, medium plasticity, red-brown, fine grained sand, w < pl.				
	1					LS = 12.0%	
	2			Borehole 25 refusal at 1.1m (Refusal on Igneous Rock)			

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

[illegible]

Latitude : -32.269203
 Longitude : 148.636753
 Total Depth : 3 m

 Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
 Logged By : GW
 Date : 23/07/2024

 Job Number : 44935
 Client : Dubbo Regional Council
 Project : Geotechnical Investigation


Latitude : -32.269577

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.635795

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.3	TS	TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w ≈ pl.			
	0.9	Cl-CH	Cl-CH	Alluvial Sandy to silty CLAY stiff to very stiff, medium to high plasticity, brown-red, fine grained sand, w < pl.			
	1	Cl	Cl	Alluvial Silty to sandy CLAY hard, medium plasticity, grey, fine grained sand, trace fine to medium sized gravel, w < pl.		LS = 13.0%	
Borehole 28 Terminated at 3m							

Latitude : -32.269041

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.634136

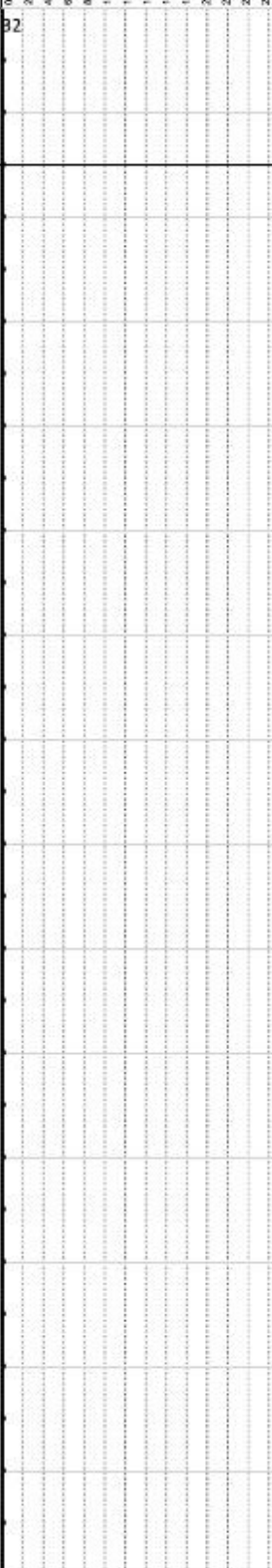
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
Auger drill with TC bit			GM	Alluvial Sandy to silty GRAVEL very dense, brown, medium to coarse sized, fine to medium grained sand, dry.			
				Borehole 29 refusal at 0.3m (Refusal on Igneous Rock)			

Latitude : -32.270118

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.633694

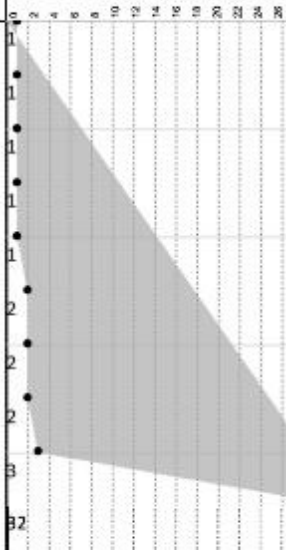
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
 Auger drill with TO bit	1		CH	Fill Silty to sandy CLAY high plasticity, soft to firm, brown, fine grained sand, trace medium sized gravel, organic, w > pl.			
						LS = 15.0%	
				Borehole 30 refusal at 1m (Refusal on Igneous Rock)			
	2						

Latitude : -32.270846

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.633627

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1.5 m

Date : 23/07/2024

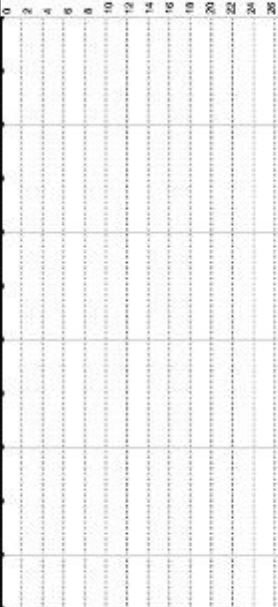
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples		Remarks
						Disturbed sample		
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w = pl.				
	0.9		CI	Alluvial Sandy to silty CLAY stiff to very stiff, medium plasticity, brown-red, fine grained sand, trace fine to medium sized gravel, w = pl.				
	1		SM	Alluvial Sandy SILT hard, low plasticity, grey, fine grained sand, with fine to medium sized gravel, trace low plasticity clay, w < pl.		LS = 5.0%		
	2			Borehole 31 refusal at 1.5m (Refusal on Igneous Rock)				

Latitude : -32.270565
Longitude : 148.642521
Total Depth : 1.1 m

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Logged By : GW
Date : 23/07/2024

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w ≈ pl.			
			CI	Alluvial Sandy to silty CLAY stiff to very stiff, medium plasticity, brown, fine grained sand, w ≈ pl.			
	0.9		CH	Alluvial Silty to sandy CLAY hard, high plasticity, grey, fine grained sand, trace medium sized gravel, w < pl.			
	1					LS = 15.0%	
				Borehole 33 refusal at 1.1m (Refusal on Igneous Rock)			
	2						

Latitude : -32.271420 Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW Job Number : 44935
Longitude : 148.643105 Logged By : GW Client : Dubbo Regional Council
Total Depth : 0.4 m Date : 23/07/2024 Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
Auger drill with TQ bit			TS	Topsoil Clayey to sandy SILT stiff, low to medium plasticity, red, fine grained sand, with coarse sized gravel, w ≈ pl.			
				Borehole 34 refusal at 0.4m (Refusal on Igneous Rock)			

Job Number : 44935

Client : Dubbo Regional Council

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0		CI	Alluvial Sandy to silty CLAY very stiff, medium plasticity, brown, fine grained sand, w = pl.			
	CH		Alluvial Silty to sandy CLAY hard, high plasticity, brown, fine grained sand, trace fine sized gravel, w < pl.	LS = 16.5%			
	CI		Alluvial Sandy to silty CLAY hard, medium plasticity, pale brown, fine grained sand, trace fine to medium sized gravel, w < pl.				
Borehole 35 Terminated at 3m							

Latitude : -32.271154

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.641315

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1.7 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.3		TS	Topsoil Sandy SILT stiff, low plasticity, brown, fine grained sand, w = pl.			
	1		CI	Alluvial Silty CLAY stiff, medium plasticity, brown, w = pl.			
	1.3		CH	Alluvial Silty to sandy CLAY hard, high plasticity, brown, fine to medium grained sand, trace fine sized gravel, w < pl.			
						LS = 18.5%	
	2			Borehole 36 refusal at 1.7m (Refusal on Igneous Rock)			

Latitude : -32.271817

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.640846

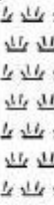
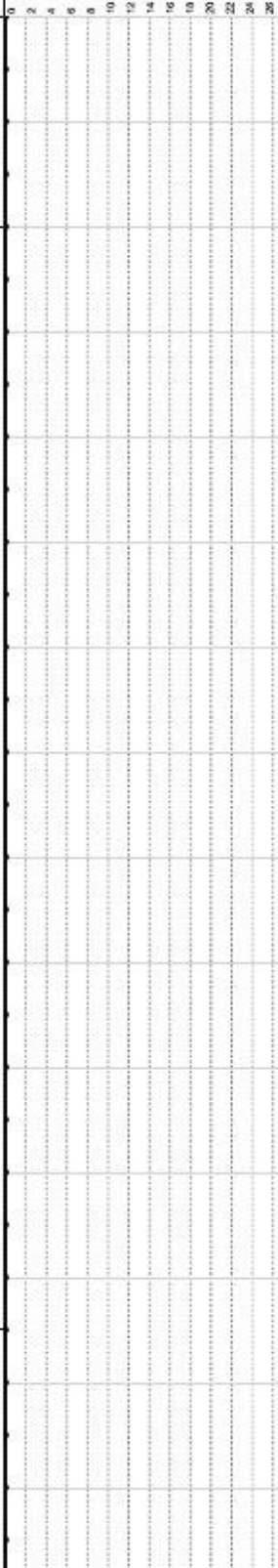
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 3 m

Date : 23/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.4		TS	Topsoil Sandy SILT firm, low plasticity, brown, fine grained sand, w > pl.			
	1		CH	Alluvial Silty CLAY stiff to very stiff, high plasticity, brown, w = pl.		LS = 15.0%	
	2.5		CI-CH	Alluvial Silty CLAY hard, medium to high plasticity, brown, trace fine sized gravel, w < pl.			
Borehole 37 Terminated at 3m							

Latitude : -32.270880

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.639602

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 4.5 m

Date : 24/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
					0 2 4 6 8 10 12 14 16 18 20 22 24 26	Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Clayey to sandy SILT stiff to very stiff, low plasticity, brown, fine grained sand, w ≈ pl.			
			CH	Alluvial Sandy to silty CLAY very stiff to hard, high plasticity, brown-red, fine grained sand, w ≈ pl to w < pl.			
	2					LS = 17.0%	
	3		CI	Alluvial Sandy to silty CLAY hard, medium plasticity, red-brown, fine grained sand, trace medium sized gravel, w < pl.			
	4						
Borehole 38 Terminated at 4.5m							

Latitude : -32.271436

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.639288

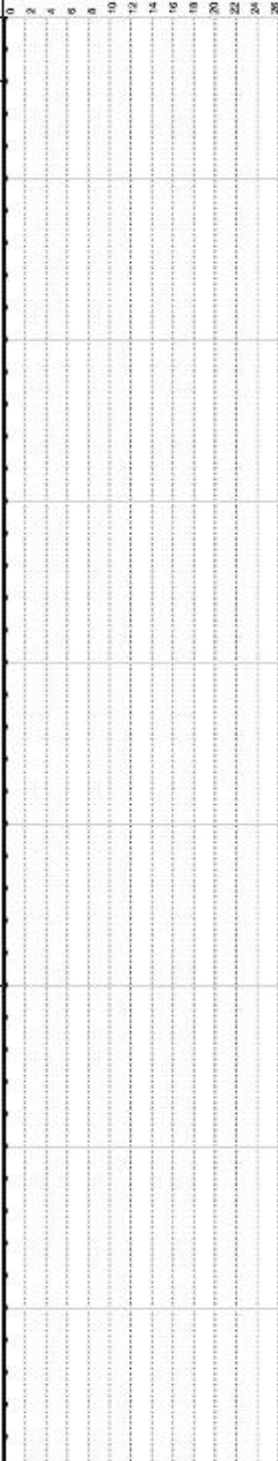
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 4.5 m

Date : 24/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		F	Fill Sandy GRAVEL medium dense, black, medium sized, medium grained sand, slightly moist.			
		CI	Alluvial Sandy to silty CLAY stiff to very stiff, medium to high plasticity, brown-red, fine grained sand, w < pl to w ≈ pl.				
	1						
	2						
	3						
	3		CH	Alluvial Sandy to silty CLAY hard, high plasticity, brown-red, fine grained sand, trace medium sized gravel, w < pl.		LS = 17.0%	
	4						
				Borehole 39 Terminated at 4.5m			

Latitude : -32.271365

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.638298

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 4.5 m

Date : 24/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Clayey to sandy SILT stiff, low plasticity, brown, fine grained sand, w ≈ pl.			
	1.2		CI-CH	Alluvial Silty to sandy CLAY soft to firm, medium to high plasticity, brown, fine grained sand, w < pl to w ≈ pl.			
	3.5		CI-CH	Alluvial Silty to sandy CLAY stiff to very stiff, medium to high plasticity, brown, fine grained sand, w < pl to w ≈ pl.			
	4		CH	Alluvial Silty to sandy CLAY hard, high plasticity, pale brown, fine grained sand, trace fine sized gravel, w < pl.		LS = 17.5%	
				Borehole 40 Terminated at 4.5m			

Job Number : 44935
Client : Dubbo Regional Council
Project : Geotechnical Investigation

Page 1 of 1

Latitude : -32.265608

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.640722

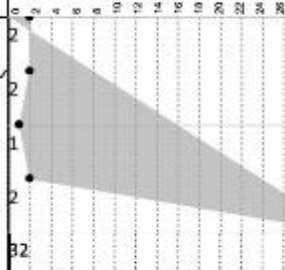
Logged By : GW

Client : Dubbo Regional Council

Total Depth : 0.5 m

Date : 24/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.1		TS	Topsoil Clayey to sandy SILT soft, low plasticity, brown, fine grained sand, w > pl.			
			CI	Alluvial Sandy to silty CLAY soft to firm, medium plasticity, brown, fine grained sand, trace medium sized gravel, w ≈ pl to w > pl.			
				Borehole 42 refusal at 0.5m (Refusal on Igneous Rock)			

Latitude : -32.266050

Location : "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

Job Number : 44935

Longitude : 148.643965

Logged By : GW

Client : Dubbo Regional Council

Total Depth : 1.8 m

Date : 24/07/2024

Project : Geotechnical Investigation

Drilling Method	Depth (m)	Graphic Log	Classification Code	Material Description	DCP graph	Samples	Remarks
						Disturbed sample	
Auger drill with TC bit	0.2		TS	Topsoil Clayey to sandy SILT soft, low plasticity, dark brown, fine grained sand, w > pl.			
			Cl-CH	Alluvial Sandy to silty CLAY firm, medium to high plasticity, dark brown, fine grained sand, w > pl to w = pl.			
	1						
	1.2						
	1.4						
			CH	Alluvial Silty to sandy CLAY very stiff to hard, high plasticity, brown, fine grained sand, with medium sized gravel, w < pl to w = pl.			
	2			Borehole 43 refusal at 1.8m (Refusal on Igneous Rock)			



APPENDIX D

NATA Laboratory Reports

Material Test Report

barnson.

Barnson Pty Ltd

Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

Phone: 1300 BARNSON

Email: jeremy@barnson.com.au

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW



Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Jeremy Wiatkowski
Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678A	D24-10678B	D24-10678C	D24-10678D	D24-10678E	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 1 Lat: - 32.264402 Long: 148.643132	Borehole 2 Lat: - 32.266642 Long: 148.643533	Borehole 3 Lat: - 32.266351 Long: 148.641564	Borehole 4 Lat: - 32.266099 Long: 148.638851	Borehole 5 Lat: - 32.266328 Long: 148.637372	
Sample Depth	400mm	700mm	800mm	1.0m	2.0m	
Material	Brown-Red Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY	Brown Sandy Silty CLAY	Brown Sandy Silty CLAY Trace Gravel	Grey-Brown Sandy Silty CLAY Trace Gravel	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	31	53	45	51	68	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	8.0	16.5	13.0	16.0	20.0	
Cracking Crumbling Curling	None	Curling	None	None	Curling	

Material Test Report

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

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Barnson Pty Ltd

Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

Phone: 1300 BARNSON

Email: jeremy@barnson.com.au

Accredited for compliance with ISO/IEC 17025 - Testing



Approved Signatory: Jeremy Wiatkowski

Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678F	D24-10678G	D24-10678H	D24-10678I	D24-10678J	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 6 Lat: - 32.266832 Long: 148.638642	Borehole 7 Lat: - 32.266592 Long: 148.640073	Borehole 8 Lat: - 32.266973 Long: 148.640993	Borehole 9 Lat: - 32.267140 Long: 148.642463	Borehole 10 Lat: - 32.267390 Long: 148.644177	
Sample Depth	3.0m	200mm	2.0m	1.3m	800mm	
Material	Pale Brown-Yellow Sandy CLAY Trace Gravel	Brown Clayey Sandy SILT With Gravel	Brown Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY With Gravel	Brown Sandy Silty CLAY	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	67	33	73	48	55	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	16.0	7.0	20.0	14.5	17.0	
Cracking Crumbling Curling	Curling	None	Curling	None	None	

Material Test Report

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

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Barnson Pty Ltd

Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

Phone: 1300 BARNSON

Email: jeremy@barnson.com.au

Accredited for compliance with ISO/IEC 17025 - Testing



Approved Signatory: Jeremy Wiatkowski

Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678K	D24-10678L	D24-10678M	D24-10678N	D24-10678O	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 11 Lat: - 32.268375 Long: 148.643926	Borehole 12 Lat: - 32.268302 Long: 148.643057	Borehole 13 Lat: - 32.267875 Long: 148.642327	Borehole 14 Lat: - 32.267934 Long: 148.641446	Borehole 15 Lat: - 32.267728 Long: 148.640665	
Sample Depth	200mm	500mm	400mm	2.0m	800mm	
Material	Red Clayey Sandy SILT With Gravel	Red Clayey Sandy SILT With Gravel	Red Clayey Sandy SILT With Gravel	Yellow Sandy Silty CLAY	Grey Sandy Silty CLAY With Gravel	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	25	28	39	78	44	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	5.0	3.5	6.5	21.0	14.0	
Cracking Crumbling Curling	None	None	None	Curling	Curling	

Material Test Report

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

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Dubbo Laboratory

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Accredited for compliance with ISO/IEC 17025 - Testing



Approved Signatory: Jeremy Wiatkowski

Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678P	D24-10678Q	D24-10678R	D24-10678S	D24-10678T	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 16 Lat: - 32.267595 Long: 148.638216	Borehole 17 Lat: - 32.267437 Long: 148.636436	Borehole 18 Lat: - 32.268359 Long: 148.636080	Borehole 19 Lat: - 32.268226 Long: 148.638672	Borehole 21 Lat: - 32.269231 Long: 148.643046	
Sample Depth	1.0m	200mm	3.0m	1.0m	400mm	
Material	Brown-Dark Brown Sandy Silty CLAY	Red Clayey Sandy SILT With Gravel	Grey Sandy Silty CLAY Trace Gravel	Brown Silty Sandy CLAY	Grey Sandy SILT With Gravel	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	57	37	66	55	33	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	19.0	8.0	19.5	17.0	5.5	
Cracking Crumbling Curling	Cracking	None	Curling	None	None	

Material Test Report

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Barnson Pty Ltd

Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

Phone: 1300 BARNSON

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Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW



Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Jeremy Wiatkowski
Geotechnical Technician
NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678U	D24-10678V	D24-10678W	D24-10678X	D24-10678Y	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 22 Lat: - 32.269874 Long: 148.642372	Borehole 23 Lat: - 32.270052 Long: 148.641059	Borehole 24 Lat: - 32.269823 Long: 148.639430	Borehole 25 Lat: - 32.269888 Long: 148.638456	Borehole 26 Lat: - 32.269307 Long: 148.637823	
Sample Depth	1.0m	1.5m	3.0m	1.0m	2.0m	
Material	Brown Sandy Silty CLAY Trace Gravel	Grey-Brown Sandy Silty CLAY With Gravel	Brown Sandy Silty CLAY	Red-Brown Sandy Silty CLAY	Red-Brown Sandy Silty CLAY	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	51	44	75	39	47	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	13.5	13.0	22.0	12.0	14.5	
Cracking Crumbling Curling	None	Curling	Curling	None	Curling	

Material Test Report

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
 P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

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Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

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Accredited for compliance with ISO/IEC 17025 - Testing



Approved Signatory: Jeremy Wiatkowski
 Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678Z	D24-10678AA	D24-10678AB	D24-10678AC	D24-10678AD	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	23/07/2024	
Sample Location	Borehole 27 Lat: - 32.269203 Long: 148.636753	Borehole 28 Lat: - 32.269577 Long: 148.635795	Borehole 30 Lat: - 32.270118 Long: 148.633694	Borehole 31 Lat: - 32.270846 Long: 148.633627	Borehole 32 Lat: - 32.270934 Long: 148.637405	
Sample Depth	3.0m	1.0m	900mm	1.0m	2.0m	
Material	Brown Sandy Silty CLAY	Grey Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY Trace Gravel	Grey Sandy SILT With Gravel	Brown Silty CLAY With Gravel	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	64	52	52	30	60	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	19.0	13.0	15.0	5.0	18.5	
Cracking Crumbling Curling	Curling	Curling	Curling	None	Curling	

Material Test Report

barnson.

Barnson Pty Ltd

Dubbo Laboratory

16 L Yarrandale Road Dubbo NSW 2830

Phone: 1300 BARNSON

Email: jeremy@barnson.com.au

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW



Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Jeremy Wiatkowski

Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678AE	D24-10678AF	D24-10678AG	D24-10678AH	D24-10678AI	
Date Sampled	23/07/2024	23/07/2024	23/07/2024	23/07/2024	24/07/2024	
Sample Location	Borehole 33 Lat: - 32.270565 Long: 148.642521	Borehole 35 Lat: - 32.272063 Long: 148.642589	Borehole 36 Lat: - 32.271154 Long: 148.641315	Borehole 37 Lat: - 32.271817 Long: 148.640846	Borehole 38 Lat: - 32.270880 Long: 148.639602	
Sample Depth	1.0m	2.0m	1.7m	1.0m	2.0m	
Material	Grey Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY Trace Gravel	Brown Silty CLAY	Brown-Red Sandy Silty CLAY	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	52	55	59	61	55	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	15.0	16.5	18.5	15.0	17.0	
Cracking Crumbling Curling	None	Curling	Cracking	Curling	Curling	

Material Test Report

Report Number: 44935-1
Issue Number: 1
Date Issued: 12/08/2024
Client: Dubbo Regional Council
 P.O. Box 81, Dubbo NSW 2830
Project Number: 44935
Project Name: Geotechnical Investigation
Project Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW
Work Request: 10678
Dates Tested: 23/07/2024 - 12/08/2024
Sampling Method: AS 1289.1.2.1 6.5.3 - Power auger drilling
Site Selection: Selected by Client
Location: "Keswick Estate Stage 7, 8 and 9" Dubbo NSW

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Dubbo Laboratory

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Accredited for compliance with ISO/IEC 17025 - Testing



Signature

Approved Signatory: Jeremy Wiatkowski

Geotechnical Technician

NATA Accredited Laboratory Number: 9605

Sample Details						
Sample Number	D24-10678AJ	D24-10678AK	D24-10678AL	D24-10678AM	D24-10678AN	
Date Sampled	24/07/2024	24/07/2024	24/07/2024	24/07/2024	24/07/2024	
Sample Location	Borehole 39 Lat: - 32.271436 Long: 148.639288	Borehole 40 Lat: - 32.271365 Long: 148.638298	Borehole 41 Lat: - 32.270883 Long: 148.638421	Borehole 42 Lat: - 32.265608 Long: 148.640722	Borehole 43 Lat: - 32.266050 Long: 148.643965	
Sample Depth	3.0m	4.0m	1.0m	500mm	1.8m	
Material	Brown-Red Sandy Silty CLAY	Brown Sandy Silty CLAY Trace Gravel	Red-Brown Sandy Silty CLAY	Brown Sandy Silty CLAY Trace Gravel	Brown Sandy Silty CLAY With Gravel	
Atterberg Limit (AS 1289.3.1.2)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Liquid Limit (%)	55	68	32	37	64	
Plastic Limit (%)	**	**	**	**	**	
Plasticity Index (%)	**	**	**	**	**	
Linear Shrinkage (AS 1289.3.4.1)						Min Max
Sample History	Oven Dried	Oven Dried	Oven Dried	Oven Dried	Oven Dried	
Preparation Method	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	Dry Sieve	
Moisture Condition Determined By	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	
Linear Shrinkage (%)	17.0	17.5	9.0	9.0	18.5	
Cracking Crumbling Curling	Curling	Curling	None	None	Curling	

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APPENDIX E
CSIRO Guide

Foundation Maintenance and Footing Performance: A Homeowner's Guide



CSIRO

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 perpend).

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

Seasonal swelling/shrinkage in clay

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

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

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



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

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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.

Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.

- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

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

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

Prevention/ Cure

Plumbing

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

Ground drainage

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

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

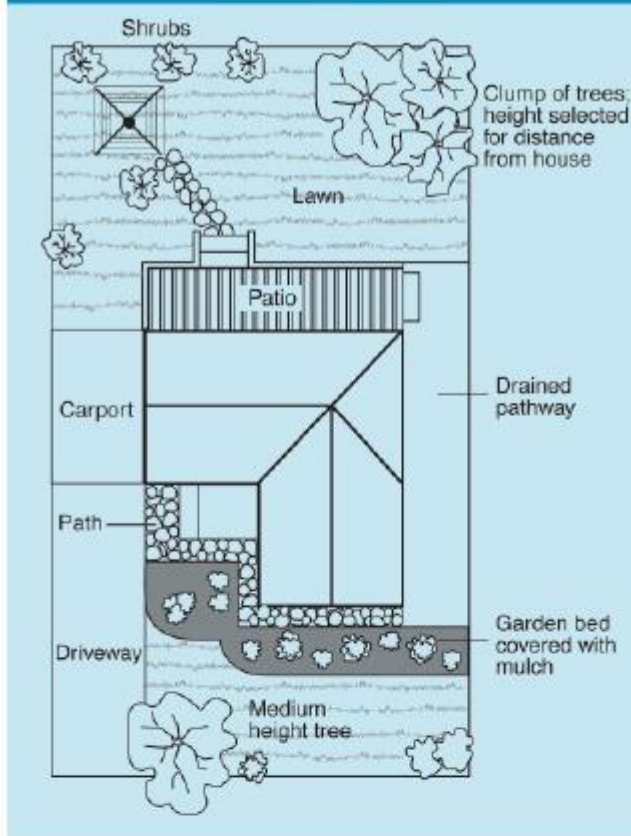
Protection of the building perimeter

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

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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



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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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:

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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