UR1986_48

1986/48. Subsurface investigation of three proposed house sites at Wulf's subdivision at Karoola.

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Abstract

Three potential house sites on the northern slope of Browns Hill at Karoola were investigated by a backhoe. A landslide in clay and weathered mudstone occurred on a neighbouring block in 1978. This landslide expanded down slope until 1984, when it was confined by a thick sandstone bed in the mudstone. The site preferred by the owners was on a 14° slope near this sandstone bed outcrop. No sandstone was encountered in the backhoe pit, with highly plastic moist clay below the sandy soil. This site was not recommended. The second preferred site was in a shallow depression with a 12° slope. A moist, soft plastic clay layer was present at the interface of the sandy soil and underlying stiff clay. Because of the high moisture content and difficulties of draining the clay, this site was considered to have potential to fail. Site 3, a well-drained slope at a lower elevation, was recommended in spite of the higher costs of access. The only danger foreseen at this site was a slope failure occurring on the 12° slope behind the house. Using shear box test results for clay from this site and comparing these results with analyses using some shear box results on Wulf's failure, it appears the risk of any failure on the slope behind Site 3 is acceptable.

INTRODUCTION

In October 1985 Block 2 (fig. 1) was examined by Mr Moore for the McLeod's, who were potential buyers from Mr Wulf. The block is adjacent to a large recent landslide which occurred on Wulf's block. The McLeod's had selected a potential house site north along the block's entrance track from Karoola Road. The site was at the same level as and close to a thick sandstone bed that crops out along the entrance track.

The McLeod's were advised that if the sandstone bed continued along strike under the sandy soil cover to their proposed site, and if the house foundations could be tied into the sandstone, the site would be recommended to the Launceston City Council. This would require subsurface investigation of the site and any other sites in the area mapped as Zone III (potential landslide) areas in 1981.

The subsurface investigation was undertaken on 7 May in the presence of Mr McLeod, Mr D. Anderson (foundation engineer, Smith, Sale and Burbury) and Mr G. Austin, house designer of Concept Drafting Ltd.

Wulf's subdivision was previously examined and zoned for landslide potential in 1981 by W. R. Moore. This report is an addendum to that unpublished report.

PROPOSED HOUSE SITES

Three pits were dug on this very large block on three potential house sites. The locations of these sites is shown on Figure 1 and the lithological logs of the pits are appended to this report. The results of laboratory analysis of the clay samples collected from the pits are included in Table 1, as are the slow shear box test results of the clay from Pit 3.

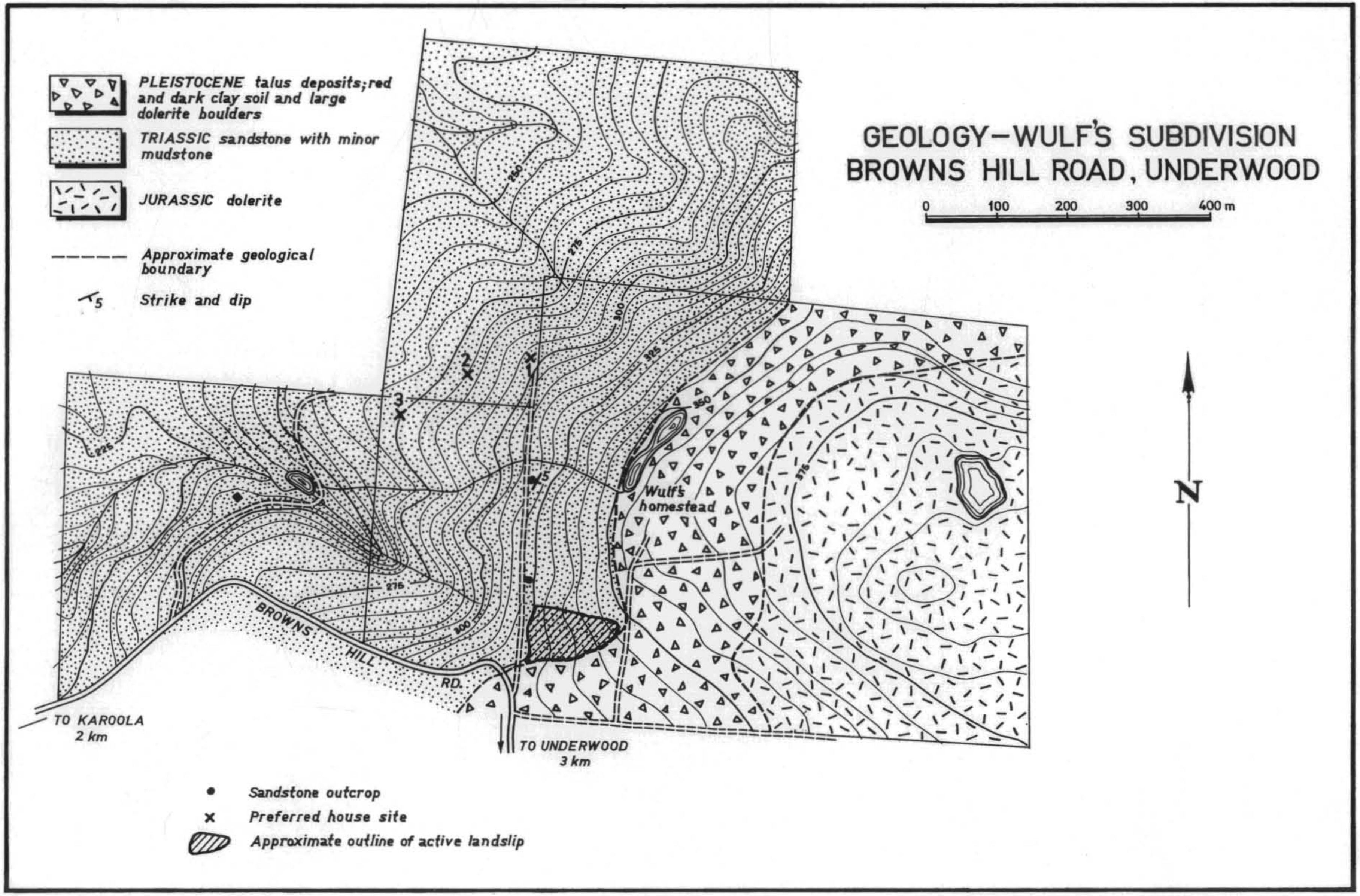

Figure 1

5 cm

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Site 1 was the site preferred by the McLeod's because of the elevation and resulting magnificent view. It also required less road construction from Karoola Road than the alternative sites. This site was also the steepest, with a slope of 14°; the slope is very long and flattens to 12° at the base of the slope.

Site 2 was the owner's second preference. It was sited in a shallow depression at the head of a small gully in a moist area with water seepages close by. The slopes were 10°-11°. Both Sites 1 and 2 were in the area mapped in 1981 as Zone 2, a potential landslide area in which it is recommended to seek the advice of an engineering geologist before building a house.

Site 3 is on a flatter area at the foot of a long 11°-12° slope (fig. 1). The actual site has a slope of 7° and is situated on a bench-like spur which is well drained and is in the Zone I landslide risk area and is considered not to be subject to landslides. The risk at this site is that any failure on the slope behind could move down onto a house built here.

GEOLOGY

All three sites are underlain by sediments of Triassic age (fig. 3; Moore, 1981). Bedded mudstone forms the major part of the sedimentary sequence with some minor, one to two metre thick sandstone beds present. Such a sandstone bed crops out on the track at the same level as Site 1 towards Karoola Road.

SUB-SURFACE INVESTIGATION AND SOIL LABORATORY TESTING

Site 1 (Log 1, Appendix 1)

No sandstone was found below the 0.6 m thick sandy soil in Pit 1, although it was anticipated to occur because the site is along strike from and close to the above sandstone outcrop. Clay was present to a depth of 2.1 m below the top sandy soil. Even though the clay at the bottom of the trench retained the bedded structure of the mudstone it was still obviously clay.

This was confirmed by the laboratory tests on the clay which showed liquid limits to be in excess of 100 and plasticity index values of 74 at 1.1 m depth, 81 at 1.6 m, and 86 at 2.0 m depth. The clay was dominantly kaolinite (55-65%) but the montmorillonite percentage was high in all three samples (15-20%). This is reflected in the high linear shrinkage of the clay (23-24%). The moisture content of clay in this trench is constantly high (37-38%) for the entire depth (Table 1).

With no sandstone present at Site 1, and being situated on a long slope of 14° underlain by highly plastic clay and with a highly permeable sandy soil cover, the potential risk for landslide appears high. Therefore Site 1 was not recommended to the McLeod's on this field evidence when the site was investigated.

It should be noted that it was on a similar slope of 12°-14° that an active failure occurred in Wulf's home paddock (Block 1) in 1978, and the landslide continued to move until 1984 (Appendix 1 in Moore, 1981).

Slope stability analysis - site 1 (Table 2)

Slope stability analysis of this slope, using the shear-box test results of the clay from Pit 3 with a high angle of friction (o) of 24°, and effective cohesion (c') of 2.3 kPa, indicated that this slope is close to failure when saturated. The calculated factor of safety (FS) is 1.24 at a maximum depth to failure plane of 28 m; and 1.22 at a maximum depth of 18 m. With a shallower failure plane (Yc = 750 m) with angle of friction of 18°, cohesion of 2.3 kPa and the slope fully saturated (ru = 0.3), the factor of safety was 1.01 at the point of failure. Given these figures, when the slope was dry (ru = 0.0) its factor of safety was only 1.43.

Site 2 (Log 2, Appendix 1)

A soft moist clay zone, 100-200 mm thick, was exposed at the interface of the sandy silt soil and the underlying stiff clay in Pit 2. As the clay in this soft moist zone was near it's liquid limit, a shallow translational slide is considered a potential danger even on this slope of 10°-11°.

Remedial drainage at this site, as suggested by the engineer, is considered likely to be effective only in the top sandy soil. The effectiveness of any drainage in the underlying clay is considered to be limited.

This site was only considered marginal, on field evidence, on the day of the investigation. The overall dampness of this site was confirmed in the laboratory, with the moisture contents of the clay from Pit 2 being consistently high (40% at 0.8 m depth, 41% at 1.0 m depth and 45% at 1.8 m depth; Table 1). This increase in moisture content with depth indicates that the moisture in the clay is not only derived from water collecting in the surface soil in the area of the small depression in which Site 2 is situated but has moved down the slope behind the site, at depth, within the clay.

With the high moisture contents in the clay and the presence of a soft, moist zone at the top of the clay, Site 2 was not recommended because of the potential slope instability.

Site 3 (Log 3, Appendix 1)

This site is on a well-drained, flat bench at the foot of a long slope between two shallow valley interfluves. It will require extra road construction to reach this site and it has the lowest elevation of the three sites.

The sandy silt soil is 0.6 m thick and overlies a grey-brown clay with some sand. The clay has similar field properties to the clay of the other two pits. This was confirmed by the composition of the clay, although it had a slightly high percentage of quartz. The clay at this site, although highly plastic, has a lower liquid limit (83) and plastic index (59), compared with clay samples from Pit 1 (Table 1). Significantly the moisture content of this clay was low (29%) compared with the clay from the other two pits.

With a low slope of 7°, absence of any soft zones in the clay and with a low moisture content, Site 3 is considered to have the lowest potential for slope failure of the three sites investigated. The only potential risk at this site seen by the writer was for a landslide to occur on the slope (11°-12°) behind the house site and envelop the house.

SLOPE STABILITY ANALYSIS OF SLOPE BEHIND SITE 3 COMPARED WITH WULF'S SLIDE (Tables 3 and 4)

In order to try and evaluate the risk of a failure on the slope behind Site 3, a slope analysis was undertaken. This analysis used an angle of friction of 24° and cohesion of 2.5 kPa, these values being obtained from the shear box test of the clay from pit 3, and a slope configuration of 110 m length with a height of 30 m.

These calculations gave a high factor of safety of 2.1, even when the slope was fully saturated (ru = 0.3). The angle of friction had to be lowered to 14° with a cohesion of 1.3 kPa, before this slope failed with a calculated factor of safety of 0.98 (Table 3).

From these analyses, it appeared that the shear box test results of the clay from Pit 3, with ø of 24° and c' of 2.3 kPa, were too high and probably not representative of the slope. To test this hypothesis a back analysis was undertaken of Wulf's 1981 slide using Moon's surface configuration (Appendix 1, Moore, 1981) and the above shear box results. Failure surfaces with a maximum depth of nine metres when partially saturated (ru = 0.1) gave a factor of safety of 2.42. With the failure plane at a maximum depth of six metres the factor of safety with slope fully saturated was 1.88, partially saturated (ru = 0.1) 2.39, and dry (ru = 0.0) 2.65 (Table 4).

The lowest factor of safety value obtained with these shear box test results was 1.80. This was for a failure plane with a maximum depth of three metres and a fully saturated slope. To obtain values for when this slide was on the point of further failure, as it was in 1981, the angle of friction had to be dropped to 14° and cohesion to 1.3 kPa, and the calculated factor of safety became 1.07. In this calculation, the slope at Wulf's was assumed to be fully saturated (ru = 0.3) (Table 4).

Forward slope analysis calculations on the slope behind Site 3, with the surface configuration as above and using an angle of friction of 14° and cohesion 1.3 kPa with a fully saturated slope (ru = 0.3), it was close to failure with a calculated factor of safety of 1.16 and failed when the angle of friction was lowered to 12°, giving a factor of safety of 0.98 (Table 3).

From these slope analyses, it appears that clay from Pit 3 gave too high a friction angle and cohesion to be representative for the slope of Sites 1 and 2 and the slope behind Site 3. This high laboratory result is probably the result of the small but significant percentage of sand present in the clay sample collected from the trench at Site 3.

CONCLUSIONS

(1) Site 3 is recommended on slope stability criteria. It is considered to have little direct risk from slope failure. Sites 1 and 2 are considered to have a high potential risk from landslides, with Site 1 having the highest potential risk.

(2) The small loss of view because of the lower elevation of Site 3, and the cost of the extra road required to reach it, appear justified to the

writer. The active failure of 1978 occurred in similar clay and mudstone of Triassic sediments and the failure occurred on a slope 11°-14°, similar to the slopes at Sites 1 and 2. It should be noted that this slide continued to extend in the period from 1978 to 1984, until it now appears to have become confined to the mudstone between two thick sandstone beds. The lower sandstone bed is the sandstone bed that crops out along the track to the road just south of Site 1 (fig. 1). This sandstone bed has either become faulted or lensed out in the short distance, between the shallow stream, where the outcrops cease, and Site 1 (fig. 1). In addition, there is evidence of old slides occurring in the more heavily vegetated area on similar slopes to the north-east of Site 1 on Block 2.

(3) The clay underlying the 0.6 m of dark grey sandy silt soil in Pit 3 is expansive, with a linear shrinkage of 21%.

(4) Stability analysis of the slope behind Site 3 indicates that this slope is sensitive to slope failure, particularly when the figures used in this analysis are those derived from back analysis of the active failure on Wulf's property.

RECOMMENDATIONS

(1) Even though Site 3 is considered stable, the slope behind it has a potential to fail. It is suggested that trees and shrubs are planted on this slope. Care should be taken in planning the access road to the site, and that cutting into the banks for this road be kept to a minimum. It is essential to ensure that the road is well drained at all times. The gutters along the sides should be of an adequate depth and should be maintained and kept clear to allow water to flow off this slope rapidly.

(2) If any further closer subdivision is planned or if other houses are to be built on this large block, a subsurface investigation of the proposed site is recommended.

(3) With expansive clay underlying this site, the foundations of the house should be designed and built to withstand or accommodate seasonal movements to avoid future house cracking. The foundations should be designed, and when constructed supervised by a foundation engineer or his agent.

REFERENCE

MOORE, W.R. 1981. Proposed landslip zoning of Wulf's farm, Browns Hill, Underwood. *Unpubl. Rep. Dep. Mines Tasm.* 1981/19.

[5 August 1986]

Table 1. SOIL LABORATORY RESULTS: McLEODS BLOCK 2 - WULF'S SUBDIVISION, KAROOLA

Hole No.	Sample Depth (m)	Moisture Content (%)	Plastic Limit	Liquid Limit	Plastic Index	Linear Shrinkage (%)	Kaolinite (%)	Montmorillonite (%)	Goethite (%)	Total Quartz (%)
1	1.1	37	26	100	74	23	60-65	20-25	10-15	5-10
	1.6	37	28	109	81	24	55-60	20-25	15-20	5-10
	2.0	38	29	115	86	24	55-60	20-25	15-20	5-10
2	0.8	40								
	1.0	41								
	1.8	45								
3	1.0	29	24	83	59	21	65-70	15-20	10-15	10-15

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SHEAR BOX TEST TRENCH 3

Ø angle of friction = 24^{o} c' effective cohesion 2.3 kN/m^{2}

Testing by R.N. Woolley, Department of Mines, Hobart.

Table 2. SLOPE STABILITY ANALYSIS, SITE 1

Slope angle approximately 14°, varies from 12.5°-14°.

ø (°)	c' (kPa)	ru	FS
Yc = 330 m, maximum depth of failure surface = 28 m			
24	2.3	0.3	1.24
	2.3	0.1	1.61
	2.3	0.0	1.77
Yc = 500 m, maximum depth of failure surface = 18 m			
24	2.3	0.3	1.22
	2.3	0.1	1.58
	2.3	0.0	1.76
Yc = 750 m			
24	2.3	0.3	1.24
	2.3	0.1	1.60
	2.3	0.0	1.78
Yc = 500 m			
14	1.3	0.3	0.76
Yc = 750 m			
14	1.3	0.3	0.75
	2.3	0.3	0.79
18	2.3	0.3	1.01
	2.3	0.1	1.29
	2.3	0.0	1.43

Table 3. SLOPE STABILITY ANALYSIS, SLOPE BEHIND SITE 3

Slope 11°-12°

ø (°)	c' (kPa)	ru	FS
Yc = 100 m, maximum depth of failure plane = 16 m			
24	2.3	0.3	2.1
Yc = 200 m, maximum depth of failure plane = 8 m			
24	2.3	0.3	2.03
Yc = 250 m, maximum depth of failure plane = 4 m			
24	2.3	0.3	2.06
14	2.3	0.3	1.24
14	1.3	0.3	1.16
12	1.3	0.3	0.98

Table 4. SLOPE STABILITY ANALYSIS WULF'S LANDSLIDE

Moon's (1981) surface configuration. Slope 12°-14°

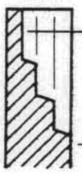
ø (°)	c' (kPa)	ru	FS
Yc = 90 m, maximum depth of failure surface = 9 m			
24	2.3	0.1	2.42
Yc = 120 m, maximum depth of failure surface = 6 m			
24	2.3	0.3	1.88
	2.3	0.1	2.39
	2.3	0.0	2.65
Yc = 200 m			
24	2.3	0.3	1.97
	2.3	0.1	2.48
Yc = 150 m, maximum depth of failure surface = 3 m			
24	2.3	0.3	1.80
24	2.3	0.1	2.41
18	2.3	0.3	1.44
15	1.3	0.3	1.14
14	1.3	0.3	1.07

EXPLANATION SHEET FOR ENGINEERING LOGS

Borehole and excavation log

Penetration

1 2 3



No resistance

ranging to

refusal

Water

22 Jan, 80 Water level on date shown.

Water inflow.

Water outflow.

Notes - samples and tests

U50	Undisturbed sample 50mm diameter.
D	Disturbed sample.
N	Standard penetrometer blow count for 300mm.
N *	SPT + sample.

Material classification

Based on Unified Soil Classification System.

In Graphic Log materials are represented by clear contrasting symbols consistent for each project.

Moisture content

D	Dry, looks and feel dry.
M	Moist, no free water on hand when remoulding.
W	Wet, free water on hand when remoulding.
LL	Liquid limit.
PL	Plastic limit.
PI	Plasticity Index.

eg. M > PL - Moist, moisture content greater than the plastic limit.

Consistency

		hand penetrometer (kPa)
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.	

Notes: X on log is test result
— is range of results.

Density index

		%
VL	Very loose.	0 - 15
L	Loose.	15 - 35
MD	Medium dense.	35 - 65
D	Dense.	65 - 85
VD	Very Dense	85 - 100

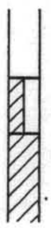
Cored borehole log

Case - lift

Casing used.

Barrel withdrawn.

Fluid loss



No loss

50% loss

100% loss.

Lugeons

Lugeon units (μL) are a measure of rock mass permeability. For a 46 to 74mm diameter borehole 1 Lugeon is defined as a rate of loss of 1 litre per metre per minute. 1 Lugeon is roughly equivalent to a permeability of 1×10^{-4} mm/sec.

Graphic log

No core.

Rock substances represented by clear, contrasting symbols consistent for each project.

Weathering

Fr	Fresh.
SW	Slightly weathered.
HW	Highly weathered.
EW	Extremely weathered.

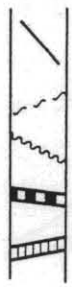
Strength

		point load strength index $I_{s(50)}$ (MPa)
EL	Extremely low.	< 0·03
VL	Very low.	0·03 - 0·1
L	Low.	0·1 - 0·3
M	Medium.	0·3 - 1
H	High	1 - 3
VH	Very high.	3 - 10
EH	Extremely high.	> 10

Note: X on log is test result.

Significant defects

Significant defects shown graphically.



Joint.

Sheared zone.

Crushed seam.

Infill seam.

Extremely weathered seam.

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

excavation no. 1
sheet 1 of 1

project House site investigation, McLeod, Wulf's subdivision, Block 2 **location** Browns Hill, Karoola

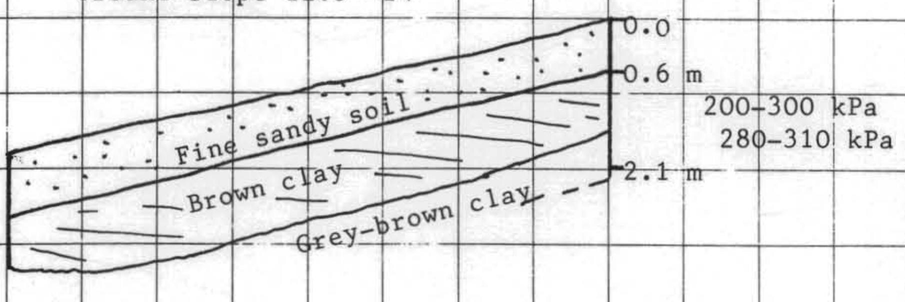
co-ordinates EQ154314 **exposure type** Trench **pit commenced** 27.5.86
equipment Backhoe **pit completed** 27.5.86
R.L. 300 m (approx.) **logged by** W.R. Moore
excavation dimensions 2 x 1 x 2.1 m **operator** Reilly, Karoola **checked by** R.C. Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	None	None				SP	SAND. Dark grey, silty sand. Poorly graded, organic. Sharp transition	D	L		Soil
			S1	1.0		CH	CLAY. Brown, highly plastic.	M < Pl	V St		Clay
			S2, S3	2.0			CLAY. Grey-brown, highly plastic. Some laminar bedding seen. No shearing or shear polish.				Clay, extremely weathered mudstone

Pit stopped, backhoe starting to slip down slope.

sketch

Ground slope 12.5°–14°



5 cm

excavation no.	2
sheet	1 of 1

TASMANIA DEPARTMENT OF MINES

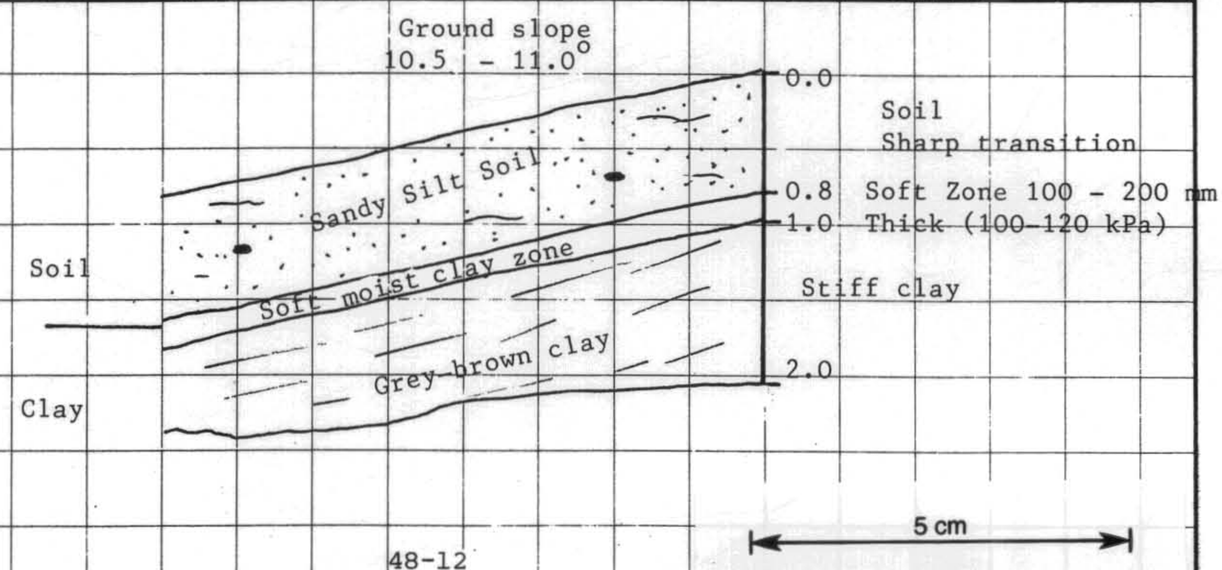
ENGINEERING LOG – EXCAVATION

project House site investigation, McLeod, Wulf's subdivision, Block 2
location Browns Hill, Karoola

co-ordinates	EQ153313	**exposure type**	Trench	**pit commenced**	27.5.86
		equipment	Backhoe	**pit completed**	27.5.86
R.L.	290 m			**logged by**	W.R. Moore
excavation dimensions	2 x 1 x 2 m	**operator**	Reilly, Karoola	**checked by**	R.C. Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
	None	None	S1			ML	SANDY SILT. Fine, dark grey, poorly-graded, organic. Some sandstone boulders.	V M	L		Soil
			S2	1.0		CH	CLAY. Grey-brown. Highly plastic	M=Pl	St		Soft Moist Zone
			S3					M < Pl	V St		Clay
				2.0			Backhoe stopped - required depth reached.				

sketch



TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

excavation no.	3
sheet	1 of 1

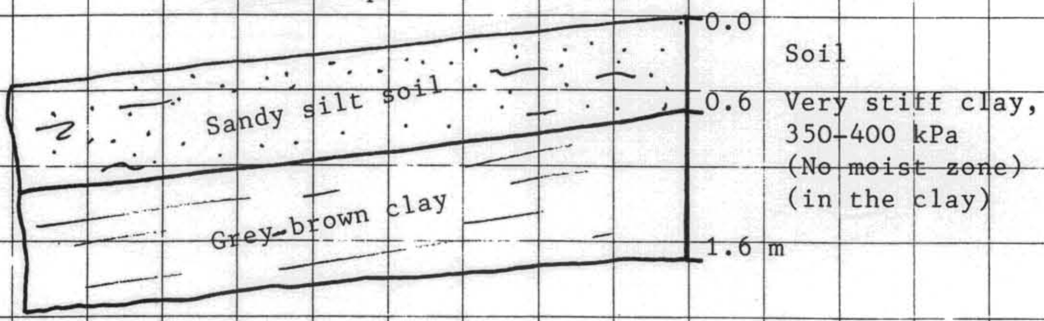
project	House site investigation, McLeod, Wulf's subdivision, Block 2	location	Browns Hill, Karoola

co-ordinates	EQ153312	exposure type	Trench	pit commenced	27.5.86
		equipment	Backhoe	pit completed	27.5.86
R.L.	280 m			logged by	W.R. Moore
excavation dimensions	2 x 1 x 1.6 m	operator	Reilly, Karoola	checked by	R.C. Donaldson

penetration 1 2 3	support	water	notes samples, tests	metres R.L. / depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
						ML	SANDY SILT. Dark grey, poorly graded. Organic.	M	L		Soil
	None	None	S1	1.0		CH	CLAY. Grey – brown, highly plastic	M < Pl	V St		Clay
							Backhoe stopped - required material seen.				

sketch

Ground slope 7°



5 cm