
Residential Subdivision
Billy's Lookout -
Stage 22
Site Classification

Fishermans Drive,
Teralba

NEW15P-0070E-AB
21 February 2019



21 February 2019

McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
NEWCASTLE NSW 2300

Attention: Harry Thomson

Dear Sir,

**RE: RESIDENTIAL SUBDIVISION – BILLY'S LOOKOUT – STAGE 22
FISHERMANS DRIVE, TERALBA
SITE CLASSIFICATION (LOTS 2201 TO 2219)**

Please find enclosed our geotechnical report for Stage 22 of the 'Billy's Lookout' residential subdivision, located at Fishermans Drive, Teralba.

The report provides site classification with respect to reactive soils, in accordance with the requirements of AS2870-2011 '*Residential Slabs and Footings*', for Stage 22 (Lots 2201 to 2219).

If you have any questions regarding this report, please do not hesitate to contact Shannon Kelly or the undersigned.

For and on behalf of Qualtest Laboratory (NSW) Pty Ltd

A handwritten signature in dark ink, appearing to read 'Jason Lee', written in a cursive style.

Jason Lee
Principal Geotechnical Engineer

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1.0 Introduction

Qualtest Laboratory NSW Pty Ltd (Qualtest) is pleased to present this site classification report on behalf of McCloy Development Management Pty Ltd (McCloy), for Stage 22 of the 'Billy's Lookout' residential subdivision, located at Fishermans Drive, Teralba.

Based on the brief and drawing provided by the client, Stage 22 is understood to comprise of nineteen residential allotments (Lots 2201 to 2219).

The scope of work for the geotechnical investigation included providing site classification with respect to reactive soils, in accordance with the requirements of AS2870-2011 '*Residential Slabs and Footings*', for Stage 22 following completion of site regrade works.

This report presents the results of the field work investigations and laboratory testing, and provides recommendations for the scope outlined above.

2.0 Desktop Study

The scope of work has included a review of the following reports completed by Qualtest:

- Level 1 Site Re-grade Assessment Report, 'Proposed Subdivision, Billy's Lookout – Stage 21 & 22, Fishermans Drive, Teralba, (Qualtest Report Reference: NEW18P-0220-AA, dated 18 February 2019).

3.0 Field Work

Field work investigations were carried out on 4 February 2019, comprising of:

- Excavation of 12 test pits (TP2201 to TP2212) using a 2.7 tonne excavator with a 0.45m wide toothed bucket, to depths of between 0.25m and 2.00m;
- Undisturbed samples (U50 tubes) were taken for subsequent laboratory testing; and,
- Test pits were backfilled with the excavation spoil and compacted using the excavator bucket and tracks.

Investigations were carried out by an experienced Geotechnical Engineer from Qualtest who located the test pits, carried out the testing and sampling, produced field logs of the test pits, and made observations of the site surface conditions.

Approximate test pit locations are shown on the attached Figure AB1. Engineering logs of the test pits are presented in Appendix A.

4.0 Site Description

4.1 Site Regrade Works

Site re-grading works were conducted between 26 October 2018 and 5 November 2018. The re-grading works consisted of the cutting and filling of proposed residential lots within both Stage 21 and Stage 22 of the subdivision. Works within Stage 22 included filling within Lot 2201 to 2203, and cutting within Lot 2202 to 2219.

Prior to filling, re-grade areas were stripped of all topsoil and unsuitable material to expose suitable natural foundation profile. Re-grade works then consisted of filling with approved site fill to finish design levels.

Filling was performed using site material won from excavations cut from around the site.

The approximate depth of fill placed ranged in the order of 0.1m to about 1.0m. The fill was compacted in maximum lifts of 0.3m thickness. Any unsuitable or deleterious material within the fill was removed by hand or mechanical means prior to final compaction of the material.

As the geotechnical testing authority engaged for the project, Qualtest state that the re-grading works performed within Stage 22 of the development (i.e. the filling of lots 2201 to 2203) was carried out to Level 1 criteria as defined in Clause 8.2 – Section 8, of AS3798-2007, *"Guidelines on Earthworks for Commercial and Residential Developments"*.

Refer to Qualtest Level 1 Site Re-grade Assessment Report (Ref. NEW18P-0220-AA, dated 18 February 2019) for further details including the approximate limit of filling works for this stage of the project.

The recommendations of this report are based on the understanding that any existing lot re-grade works are limited to the controlled earthworks supervised by Qualtest, placement of the fill material observed to depths of 0.4m or less within test pits, and placement of low reactivity topsoil material such that total depth of topsoil and uncontrolled fill does not exceed 0.4m. Qualtest should be informed without delay if additional earthworks are known to have been carried out.

4.2 Surface Conditions

The site comprises proposed Stage 22 of the Billy's Lookout subdivision, located off Fishermans Drive, Teralba, as shown on Figure AB1.

It is located in a region of gently to moderately undulating topography, on the upper to mid slopes of a broad hill formation.

The site is bounded to the south and southeast by a narrow strip of bushland and the Main Northern Railway, and to the north by Fishermans Drive and adjoining stages of the subdivision development.

On the day of the field investigations, the site had been cleared, topsoiled, and associated retaining walls and pavements had been constructed.

The majority of the site was judged to be moderately drained by way of surface runoff and inter-allotment drainage, typically towards the north and northeast. Infiltration and ponded water from recent wet weather had caused isolated wet and boggy areas in the near surface soils.

Trafficability was judged to be good by way of 4WD vehicle along the existing pavement at the front of the lots.

Selected photographs of the site taken on the day of the site investigations are shown below.



Photograph 1: From southeast corner of Lot 2203, facing northwest.



Photograph 2: From southeast corner of Lot 2203, facing northeast.



Photograph 3: From Fishermans Drive near Lot 2205, facing southeast.



Photograph 4: From Fishermans Drive near Lot 2205, facing southwest.



Photograph 5: From Lot 2211, facing southwest.



Photograph 6: From Lot 2211, facing northeast.



Photograph 7: From near western boundary of Lot 2219, facing northeast.



Photograph 8: From near western boundary of Lot 2219, facing east.

4.3 Subsurface Conditions

Reference to the 1:100,000 Newcastle Coalfield Regional Geology Sheet indicates the site to be underlain by the Clifton Subgroup of the Narrabeen Group, and the Moon Island Beach Subgroup of the Newcastle Coal Measures, which are characterised by Conglomerate, Sandstone, Siltstone, Claystone, Tuff and Coal rock types.

Table 1 presents a summary of the typical soil types encountered on site during the field investigations, divided into representative geotechnical units.

Table 2 contains a summary of the distribution of the above geotechnical units at the test pit locations.

TABLE 1 – SUMMARY OF GEOTECHNICAL UNITS AND SOIL TYPES

Unit	Soil Type	Description
1A	FILL – TOPSOIL & MULCH	Mulch – generally up to about 50mm depth, overlying; Sandy CLAY – low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, trace fine to medium grained angular to sub-angular gravel in places. Clayey SAND in TP2211, TP2212.
1B	FILL - Controlled	Gravelly Sandy CLAY, Sandy CLAY – medium plasticity, brown, orange-brown, grey-brown, fine to coarse grained sand, fine to medium/coarse grained angular to sub-angular gravel. Clayey Sandy GRAVEL – fine to medium/coarse grained, sub-rounded to sub-angular gravel, pale orange-brown, pale grey, fines of low to medium plasticity, fine to coarse grained sand.
2	TOPSOIL	Not Encountered.
3	SLOPEWASH / COLLUVIUM	Not Encountered.
4	RESIDUAL SOIL	Sandy CLAY, CLAY – medium and medium to high plasticity, pale grey to grey and pale brown to orange, fine to medium grained sand, generally of very stiff or better consistency, with some roots in places. Sandy CLAY / Clayey SAND – low to medium plasticity, pale orange-brown, fine to medium/coarse grained sand.
5	EXTREMELY WEATHERED (XW) ROCK	Extremely Weathered SANDSTONE with Soil Properties; breaks down into Clayey SAND / SAND / Sandy CLAY– fine to coarse grained, orange-brown and pale grey, fines of low to medium plasticity. Breaks down into Sandy CLAY in places.
6	HIGHLY WEATHERED (HW) ROCK	Silty SANDSTONE, SANDSTONE, Pebbly SANDSTONE - fine to medium grained, orange-brown and grey to white, estimated very low to high rock strength. Sandy SILTSTONE – fine grained sand, pale grey-grey with orange-brown, estimated low to medium rock strength. CONGLOMERATE – fine to coarse grained sand, fine to medium grained rounded clasts, pale brown, estimated medium to high strength.

TABLE 2 – SUMMARY OF GEOTECHNICAL UNITS ENCOUNTERED AT TEST PIT LOCATIONS

TEST PIT No.	UNIT 1A Fill - Topsoil & Mulch	UNIT 1B Fill - Controlled	Unit 4 Residual Soil	Unit 5 XW Rock	Unit 6 HW Rock
	Depth (m)				
TP2201	0.00 - 0.15	0.15 - 0.90	0.90 - 1.95	1.95 - 2.00	-
TP2202	0.00 - 0.20	0.20 - 0.55	0.55 - 0.80	0.80 - 1.00	1.00 - 1.25*
TP2203	0.00 - 0.10	0.10 - 0.40	-	-	0.40 - 0.65*
TP2204	0.00 - 0.15	0.15 - 0.35	-	-	0.35 - 0.40*
TP2205	0.00 - 0.15	-	-	-	0.15 - 0.25*
TP2206	0.00 - 0.15	-	-	-	0.15 - 0.80^
TP2207	0.00 - 0.25	-	0.25 - 0.35	0.35 - 0.55	0.55 - 0.80^
TP2208	0.00 - 0.10	-	0.10 - 0.35	0.35 - 0.80^	-
TP2209	0.00 - 0.20	0.20 - 0.40	-	-	0.40 - 0.45*
TP2210	0.00 - 0.35	-	0.35 - 0.70	-	0.70 - 0.75*
TP2211	0.00 - 0.25	-	0.25 - 0.45	0.45 - 0.55	0.55 - 0.60*
TP2212	0.00 - 0.30	-	0.30 - 0.60	0.60 - 0.70*	-
Notes: * = Practical refusal of 2.7 tonne excavator on Highly Weathered Rock. ^ = Very slow progress, close to practical refusal.					

No groundwater was encountered in the test pits during the limited time that they remained open on the day of the field investigation.

It should be noted that groundwater conditions can vary due to rainfall and other influences including regional groundwater flow, temperature, permeability, recharge areas, surface condition, and subsoil drainage.

5.0 Laboratory Testing

Samples collected during the field investigations were returned to our NATA accredited Warabrook Laboratory for testing which comprised of:

- (8 no.) Shrink / Swell test.

Results of the laboratory testing are included in Appendix B, with a summary of the Shrink/Swell tests presented in Table 3.

TABLE 3 – SUMMARY OF SHRINK / SWELL TESTING RESULTS

Location	Depth (m)	Material Description	I _{ss} (%)
TP2201	0.30 – 0.40	FILL: (CI) Gravelly Sandy CLAY	1.8
TP2201	1.00 – 1.20	(CH) Sandy CLAY	2.4
TP2202	0.60 – 0.80	(CH) Sandy CLAY	1.9
TP2208	0.20 – 0.35	(CI) Sandy CLAY	1.2
TP2209	0.25 – 0.40	FILL: (CI) Sandy CLAY	1.4
TP2210	0.40 – 0.55	(CH) CLAY	2.8
TP2211	0.30 – 0.40	(CI) Sandy CLAY	0.9
TP2212	0.30 – 0.50	(CI) Sandy CLAY	1.5

6.0 Site Classification to AS2870-2011

Based on the results of the field work and laboratory testing, residential lots located within Stage 22 of the Billy's Lookout subdivision located at Fishermans Drive, Teralba, as shown on Figure AB1, are classified in their current condition in accordance with AS2870-2011 '*Residential Slabs and Footings*', as shown in Table 4.

TABLE 4 – SITE CLASSIFICATION TO AS2870-2011

Stage	Lot Numbers	Site Classification
22	2201, 2202, 2203	H1
	2204 to 2219	M

A characteristic free surface movement in the range of 40mm to 60mm is estimated for lots classified as **Class 'H1'**.

A characteristic free surface movement in the range of 20mm to 40mm is estimated for lots classified as **Class 'M'**.

The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement.

If site re-grading works involving cutting or filling are performed after the date of this assessment the classification may change and further advice should be sought.

Final site classification will be dependent on the type of fill and level of supervision carried out. Re-classification of lots should be confirmed by the geotechnical authority at the time of construction following any site re-grade works.

Footings for the proposed development should be designed and constructed in accordance with the requirements of AS2870-2011.

The classification presented above assumes that:

- All footings are founded in controlled fill (if applicable) or in the residual clayey soils or rock below all non-controlled fill, topsoil material and root zones, and fill under slab panels meets the requirements of AS2870-2011, in particular, the root zone must be removed prior to the placement of fill materials beneath slabs;
- The performance expectations set out in Appendix B of AS2870-2011 are acceptable, and that site foundation maintenance is undertaken to avoid extremes of wetting and drying;
- Footings are to be founded outside of or below all zones of influence resulting from existing or future service trenches;
- The constructional and architectural requirements for reactive clay sites set out in AS2870-2011 are followed;
- Adherence to the detailing requirement outlined in Section 5 of AS2870-2011 '*Residential Slabs and Footings*' is essential, in particular Section 5.6, '*Additional requirements for Classes M, H1, H2 and E sites*' including architectural restrictions, plumbing and drainage requirements; and,
- Site maintenance complies with the provisions of CSIRO Sheet BTF 18, "*Foundation Maintenance and Footing Performance: A Homeowner's Guide*", a copy of which is attached in Appendix C.

All structural elements on all lots regardless of their site classification should be supported on footings founded beneath all uncontrolled fill, layers of inadequate bearing capacity, soft/loose, or other potentially deleterious material.

If any areas of uncontrolled fill of depths greater than 0.4m are encountered during construction, footings should be designed in accordance with engineering principles for Class 'P' sites.

7.0 Limitations

The findings presented in the report and used as the basis for recommendations presented herein were obtained using normal, industry accepted geotechnical design practices and standards. To our knowledge, they represent a reasonable interpretation of the general conditions of the site.

The extent of testing associated with this assessment is limited to discrete test pit locations. It should be noted that subsurface conditions between and away from the test pit locations may be different to those observed during the field work and used as the basis of the recommendations contained in this report.

If subsurface conditions encountered during construction differ from those given in this report, further advice should be sought without delay.

Data and opinions contained within the report may not be used in other contexts or for any other purposes without prior review and agreement by Qualtest. If this report is reproduced, it must be in full.

If you have any further questions regarding this report, please do not hesitate to contact Shannon Kelly or the undersigned.

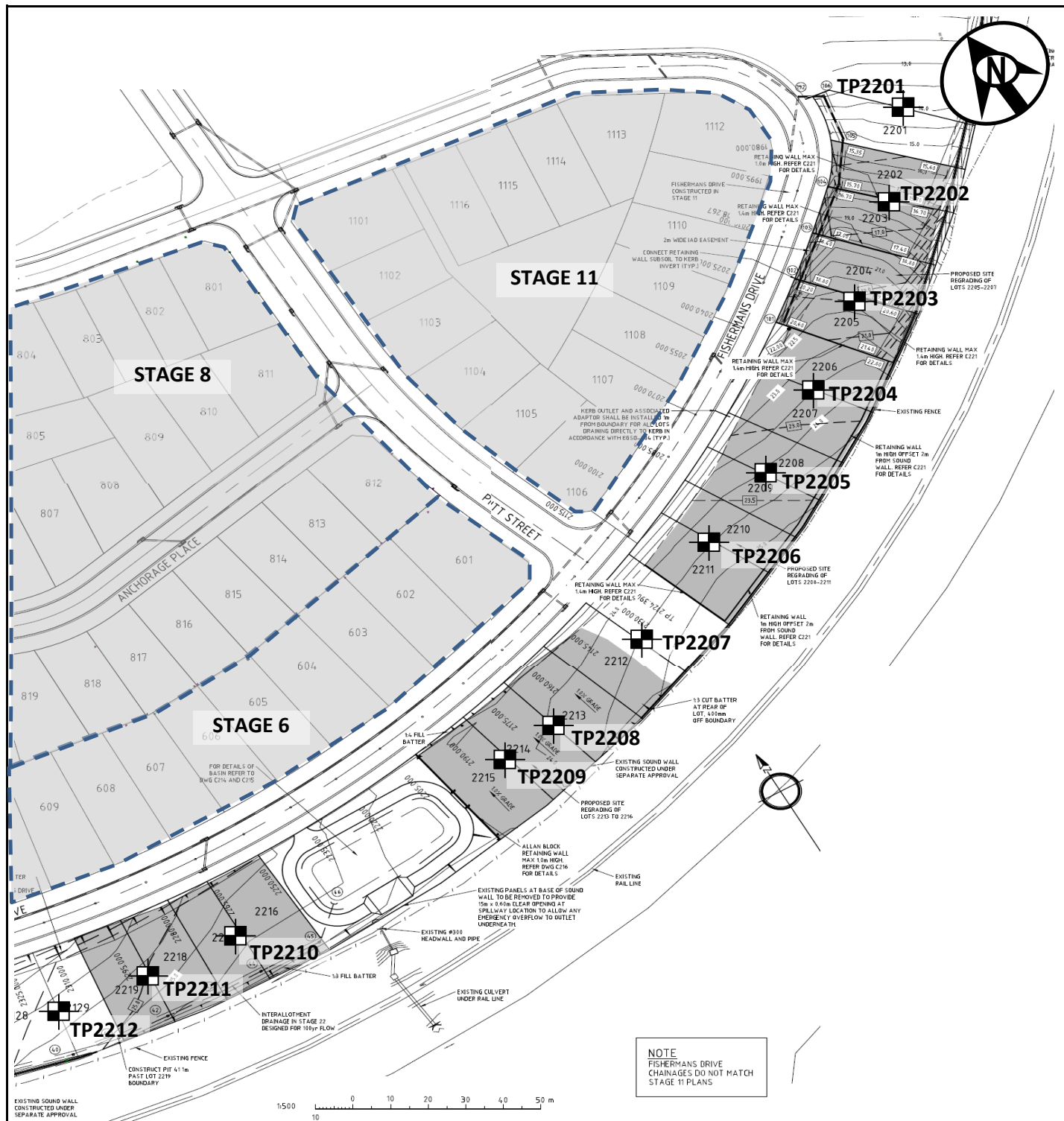
For and on behalf of Qualtest Laboratory (NSW) Pty Ltd.

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Jason Lee
Principal Geotechnical Engineer

FIGURES:

Figure AB1 – Site Plan and Approximate Test Locations



Site plan based on drawings prepared by GCA Engineering Solutions (Project No. 17226C, Dwg Nos C202 & C203, Rev. 6, dated 29/08/2018)

LEGEND:



Approximate Test Pit Location (Qualtest, 2019)



Client:	MCCLOY DEVELOPMENT MANAGEMENT PTY LTD	Drawing No:	FIGURE AB1
Project:	RESIDENTIAL SUBDIVISION - BILLYS LOOKOUT - STG 22	Project No:	NEW15P-0070E-AB
Location:	FISHERMANS DRIVE, TERALBA	Scale:	AS SHOWN
Title:	SITE PLAN AND APPROXIMATE TEST LOCATIONS	Date:	21/02/2019

APPENDIX A:

Engineering Logs of Test Pits

ENGINEERING LOG - TEST PIT

CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2201
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered					CL	FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained sand, trace fine to medium grained angular to sub-angular gravel, with some mulch.	M > w _p				FILL - TOPSOIL
		0.30m					FILL: Gravelly Sandy CLAY - medium plasticity, brown with some pale orange-brown and pale grey, fine to coarse grained sand, fine to coarse grained angular to sub-angular gravel.			HP	500	FILL - CONTROLLED
		U50 0.40m			0.5	CI		M ~ w _p	H	HP	>600	
										HP	>600	
										HP	480	
		1.00m		1.0			Sandy CLAY - medium to high plasticity, grey to pale grey with some pale orange-brown, fine to medium grained sand, with some roots.			HP	320	RESIDUAL SOIL
		U50 1.20m				CH		M > w _p	VSt	HP	250	
							With some green-grey.			HP	220	
										HP	>600	
					1.5		CL	Sandy CLAY / Clayey SAND - low to medium plasticity, pale orange-brown, fine to medium grained sand.	M < w _p	H	HP	>600
			2.0		SC	Extremely Weathered Sandstone with soil properties; breaks down into Clayey SAND - fine to medium grained, pale orange-brown to orange-brown and pale grey to white, fines of low plasticity. Hole Terminated at 2.00 m	M				EXTREMELY WEATHERED ROCK	

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)		Moisture Condition	
Water		U ₅₀ 50mm Diameter tube sample		VS Very Soft		<25		D Dry	
Water Level (Date and time shown)		CBR Bulk sample for CBR testing		S Soft		25 - 50		M Moist	
Water Inflow		E Environmental sample (Glass jar, sealed and chilled on site)		F Firm		50 - 100		W Wet	
Water Outflow		ASS Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)		St Stiff		100 - 200		w _p Plastic Limit	
Strata Changes		B Bulk Sample		VSt Very Stiff		200 - 400		w _L Liquid Limit	
Gradational or transitional strata		Field Tests		H Hard		>400			
Definitive or distinct strata change		PID Photoionisation detector reading (ppm)		Fb Friable					
		DCP(x-y) Dynamic penetrometer test (test depth interval shown)		Density		V Very Loose		Density Index <15%	
		HP Hand Penetrometer test (UCS kPa)		L Loose		MD Medium Dense		Density Index 15 - 35%	
				D Dense		VD Very Dense		Density Index 35 - 65%	
								Density Index 65 - 85%	
								Density Index 85 - 100%	

ENGINEERING LOG - TEST PIT

CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2202
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations						
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result							
E	Not Encountered	U50	0.60m	0.5		0.05m	FILL: Mulch	M	H	HP	>600	FILL - MULCH						
						CL	FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, with some mulch.	M > w _p				FILL - TOPSOIL						
						0.20m	FILL: Gravelly Sandy CLAY - medium plasticity, pale orange-brown to pale brown, fine to coarse grained sand, fine to medium grained sub-angular to sub-rounded gravel.	M ~ w _p				FILL - CONTROLLED						
						CI												
						0.55m												
						CH	Sandy CLAY - medium to high plasticity, pale orange-brown and pale grey, fine to medium grained sand.	M < w _p				RESIDUAL SOIL						
						0.80m	Extremely Weathered Sandstone with soil properties; breaks down into Sandy CLAY / Clayey SAND - medium plasticity, pale orange-brown and pale grey, fine to medium grained sand.											
						CI	D					EXTREMELY WEATHERED ROCK						
						1.00m						SANDSTONE - fine to medium grained, pale orange-brown to orange-brown and pale grey to white, estimated very low strength.	HIGHLY WEATHERED ROCK					
						1.25m						Hole Terminated at 1.25 m Practical Refusal						
						1.5												
						2.0												

LEGEND: Water Water Level (Date and time shown) Water Inflow Water Outflow Strata Changes Gradational or transitional strata Definitive or distinct strata change	Notes, Samples and Tests U ₅₀ 50mm Diameter tube sample CBR Bulk sample for CBR testing E Environmental sample (Glass jar, sealed and chilled on site) ASS Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled) B Bulk Sample Field Tests PID Photoionisation detector reading (ppm) DCP(x-y) Dynamic penetrometer test (test depth interval shown) HP Hand Penetrometer test (UCS kPa)	Consistency VS Very Soft <25 S Soft 25 - 50 F Firm 50 - 100 St Stiff 100 - 200 VSt Very Stiff 200 - 400 H Hard >400 Fb Friable Density V Very Loose Density Index <15% L Loose Density Index 15 - 35% MD Medium Dense Density Index 35 - 65% D Dense Density Index 65 - 85% VD Verv Dense Density Index 85 - 100%	UCS (kPa) <25 25 - 50 50 - 100 100 - 200 200 - 400 >400	Moisture Condition D Dry M Moist W Wet W _p Plastic Limit W _L Liquid Limit
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LEGEND:

Water

- Water Level (Date and time shown)
- Water Inflow
- Water Outflow

Strata Changes

- Gradational or transitional strata
- Definitive or distinct strata change

Notes, Samples and Tests

- U₅₀ 50mm Diameter tube sample
- CBR Bulk sample for CBR testing
- E Environmental sample (Glass jar, sealed and chilled on site)
- ASS Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)
- B Bulk Sample

Field Tests

- PID Photoionisation detector reading (ppm)
- DCP(x-y) Dynamic penetrometer test (test depth interval shown)
- HP Hand Penetrometer test (UCS kPa)

Consistency

- VS Very Soft
- S Soft
- F Firm
- St Stiff
- VSt Very Stiff
- H Hard
- Fb Friable

UCS (kPa)

- <25
- 25 - 50
- 50 - 100
- 100 - 200
- 200 - 400
- >400

Moisture Condition

- D Dry
- M Moist
- W Wet
- w_p Plastic Limit
- w_L Liquid Limit

Density

- V Very Loose
- L Loose
- MD Medium Dense
- D Dense
- VD Very Dense

- Density Index <15%
- Density Index 15 - 35%
- Density Index 35 - 65%
- Density Index 65 - 85%
- Density Index 85 - 100%


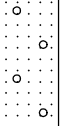
ENGINEERING LOG - TEST PIT






CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2203
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered			0.5		CL	0.05m FILL: Mulch	M				FILL - MULCH
						0.10m FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, with some fine to medium grained angular to sub-angular gravel.	M		FILL - TOPSOIL			
					GC	FILL: Clayey Sandy GRAVEL - fine to medium grained, sub-rounded to sub-angular, pale orange-brown and pale grey, fine to coarse grained sand, fines of low to medium plasticity.	M	D	FILL			
						0.40m Pebbly SANDSTONE - fine to medium grained, pale orange-brown with pale grey to white, estimated very low to medium strength.	D		HIGHLY WEATHERED ROCK			
							0.65m Hole Terminated at 0.65 m Practical Refusal					
				1.0								
				1.5								
				2.0								

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition	
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D	Dry
	Water Level (Date and time shown)	CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M	Moist
	Water Inflow	E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W	Wet
	Water Outflow	ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p	Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L	Liquid Limit
	Gradational or transitional strata	Field Tests		H	Hard	>400	Density Index <15% Density Index 15 - 35% Density Index 35 - 65% Density Index 65 - 85% Density Index 85 - 100%	
	Definitive or distinct strata change	PID	Photoionisation detector reading (ppm)	Fb	Friable			
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	Density	V	Very Loose		
		HP	Hand Penetrometer test (UCS kPa)	L	Loose			
				MD	Medium Dense			
				D	Dense			
				VD	Very Dense			

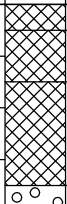
ENGINEERING LOG - TEST PIT






CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2204
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered			0.5		CL	0.05m FILL: Mulch	M				FILL - MULCH
							FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to medium grained sand, trace mulch.	M > w _p				FILL - TOPSOIL
						GC	FILL: Clayey Sandy GRAVEL - fine to coarse grained rounded to sub-angular, pale brown to pale orange-brown, fine to coarse grained sand, fines of low plasticity.	M	D			FILL
							CONGLOMERATE - fine to coarse grained sand, fine to medium grained rounded clasts, pale brown, estimated medium to high strength.	D				HIGHLY WEATHERED ROCK
				2.0			Hole Terminated at 0.40 m Practical Refusal					

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₃₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
 Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
 Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
 Gradational or transitional strata		Field Tests		H	Hard	>400	
 Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	Density	V	Very Loose	Density Index <15%
		HP	Hand Penetrometer test (UCS kPa)	L	Loose		Density Index 15 - 35%
				MD	Medium Dense		Density Index 35 - 65%
				D	Dense		Density Index 65 - 85%
				VD	Very Dense		Density Index 85 - 100%


ENGINEERING LOG - TEST PIT






CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2205
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations	
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result		
E	Not Encountered					CL	0.05m FILL: Mulch	M					FILL - MULCH
							0.15m FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, with some fine grained rounded to sub-rounded gravel.	M < w _p					FILL - TOPSOIL
							0.25m Pebbly SANDSTONE - fine to coarse grained (mostly fine to medium grained), orange-brown and pale grey to white, estimated low to medium strength.	D				HIGHLY WEATHERED ROCK	
				0.5			Hole Terminated at 0.25 m Practical Refusal						
				1.0									
				1.5									
				2.0									

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
 Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
 Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
 Gradational or transitional strata		Field Tests		H	Hard	>400	
 Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	V	Very Loose	Density Index <15%	
		HP	Hand Penetrometer test (UCS kPa)	L	Loose	Density Index 15 - 35%	
				MD	Medium Dense	Density Index 35 - 65%	
				D	Dense	Density Index 65 - 85%	
				VD	Very Dense	Density Index 85 - 100%	


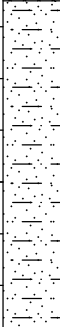
ENGINEERING LOG - TEST PIT






CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2206
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered			0.5		CL	0.05m FILL: Mulch	M				FILL - MULCH
					0.15m		FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, trace fine to medium grained rounded to sub-rounded gravel.	M ~ w _p				FILL - TOPSOIL
							Sandy SILTSTONE - fine grained sand, pale grey to grey with orange to brown, estimated low strength.	D				HIGHLY WEATHERED ROCK
				1.0			Hole Terminated at 0.80 m Very slow progress					
				1.5								
				2.0								

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₃₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
 Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
 Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
 Gradational or transitional strata		Field Tests		H	Hard	>400	
 Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	Density		V Very Loose	Density Index <15%
		HP	Hand Penetrometer test (UCS kPa)	L	Loose	L Loose	Density Index 15 - 35%
				MD	Medium Dense	MD Medium Dense	Density Index 35 - 65%
				D	Dense	D Dense	Density Index 65 - 85%
				VD	Very Dense	VD Very Dense	Density Index 85 - 100%

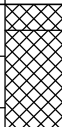


ENGINEERING LOG - TEST PIT




CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2207
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered			0.5		CL	0.05m FILL: Mulch FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained (mostly fine to medium grained) sand, with some fine to medium grained rounded to sub-rounded gravel.	M				FILL - MULCH
							M ~ w _p	FILL - TOPSOIL				
						SC	0.25m Clayey SAND - fine to coarse grained (mostly fine to medium grained), pale grey with some pale orange-brown, fines of low to medium plasticity.	M				RESIDUAL SOIL
						SP	0.35m Extremely Weathered Sandstone with soil properties; breaks down into SAND - fine to coarse grained sand, pale brown to pale orange-brown with some pale grey, trace fine to medium grained angular gravel.	D	EXTREMELY WEATHERED ROCK			
							0.55m SANDSTONE - fine to coarse grained, pale brown to pale orange-brown pale grey to white, estimated very low to low strength.		HIGHLY WEATHERED ROCK			
						0.80m	Hole Terminated at 0.80 m Very slow progress					
				1.0								
				1.5								
				2.0								

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₃₀ 50mm Diameter tube sample		VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR Bulk sample for CBR testing		S	Soft	25 - 50	M Moist
 Water Inflow		E Environmental sample (Glass jar, sealed and chilled on site)		F	Firm	50 - 100	W Wet
 Water Outflow		ASS Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)		St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B Bulk Sample		VSt	Very Stiff	200 - 400	W _L Liquid Limit
--- Gradational or transitional strata		Field Tests		H	Hard	>400	
— Definitive or distinct strata change		PID Photoionisation detector reading (ppm)		Fb	Friable		
		DCP(x-y) Dynamic penetrometer test (test depth interval shown)		Density	V	Very Loose	Density Index <15%
		HP Hand Penetrometer test (UCS kPa)			L	Loose	Density Index 15 - 35%
					MD	Medium Dense	Density Index 35 - 65%
					D	Dense	Density Index 65 - 85%
					VD	Very Dense	Density Index 85 - 100%


ENGINEERING LOG - TEST PIT

CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2208
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered	0.20m		0.5		CL	0.05m FILL: Mulch	M	H	HP	480	FILL - MULCH
		CL				0.10m FILL-TOPSOIL: Sandy CLAY - medium plasticity, dark grey-brown, fine to medium grained sand, with some mulch.		FILL - TOPSOIL				
		CI				Sandy CLAY - medium plasticity, pale brown, fine to medium grained sand.		RESIDUAL SOIL				
		0.35m				SC	Extremely Weathered Sandstone with soil properties; breaks down into Clayey SAND / Sandy CLAY - fine to coarse grained, pale brown to orange and grey, fines of low plasticity.	D	VD	EXTREMELY WEATHERED ROCK		
							Grading into highly weathered SANDSTONE.					
				1.0			Hole Terminated at 0.80 m Very slow progress					
				1.5								
				2.0								

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
Gradational or transitional strata		Field Tests		H	Hard	>400	
Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	V	Very Loose	Density Index <15%	
		HP	Hand Penetrometer test (UCS kPa)	L	Loose	Density Index 15 - 35%	
				MD	Medium Dense	Density Index 35 - 65%	
				D	Dense	Density Index 65 - 85%	
				VD	Very Dense	Density Index 85 - 100%	

ENGINEERING LOG - TEST PIT

CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2209
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered	0.25m				CL	0.05m FILL: Mulch FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine grained sand, with some mulch.	M				FILL - MULCH FILL - TOPSOIL
		U50				CI	0.20m FILL: Sandy CLAY - medium plasticity, orange-brown and grey to pale grey, fine to coarse grained sand, with some fine to coarse grained angular gravel, trace cobbles.	M < W _p				FILL / POSSIBLE RESIDUAL SOIL
		0.40m					0.40m Silty SANDSTONE - fine grained, orange-brown and grey with some pale grey, estimated high strength.	M ~ W _p	H	HP	430	SLIGHTLY WEATHERED ROCK
							0.45m Hole Terminated at 0.45 m Practical Refusal	D				

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
Gradational or transitional strata		Field Tests		H	Hard	>400	
Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	V	Very Loose	Density Index <15%	
		HP	Hand Penetrometer test (UCS kPa)	L	Loose	Density Index 15 - 35%	
				MD	Medium Dense	Density Index 35 - 65%	
				D	Dense	Density Index 65 - 85%	
				VD	Very Dense	Density Index 85 - 100%	

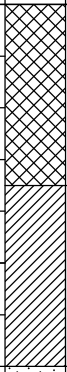
ENGINEERING LOG - TEST PIT




CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2210
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations			
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result				
E	Not Encountered	0.40m		0.5		CL	FILL-TOPSOIL: Sandy CLAY - low plasticity, dark grey-brown, fine to coarse grained sand, trace fine to medium grained angular to sub-angular gravel, root affected.	M > w _p				FILL - TOPSOIL			
		CH				0.35m	CLAY - high plasticity, pale grey with some pale orange-brown.					HP	310	RESIDUAL SOIL	
						0.70m	0.75m					Sandy SILTSTONE - fine grained sand, grey, estimated low to medium strength.	HP		290
													HP		350
								D				SLIGHTLY WEATHERED ROCK			
				1.0			Hole Terminated at 0.75 m Practical Refusal								
				1.5											
				2.0											

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M Moist
 Water Inflow		E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W Wet
 Water Outflow		ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L Liquid Limit
--- Gradational or transitional strata		Field Tests		H	Hard	>400	
— Definitive or distinct strata change		PID	Photoionisation detector reading (ppm)	Fb	Friable		
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	V	Very Loose	Density Index <15%	
		HP	Hand Penetrometer test (UCS kPa)	L	Loose	Density Index 15 - 35%	
				MD	Medium Dense	Density Index 35 - 65%	
				D	Dense	Density Index 65 - 85%	
				VD	Very Dense	Density Index 85 - 100%	

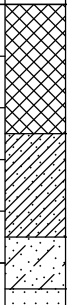
ENGINEERING LOG - TEST PIT






CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2211
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result	
E	Not Encountered	0.30m	U50	0.40m		SC	FILL-TOPSOIL: Clayey SAND - fine to medium grained, dark grey-brown, fines of low plasticity, root affected.	M		HP	160	FILL - TOPSOIL
		CI				Sandy CLAY - medium plasticity, pale orange-brown, fine to coarse grained (mostly fine to medium grained) sand.	M ~ w _p	St	RESIDUAL SOIL			
		SC				Extremely Weathered Silty Sandstone with soil properties; breaks down into Clayey SAND - fine to medium grained, pale orange-brown with grey, fines of low to medium plasticity.	M	VD	EXTREMELY WEATHERED ROCK			
						Silty SANDSTONE - fine to medium grained, grey and pale orange-brown, estimated very low to low strength. Hole Terminated at 0.60 m Practical Refusal	D		HIGHLY WEATHERED ROCK			

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition	
Water		U ₅₀	50mm Diameter tube sample	VS	Very Soft	<25	D	Dry
	Water Level (Date and time shown)	CBR	Bulk sample for CBR testing	S	Soft	25 - 50	M	Moist
	Water Inflow	E	Environmental sample (Glass jar, sealed and chilled on site)	F	Firm	50 - 100	W	Wet
	Water Outflow	ASS	Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)	St	Stiff	100 - 200	W _p	Plastic Limit
Strata Changes		B	Bulk Sample	VSt	Very Stiff	200 - 400	W _L	Liquid Limit
	Gradational or transitional strata	Field Tests		H	Hard	>400		
	Definitive or distinct strata change	PID	Photoionisation detector reading (ppm)	Fb	Friable			
		DCP(x-y)	Dynamic penetrometer test (test depth interval shown)	V	Very Loose		Density Index <15%	
		HP	Hand Penetrometer test (UCS kPa)	L	Loose		Density Index 15 - 35%	
				MD	Medium Dense		Density Index 35 - 65%	
				D	Dense		Density Index 65 - 85%	
				VD	Very Dense		Density Index 85 - 100%	

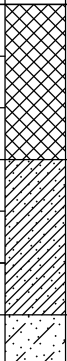
ENGINEERING LOG - TEST PIT




CLIENT: MCCLOY DEVELOPMENT MANAGEMENT PTY LTD
PROJECT: BILLYS LOOKOUT - STAGE 22
LOCATION: FISHERMANS DRIVE, TERALBA

TEST PIT NO: TP2212
PAGE: 1 OF 1
JOB NO: NEW15P-0070E
LOGGED BY: BB
DATE: 4/2/19

EQUIPMENT TYPE: 2.7 TONNE EXCAVATOR
TEST PIT LENGTH: 2.0 m **WIDTH:** 0.5 m

SURFACE RL:
DATUM:

Drilling and Sampling					Material description and profile information					Field Test		Structure and additional observations	
METHOD	WATER	SAMPLES	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION: Soil type, plasticity/particle characteristics, colour, minor components	MOISTURE CONDITION	CONSISTENCY DENSITY	Test Type	Result		
E	Not Encountered	0.30m		0.5		SC	FILL-TOPSOIL: Clayey SAND - fine to medium grained, dark grey-brown, fines of low plasticity, root affected.	M				FILL - TOPSOIL	
		U50					CI	Sandy CLAY - medium plasticity, pale orange-brown to pale brown with some pale grey, fine to coarse grained (mostly fine to medium grained) sand.	M > w _p	VSt	HP	250	RESIDUAL SOIL
		0.50m						Becoming Extremely Weathered Sandstone.	M ~ w _p	H	HP	500	
							SC	Extremely Weathered Sandstone with soil properties; breaks down into Clayey SAND - fine to medium grained, pale orange-brown with some pale grey to white, fines of low plasticity.	M	VD	HP	>600	EXTREMELY WEATHERED ROCK
				1.0			Hole Terminated at 0.70 m Practical Refusal						
				1.5									
				2.0									

LEGEND:		Notes, Samples and Tests		Consistency		UCS (kPa)	Moisture Condition
Water		U ₅₀ 50mm Diameter tube sample		VS	Very Soft	<25	D Dry
 Water Level (Date and time shown)		CBR Bulk sample for CBR testing		S	Soft	25 - 50	M Moist
 Water Inflow		E Environmental sample (Glass jar, sealed and chilled on site)		F	Firm	50 - 100	W Wet
 Water Outflow		ASS Acid Sulfate Soil Sample (Plastic bag, air expelled, chilled)		St	Stiff	100 - 200	W _p Plastic Limit
Strata Changes		B Bulk Sample		VSt	Very Stiff	200 - 400	W _L Liquid Limit
--- Gradational or transitional strata		Field Tests		H	Hard	>400	
— Definitive or distinct strata change		PID Photoionisation detector reading (ppm)		Fb	Friable		
		DCP(x-y) Dynamic penetrometer test (test depth interval shown)		Density	V	Very Loose	Density Index <15%
		HP Hand Penetrometer test (UCS kPa)			L	Loose	Density Index 15 - 35%
					MD	Medium Dense	Density Index 35 - 65%
					D	Dense	Density Index 65 - 85%
					VD	Very Dense	Density Index 85 - 100%

APPENDIX B:

Results of Laboratory Testing

Report No: SSI:NEW19W-0272--S01
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



Accredited for compliance with ISO/IEC 17025-Testing.
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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S01

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Gravelly CLAY

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2201 - 0.30 to 0.40m

Borehole Number: TP2201

Borehole Depth (m): 0.3 - 0.4

Swell Test

AS 1289.7.1.1

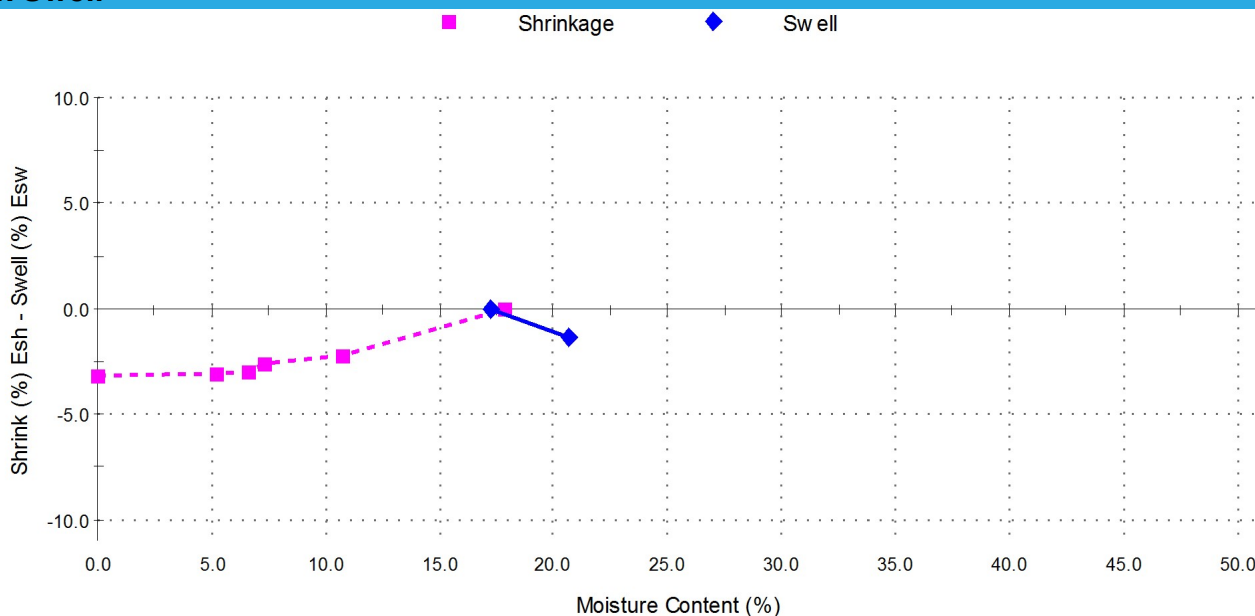
Swell on Saturation (%): -1.4
Moisture Content before (%): 17.3
Moisture Content after (%): 20.7
Est. Unc. Comp. Strength before (kPa): 440
Est. Unc. Comp. Strength after (kPa): 340

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 3.2
Shrinkage Moisture Content (%): 17.9
Est. inert material (%): 20%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Moderate

Shrink Swell



Shrink Swell Index - Iss (%): 1.8

Comments

Report No: SSI:NEW19W-0272--S02
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S02

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2201 - 1.00 to 1.20m

Borehole Number: TP2201

Borehole Depth (m): 1.0 - 1.2

Swell Test

AS 1289.7.1.1

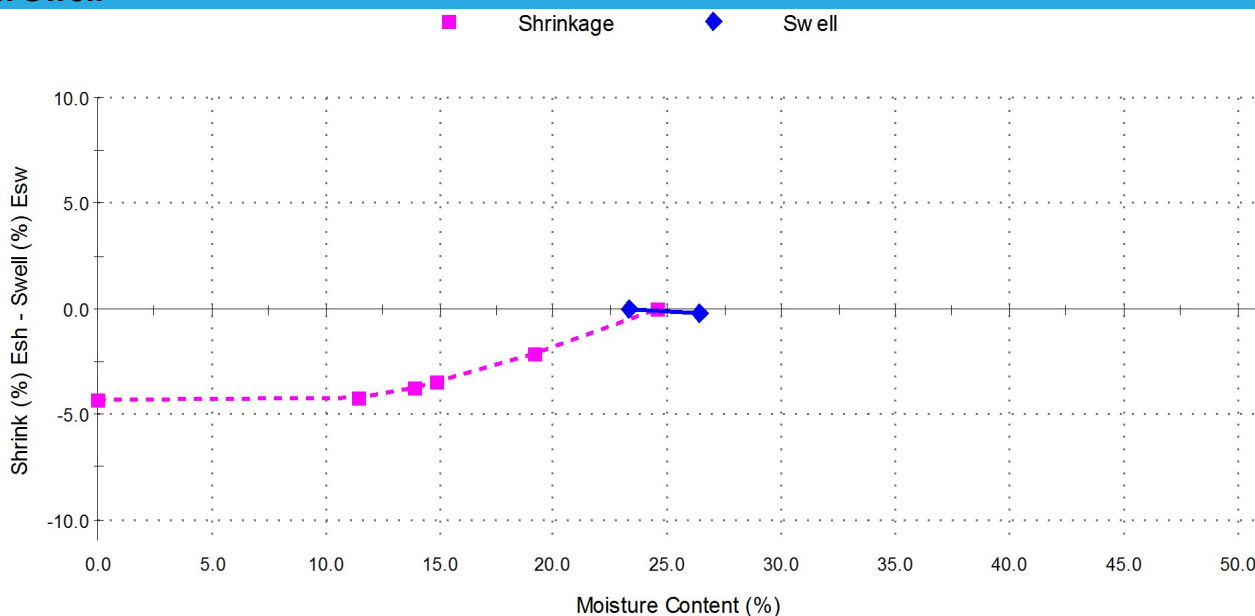
Swell on Saturation (%): -0.2
Moisture Content before (%): 23.3
Moisture Content after (%): 26.3
Est. Unc. Comp. Strength before (kPa): 300
Est. Unc. Comp. Strength after (kPa): 150

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 4.3
Shrinkage Moisture Content (%): 24.5
Est. inert material (%): <1%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Minor

Shrink Swell



Shrink Swell Index - Iss (%): 2.4

Comments

Report No: SSI:NEW19W-0272--S03
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S03

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2202 - 0.60 to 0.80m

Borehole Number: TP2202

Borehole Depth (m): 0.6 - 0.8

Swell Test

AS 1289.7.1.1

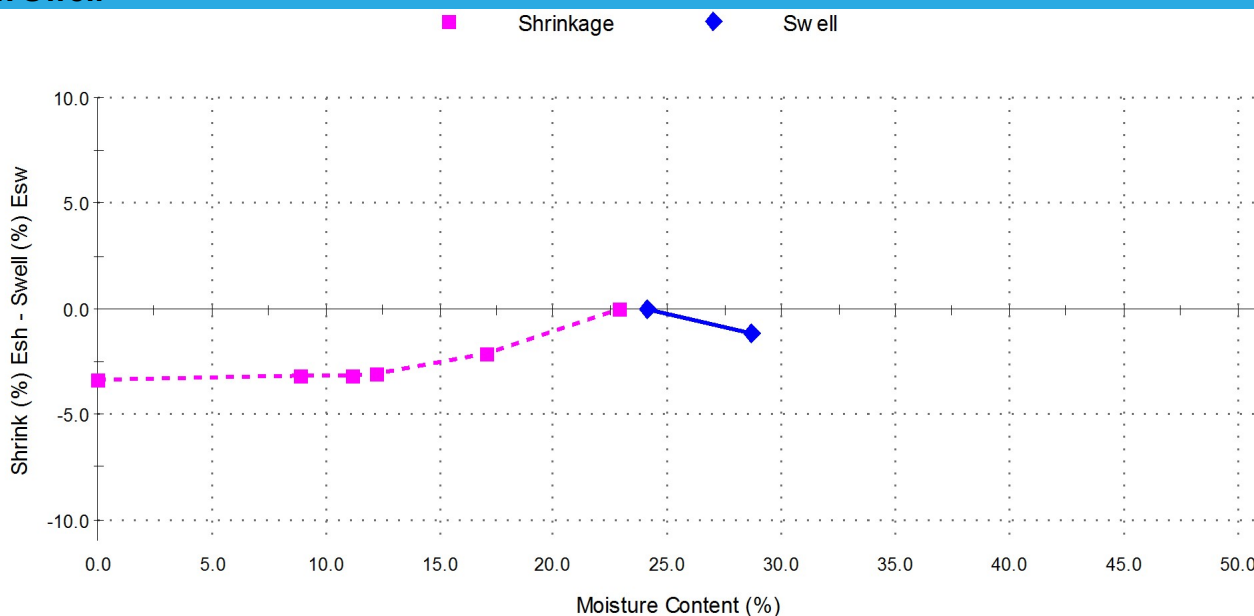
Swell on Saturation (%): -1.1
Moisture Content before (%): 24.1
Moisture Content after (%): 28.7
Est. Unc. Comp. Strength before (kPa): 280
Est. Unc. Comp. Strength after (kPa): 130

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 3.4
Shrinkage Moisture Content (%): 22.8
Est. inert material (%): 10%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Major

Shrink Swell



Shrink Swell Index - Iss (%): 1.9

Comments

Report No: SSI:NEW19W-0272--S04
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



Accredited for compliance with ISO/IEC 17025-Testing.
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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S04

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2208 - 0.20 to 0.35m

Borehole Number: TP2208

Borehole Depth (m): 0.2 - 0.35

Swell Test

AS 1289.7.1.1

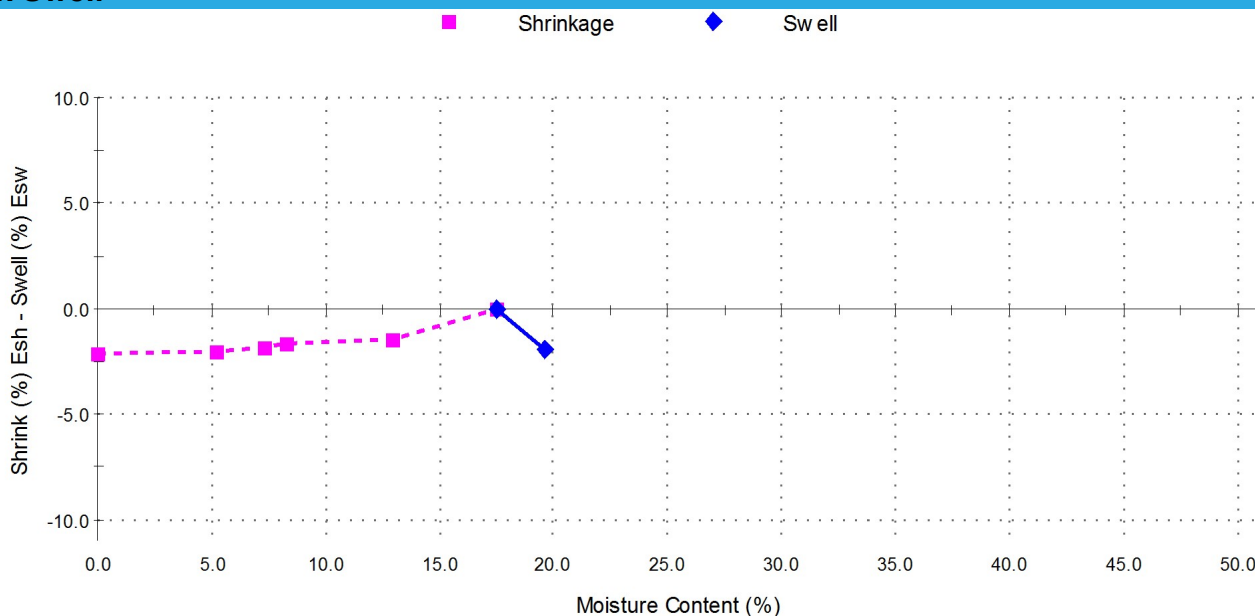
Swell on Saturation (%): -1.9
Moisture Content before (%): 17.5
Moisture Content after (%): 19.6
Est. Unc. Comp. Strength before (kPa): >600
Est. Unc. Comp. Strength after (kPa): 190

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 2.1
Shrinkage Moisture Content (%): 17.5
Est. inert material (%): <1%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Major

Shrink Swell



Shrink Swell Index - Iss (%): 1.2

Comments

Report No: SSI:NEW19W-0272--S05
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



Accredited for compliance with ISO/IEC 17025-Testing.
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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S05

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2209 - 0.25 to 0.40m

Borehole Number: TP2209

Borehole Depth (m): 0.25 - 0.4

Swell Test

AS 1289.7.1.1

Swell on Saturation (%): -0.9

Moisture Content before (%): 18.6

Moisture Content after (%): 22.2

Est. Unc. Comp. Strength before (kPa): 220

Est. Unc. Comp. Strength after (kPa): 180

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 2.4

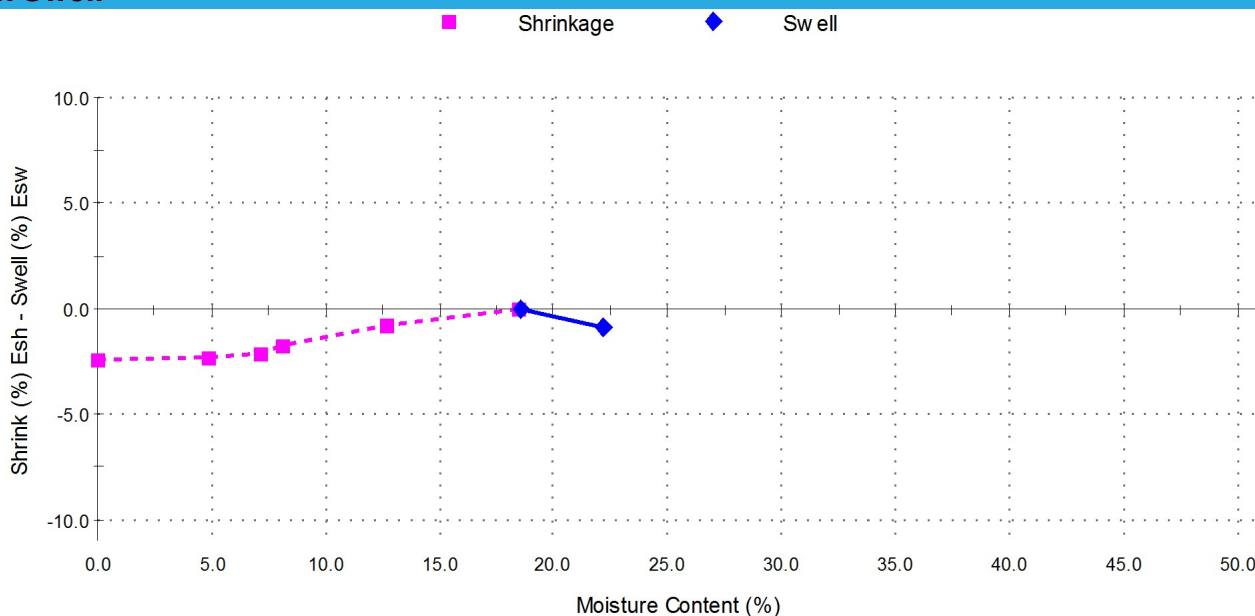
Shrinkage Moisture Content (%): 18.5

Est. inert material (%): <1%

Crumbling during shrinkage: Nil

Cracking during shrinkage: Nil

Shrink Swell



Shrink Swell Index - Iss (%): 1.4

Comments

Report No: SSI:NEW19W-0272--S06
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S06

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: CLAY

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2210 - 0.40 to 0.55m

Borehole Number: TP2210

Borehole Depth (m): 0.4 - 0.55

Swell Test

AS 1289.7.1.1

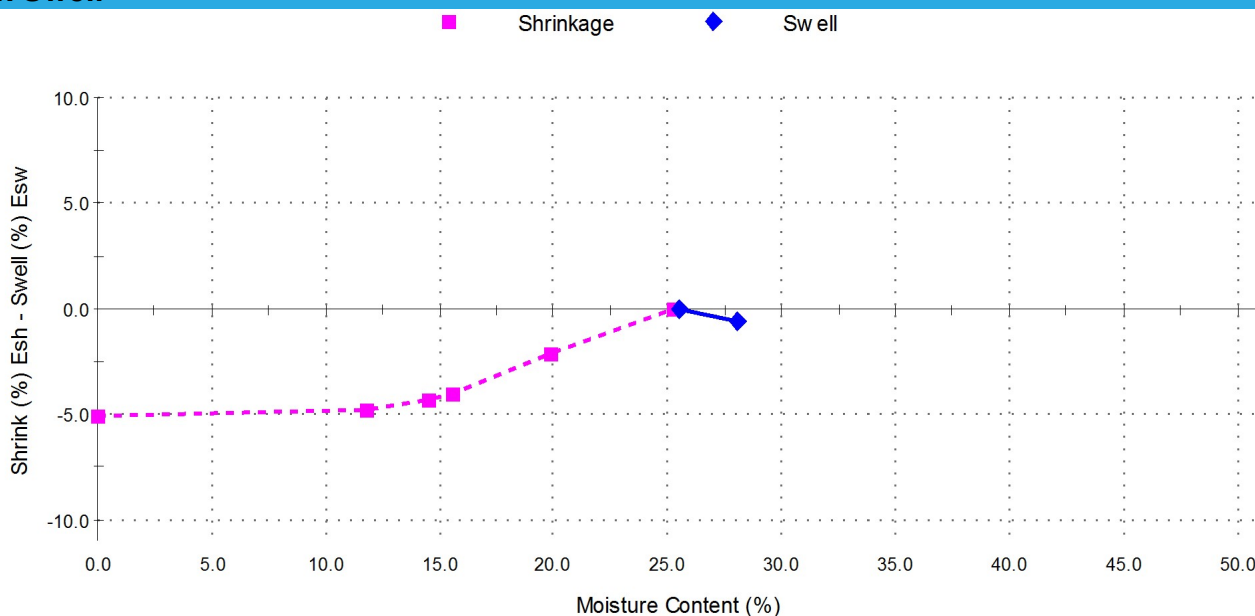
Swell on Saturation (%): -0.6
Moisture Content before (%): 25.5
Moisture Content after (%): 28.1
Est. Unc. Comp. Strength before (kPa): 500
Est. Unc. Comp. Strength after (kPa): 300

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 5.1
Shrinkage Moisture Content (%): 25.2
Est. inert material (%): <1%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Nil

Shrink Swell



Shrink Swell Index - Iss (%): 2.8

Comments

Report No: SSI:NEW19W-0272--S07
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



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B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686

Date of Issue: 11/02/2019

Sample Details

Sample ID: NEW19W-0272--S07

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2211 - 0.30 to 0.40m

Borehole Number: TP2211

Borehole Depth (m): 0.3 - 0.4

Swell Test

AS 1289.7.1.1

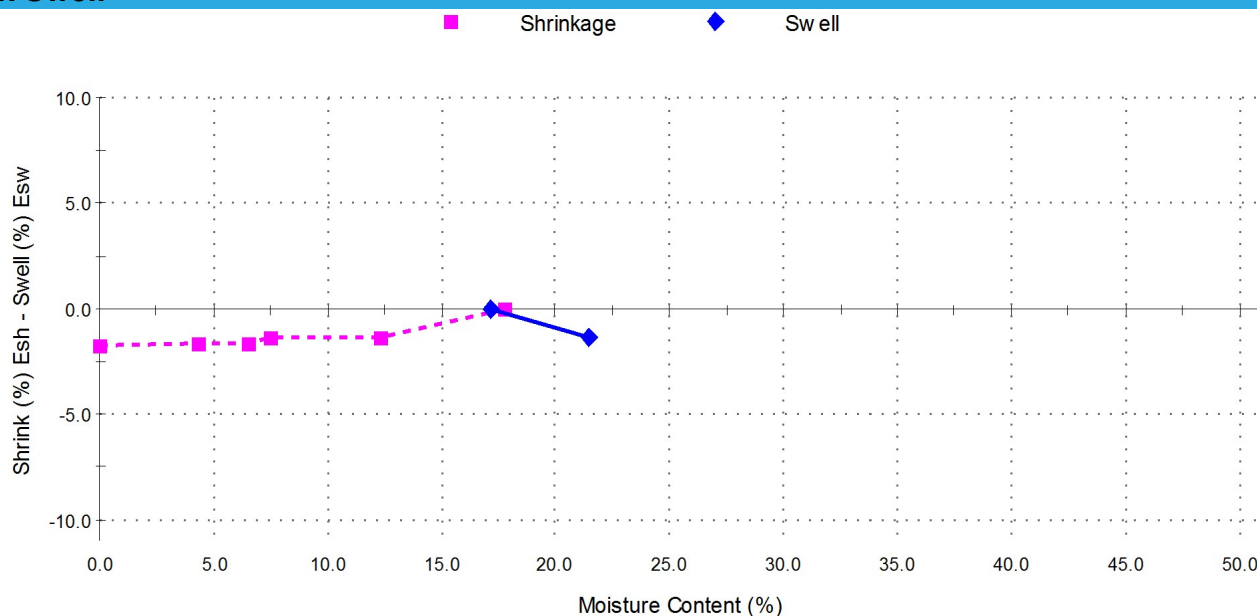
Swell on Saturation (%): -1.3
Moisture Content before (%): 17.2
Moisture Content after (%): 21.5
Est. Unc. Comp. Strength before (kPa): 130
Est. Unc. Comp. Strength after (kPa): 120

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 1.7
Shrinkage Moisture Content (%): 17.7
Est. inert material (%): <1%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Moderate

Shrink Swell



Shrink Swell Index - Iss (%): 0.9

Comments

Report No: SSI:NEW19W-0272--S08
Issue No: 1

Shrink Swell Index Report

Client: McCloy Development Management Pty Ltd
Suite 2, Ground Floor, 317 Hunter Street
Newcastle NSW 2300

Principal:

Project No.: NEW15P-0070E

Project Name: Billys Lookout - Stage 22



Accredited for compliance with ISO/IEC 17025-Testing.
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.
Results provided relate only to the items tested or sampled.
This report shall not be reproduced except in full.

B. Cullen

Approved Signatory: Brent Cullen
(Senior Geotechnician)

NATA Accredited Laboratory Number: 18686
Date of Issue: 12/02/2019

Sample Details

Sample ID: NEW19W-0272--S08

Client Sample ID: -

Test Request No.: -

Sampling Method: AS1289.1.2.1 cl 6.5

Material: Sandy Clay

Date Sampled: 4/02/2019

Source: On-Site

Date Submitted: 4/02/2019

Specification: No Specification

Project Location: Teralba, NSW

Sample Location: TP2212 - 0.30 to 0.50m

Borehole Number: TP2212

Borehole Depth (m): 0.3 - 0.5

Swell Test

AS 1289.7.1.1

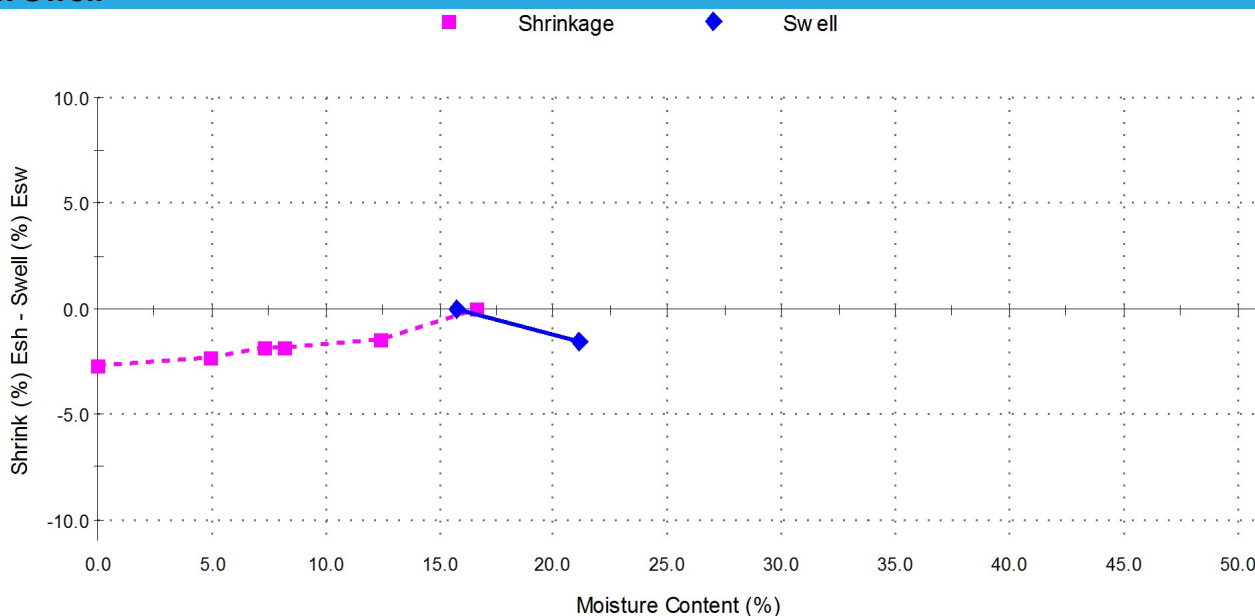
Swell on Saturation (%): -1.5
Moisture Content before (%): 15.8
Moisture Content after (%): 21.1
Est. Unc. Comp. Strength before (kPa): 150
Est. Unc. Comp. Strength after (kPa): 130

Shrink Test

AS 1289.7.1.1

Shrink on drying (%): 2.7
Shrinkage Moisture Content (%): 16.6
Est. inert material (%): <1%
Crumbling during shrinkage: Nil
Cracking during shrinkage: Minor

Shrink Swell



Shrink Swell Index - Iss (%): 1.5

Comments

APPENDIX C:

CSIRO Sheet BTF 18

**Foundation Maintenance and Footing
Performance: A Homeowner's 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.

Trees can cause shrinkage and damage



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

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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

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

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

Plumbing

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

Ground drainage

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

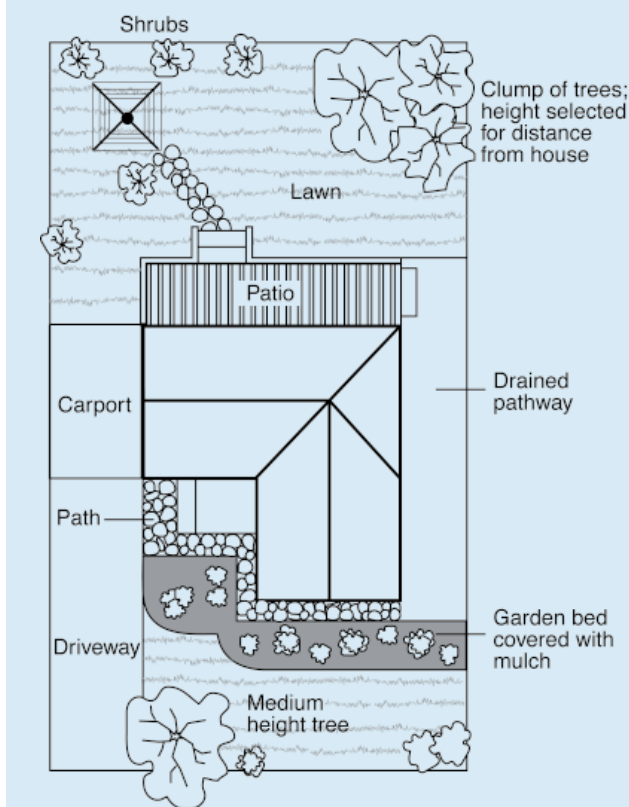
It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

Protection of the building perimeter

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

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

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



- 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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