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Geotechnical Investigation Report

Proposed Development at
9-13 Goulburn Street, Warwick Farm NSW

prepared for

Ventus Group Pty Ltd

Report No. G186

October 2016

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REFERENCES

1. Australian Standard AS1726-1993 'Geotechnical Site Investigation'; and
2. Australian Standard AS2870-2011 'Residential Slabs and Footings';
3. Australian Standards – Guidelines on Earthworks for Commercial and Residential Developments, AS3798-2007.
4. Australian Geomechanics Society, Landslide Risk Management Sub-Committee Guidelines: *Landslip Risk Management Concepts and Guidelines,* March 2000.

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1.0 INTRODUCTION

Benviron Group was engaged to undertake a geotechnical investigation at the subject site located at 9-13 Goulburn Street, Warwick Farm (Figure 1-Site Location). The purpose of this investigation is to assess the existing site and subsurface conditions in order to provide recommendations from a geotechnical viewpoint on the proposed development.

This report presents and interprets the findings of the geotechnical investigation carried out on 28th September 2016 at the subject site, known as number 9-13 Goulburn Street, Warwick Farm, NSW, and presents the followings:

- Method of investigation,
- Site description, including surface and sub-surface conditions,
- Site plan indicating borehole locations and footprint of the proposed roads and buildings in the development,
- Groundwater conditions and management, if encountered,
- Recommendations on the excavation conditions,
- Provision of earth pressure parameters for design of retaining structures if required,
- Recommendations on footings and serviceability bearing pressures,
- Recommendations on pavement and design parameters.
- Risk assessment of the site.

2.0 AVAILABLE INFORMATION

At the time of writing this report, information available for the proposed scheme from the client is summarized as follows:

1. Drawings prepared by Urbanlink dated September 2016.

3.0 PROPOSED DEVELOPMENT

3.1 Site Description

The site is located in Warwick Farm, approximately 30 Km south west of the Sydney CBD as shown in the Locality Plan (Figure 1). It comprises two lots and is accessed by Goulburn Street in the east as shown in the Site Plan (Figure 2). The proposed development comprises a multi storey building with a double basement carpark. The footprint of the proposed basement carpark with set-backs from the boundaries and the utility line in the south together with the investigation holes are shown in Figure 2.

3.2 Regional Geology

The Geological Map of Penrith (Geological Series Sheet 9030, Scale 1:100,000, Edition 1, 1991), published by the Department of Minerals and Energy indicates the residual soils within the site to be underlain by Triassic Age Shale of the Wianamatta Group, comprising shale, carbonaceous claystone, claystone, laminite, fine to medium grained lithic sandstone, rare coal and tuff.

4.0 FIELDWORK

Fieldwork for the geotechnical investigation was carried on the 28th September 2016 and comprised the following works:

- Drilling of three (3) boreholes using drilling rig with V-bit attachment and SPT field testing were carried out. Rock coring was undertaken within two of the boreholes to achieve the necessary depths. Most of the holes were terminated at approximately 8m below existing ground level.

The approximate locations of the three boreholes are shown in Figure 2 and the Engineering Borehole Logs are presented in Appendix B.

5.0 FIELD WORK RESULTS

5.1 Subsoil Conditions

Based on information gathered and observations made from the site inspection, it can be inferred that it is likely the subsoil profile comprises residual soil of differing degree of weathering from a soft to stiff and hard nature with increasing depth. It is anticipated that the Extremely Weathered Shale bedrock is likely to be encountered at between 3.5m to 7.0m below existing ground surface, and the more Distinctly Weathered Shale bedrock is likely to be encountered at a depths below approximately 7.0 below the existing ground level across the site.

A Summary of the generalized anticipated subsoil profile across the site is shown in Table 1.

Table 1: Generalised Subsurface Profile

Layer	Description	BH1	BH2	BH3
Residual Soil	CLAY, medium plasticity, Red/brown/grey	0-3.5m	0-3.5m	0-3.5m
Bedrock	Shale, extremely low strength , Light brown/Grey	3.5-4.0m	-	3.5-4.0m
	Shale, low strength , Light Brown/Grey (Class V)	4.0-7.1m	-	4.0-7.2m
	Shale, low strength , Light Brown/Grey (Class IV)	7.1-8m	-	7.2-8.0m

5.2 Ground Water

Groundwater observations were not made within the investigation holes during the drilling process. However, it should be noted groundwater levels may be subject to seasonal fluctuations, rainfall, prevailing weather conditions and also future developments of the areas and land forms.

6.0 LABORATORY TEST RESULTS

Rock cores drilled are kept in core-boxes. Samples have been collected from these core-boxes to assess the rock strength at the various level within the Shale bedrock. The testing carried out on the rock samples was the Point Load Strength Index Test, and the Point Load Strength Indices for the rock cores and the assessed rock strengths in accordance with the Australian Standards (Reference 1). The test results are enclosed in Appendix C and are summarised in the following Table 1.

Table 2: Point Load Test Results

Sample ID	Location	Depth (m)	Diametrical Is(50) (MPa)	Axial Is(50) (MPa)	Assessed Strength
1	BH1	6.5	0.17	0.38	Low
2	BH2	6.5	0.27	0.34	Medium

Based on the rock core strengths (*Table 1*) and the rock discontinuities (shown in the core logs and core photographs), the bedrock from the proposed development site for foundation design purposes in accordance with Pells et al (*Reference 4*) is classified in general as a Class V/IV Shale.

7.0 RETAINING STRUCTURES AND FOUNDATIONS

7.1 Excavation Conditions

Based on currently information provided, excavations may be required for the construction of retaining structures within the development. However, should any excavation be considered or planned in the final stages of the development design, the following should be considered.

It is expected materials encountered during excavation are likely to comprise stiff to hard clays. Excavation of soil-based materials and extremely to highly weathered Shale may be achieved using conventional earthmoving equipment such as backhoes or tracked excavators. Heavy ripping and/or vibratory rock breaking techniques are not likely to be required.

However, where percussive excavation techniques are to be adopted, we recommend saw cutting method is applied along the excavation perimeter to reduce the vibrations transferred to neighbouring structures and to minimise potential risks to their structural integrity. In such situation, we also recommend dilapidation reports are to be carried out on all adjoining buildings, roads and civil structures so that an accurate record of the existing conditions of these elements are mapped prior to the commencement of excavation. These records shall be agreed by the respective owner in order to reduce the risk of future owner's dispute on subsequent potential damage claims.

Site earthworks should be properly drained to minimise the effects of wetting up and softening of exposed, natural subgrade soils, which may be caused by extraneous water sources and climatic variations. Trafficability across the site may be restricted to tracked plant during and following periods of wet weather and the trafficking of wet subgrades with any plant would be expected to result in significant subgrade damage. Should possible bulk excavation be terminated within the silty clay or clay layers, it is considered the natural materials at the base of such excavations may be trafficable under favourable climatic conditions and lack of groundwater presence. However, similar trafficability problems, as outlined for site subgrades, may be anticipated where “wetting” may occur.

It is therefore suggested that consideration be given to the placement of a granular layers to provide convenient working platforms and improve site trafficability. Such a layer would also significantly assist in reducing potential drying out of reactive soil subgrades. Where such platforms are to be utilised for the support of heavy machinery or plant, it may be appropriate to design these platforms to such loads and if necessary have these confirmed and inspected by a geotechnical engineer.

7.2 Groundwater Management

Groundwater seepage was not observed at the time of the investigation. However, it should be noted groundwater levels may vary subject to seasonal fluctuations, rainfall, prevailing weather conditions and also future development of the surrounding lands.

7.3 Temporary Batter Slopes

Temporary batter slopes may be appropriate for possible excavations or cut slopes provided excavations or cut slopes are set back sufficiently from common site boundaries to facilitate the formation of the recommended safe temporary batters outlined in Table 2.

Table 5 - Minimum Temporary Batter Slopes

Materials	Temporary (Horizontal: Vertical)
Stiff CLAY	3.0:1.0
Very Stiff/ Hard Silty Clay	2.0:1.0
Distinctly Weathered Shale	1.0:1.0

Temporary surface protection against erosion may be provided by covering the batter with plastic sheets or other applicable methods. It is considered that plastic sheeting, if adopted, should extend at least 1.5m behind the crest of the cut face or at least up to the common site boundaries. Plastic sheeting should be positioned and fastened to prevent water infiltration into or onto the batter which may lead to softening and possible instability. All stormwater run-offs should be directed away from all temporary and permanent slopes.

7.4 Retaining Structures

In the long term, the excavation faces must be retained by engineered retaining structure in particularly along the Goulburn Street section of the site. These structures should be designed to withstand the applied lateral pressures of the soil/rock layers, the existing surcharges in their zone of influence; including existing structures, and construction related activities, and also hydrostatic pressures (if it is appropriate).

The pressure distribution on cantilever retaining structures, only due to the earth pressures and surcharges behind the wall, may be assumed to be triangular and estimated as follows (ignoring cohesion effect):

$$p_h = gkH + qk$$

Where,

p_h = Horizontal pressure (kN/m^2)
g = Wet density (kN/m^3)
k = Coefficient of earth pressure (k_a or k_o)
H = Retained height (m)
q = Surcharge pressure behind retaining wall (kN/m^2)

For the design of flexible retaining structures, where some lateral movement is acceptable, an active earth pressure coefficient is recommended. Should it be critical to limit the horizontal deformation of a retaining structure, use of an earth pressure coefficient at rest should be considered. Recommended parameters for the design of retaining structures are presented in the following Table 3.

Table 6: Geotechnical Design Parameters

Materials	Unit Weight (kN/m^3)	Active Earth Pressure coefficient (K_a)	At Rest Earth Pressure Coefficient (K_o)	Passive Earth Pressure coefficient (K_p)
Stiff/very stiff silty clay	18	0.40	0.60	ignore
Hard silty clay	20	0.33	0.50	3
Extremely Weathered Shale (Class V or IV)	20	0.20	0.30	150kPa

* Passive lateral earth pressure.

The above coefficients assume that ground level behind the retaining structures is horizontal and the retained material is effectively drained. It should be noted that hydrostatic pressures due to ground water table (if present) and surcharge due to nearby structures (within the influence zone) should also be taken into the account in the design of the retaining structures. The influence zone of a retaining wall may be defined between the wall and a line drawn from its heel with 45^o from the horizon. The design of any retaining structure should be checked for bearing capacity, overturning, and overall stability of the slope.

7.5 Foundation System

The loading conditions for the proposed development are not known at the time of preparation of this report. However, considering the scale of the development, it is envisaged that foundation materials required to support the proposed structure would comprise Class V or better shale bedrock. Based on the borehole information and rock strength testing, it is envisaged that the shale bedrock likely to be exposed at basement bulk excavation levels would constitute either Class V or Class IV and may be feasible to meet this requirement.

Spread footings comprising strip or pad footings founded in Class V bedrock below the basement bulk excavation level may be designed for a serviceability end bearing capacity of 700kPa.

Spread footings comprising strip or pad footings founded in Class IV or better shale bedrock below the basement bulk excavation level may be designed for a serviceability end bearing capacity of 1000kPa. It is recommended that a further drilling for assessment of the foundation material of the proposed footings be carried out once excavation to the final basement level has been reached. The footing inspection and assessment requirement can be referred to the guidelines given in accordance with Pells, Douglas et al.

Footing inspections by a Geotechnical Engineer will be required during footing excavation to confirm appropriate founding materials, that the recommended serviceability bearing pressures could be met and to ensure that all soft and wet materials have been removed from the foundation footprint prior to concrete placement.

8.0 CONCLUSIONS

This report presents the results of a geotechnical investigation for the proposed development of a residential subdivision at 9-13 Goulburn Street, Warwick Farm NSW. Geotechnical recommendations have been provided to address the issues as requested.

We consider that the proposed development is feasible in this site subjected to the recommendations presented in this report.

LIMITATIONS

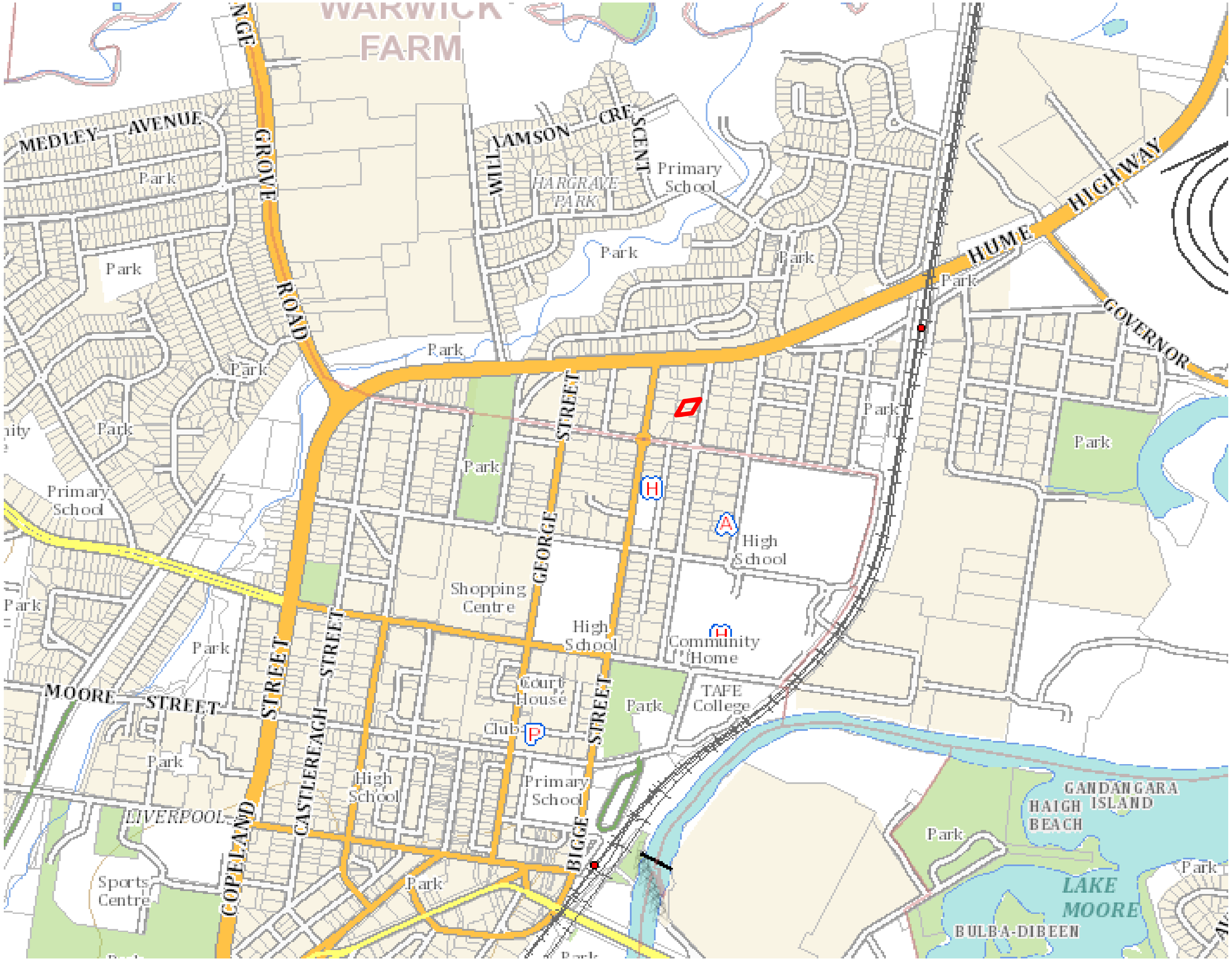
The assessment of the sub-surface profile within the proposed development area and the recommendations presented in this report are based on limited information available to date.

The recommendations and advice presented in this report on soil and rock condition is considered to be indicative only as only very limited areas were assessed on site to date. Site inspection by a consulting Geotechnical Engineer or Engineering Geologist are to be undertake when further investigation works are to be carried out to confirm the condition of founding materials in which this geotechnical assessment recommends.

Anecdotal evidence and Information provided by client is assumed to be relevant and to the best of knowledge be appropriate for its interpretation.

There is a possibility that the actual geotechnical and groundwater conditions across the site could differ from the inferred geotechnical assumptions and derivations on which our recommendations are presented in this report.

FIGURE 1 – SITE LOCATION



Key

Site Location

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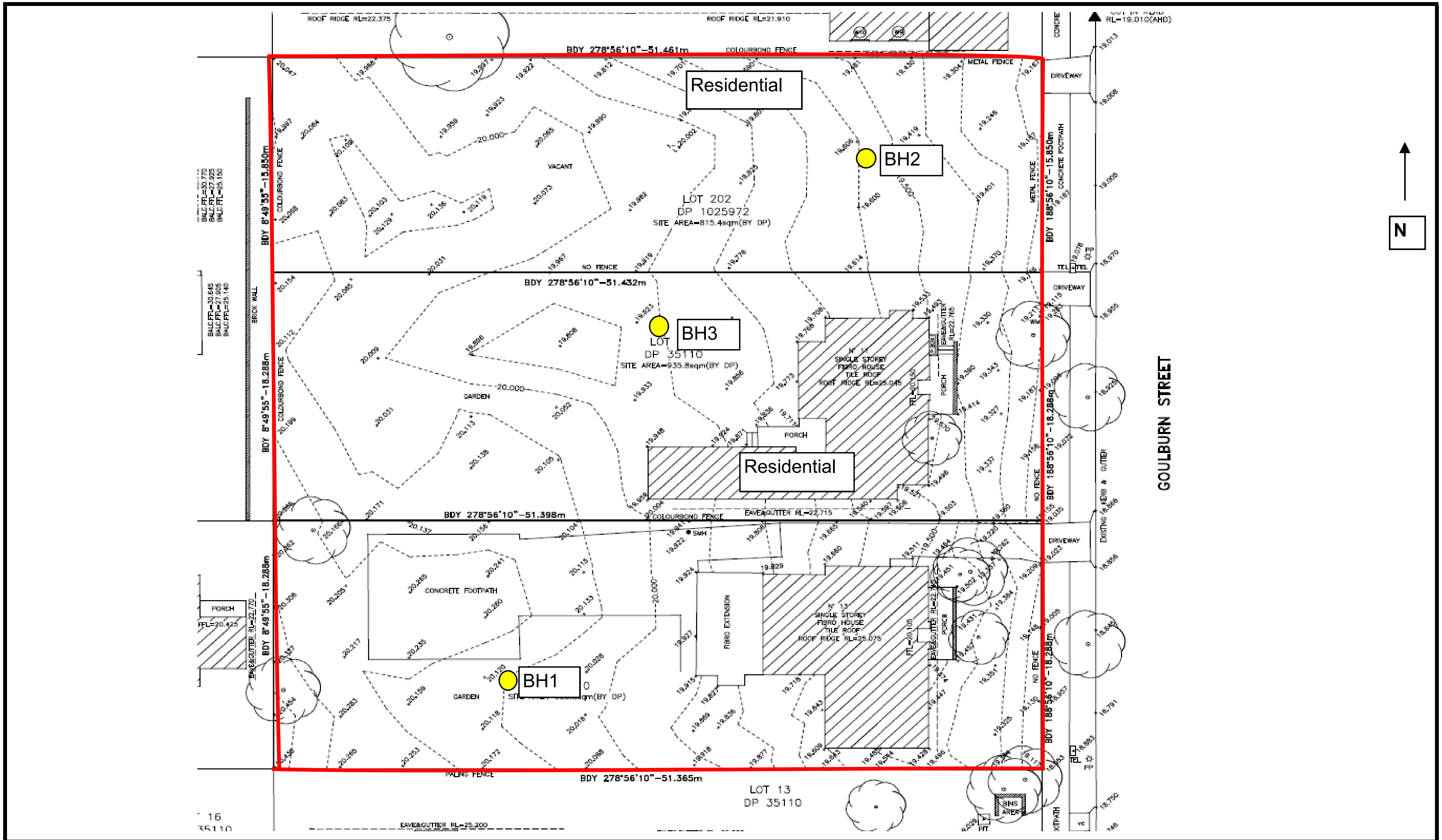
DRAWN BB	SITE LOCATION	
FIGURE 1	Ventus Group Pty Ltd	
Job # G186	9-13 Goulburn Street, Warwick Farm NSW	

FIGURE 2 – SITE PLAN



Key

Site Boundary

Borehole Location

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DRAWN	SITE PLAN
BB	
FIGURE	Ventus Group Pty Ltd
2	
Job #	9-13 Goulburn Street, Warwick Farm NSW
G186	

APPENDIX A – ENGINEERING BOREHOLE LOGS

Job No:	G186
Hole No:	BH1
Sheet	1 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: RL 20.120	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		0.1		SM	Silty SAND, coarse grained, dark brown, trace with some gravels	D	L		0.1
		0.2							0.2
		0.3							0.3
		0.4							0.4
		0.5							0.5
		0.6		CL	Silty CLAY, fine grained, medium plasticity, red/brown, trace of sand	M	S	Low V-bit Resistance	0.6
		0.7							0.7
		0.8							0.8
		0.9							0.9
	SPT	1.0							1.0
	3,6,7	1.1							1.1
	N=13	1.2							1.2
		1.3		SM	Silty CLAY, coarse grained, red/brown, trace with mottled grey	D	L	Low V-bit Resistance	1.3
		1.4							1.4
		1.5							1.5
		1.6							1.6
		1.7							1.7
		1.8							1.8
		1.9							1.9
	SPT	2.0							2.0
	5,14,23	2.1							2.1
	N=37	2.2							2.2
		2.3							2.3
		2.4							2.4
		2.5							2.5
		2.6							2.6
		2.7							2.7
		2.8							2.8
		2.9							2.9
		3.0							3.0
	SPT	3.1		CI	Shaley CLAY, fine grained, medium plasticity, red/brown, mottled grey, trace with gravels	M	H	Medium to High V-bit Resistance	3.1
	8,17,30	3.2							3.2
	N=47	3.3							3.3
		3.4							3.4
		3.5							3.5

Continued on Sheet 2 of 3

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH1
Sheet	2 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: RL 20.120	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		3.6			Start NMLC Core Drilling at 3.5m				3.6
		3.7		-	SHALE, fine grained, dark grey, low strength, slightly weathered, highly fractured, Class V SHALE	M	H/VD	Bedrock - Rockhead High Core Bit Resistance	3.7
		3.8							3.8
		3.9							3.9
GW		4.0							4.0
		4.1							4.1
		4.2							4.2
		4.3							4.3
		4.4							4.4
		4.5							4.5
		4.6							4.6
		4.7							4.7
		4.8							4.8
		4.9							4.9
		5.0							5.0
		5.1							5.1
		5.2							5.2
		5.3							5.3
		5.4							5.4
		5.5							5.5
		5.6							5.6
		5.7							5.7
		5.8							5.8
		5.9							5.9
		6.0		-	SHALE, fine grained, dark grey, low strength, slightly weathered, Class V SHALE	M	H/VD	High Core Bit Resistance	6.0
		6.1							6.1
		6.2							6.2
		6.3							6.3
		6.4							6.4
		6.5							6.5
		6.6							6.6
		6.7							6.7
		6.8							6.8
		6.9							6.9
		7.0							7.0

Continued on Sheet 3 of 3

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH1
Sheet	3 of 3

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ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: RL 20.120	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		7.1		-	SHALE, fine grained, dark grey, low strength, slightly weathered, Class IV SHALE	M	H/VD	High Core Bit Resistance	7.1
		7.2							7.2
		7.3							7.3
		7.4							7.4
		7.5							7.5
		7.6							7.6
		7.7							7.7
		7.8							7.8
		7.9							7.9
		8.0			Borehole BH1 terminated at 8.00m				8.0
		8.1							8.1
		8.2							8.2
		8.3							8.3
		8.4							8.4
		8.5							8.5
		8.6							8.6
		8.7							8.7
		8.8							8.8
		8.9							8.9
		9.0							9.0
		9.1							9.1
		9.2							9.2
		9.3							9.3
		9.4							9.4
		9.5							9.5
		9.6							9.6
		9.7							9.7
		9.8							9.8
		9.9							9.9
		10.0							10.0
		10.1							10.1
		10.2							10.2
		10.3							10.3
		10.4		-					10.4
		10.5							10.5

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH2
Sheet	1 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016 Logged by: BB
		Surface Level: RL 19.606

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		0.1		SM	Silty SAND, coarse grained, dark brown, trace with some gravels	D	L		0.1
		0.2							0.2
		0.3							0.3
		0.4		CL	Silty CLAY, fine grained, medium plasticity, yellow/brown,	M	S	Low V-bit Resistance	0.4
		0.5							0.5
	SPT	0.6							0.6
	3,6,6	0.7							0.7
	N=12	0.8							0.8
		0.9							0.9
		1.0							1.0
		1.1		SM	Silty CLAY, coarse grained, red/brown, trace with mottled grey gravels	D	L	Low V-bit Resistance	1.1
		1.2							1.2
		1.3							1.3
		1.4							1.4
		1.5							1.5
	SPT	1.6							1.6
	5,13,25	1.7							1.7
	N=38	1.8							1.8
		1.9							1.9
		2.0							2.0
		2.1							2.1
		2.2							2.2
		2.3							2.3
		2.4							2.4
		2.5							2.5
		2.6							2.6
		2.7							2.7
		2.8							2.8
		2.9							2.9
		3.0							3.0
	SPT	3.1		CI	Shaley CLAY, fine grained, medium plasticity, red/brown, mottled grey, trace with gravels	M	H	Medium to High V-bit Resistance	3.1
	8,16,30	3.2							3.2
	N=46	3.3							3.3
		3.4							3.4
		3.5							3.5

Continued on Sheet 2 of 3

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH2
Sheet	2 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: RL 19.606	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		3.6							3.6
		3.7			Start NMLC Core Drilling at 3.7m				3.7
		3.8		-	SHALE, fine grained, dark grey, low strength, slightly weathered,	M	H/VD	Bedrock - Rockhead	3.8
		3.9			highly fractured, Class V SHALE			High Core Bit Resistance	3.9
GW		4.0		-	SHALE, fine grained, dark grey, low strength, slightly weathered,	M	H/VD	High Core Bit	4.0
		4.1			fractured, Class V SHALE			Resistance	4.1
		4.2							4.2
		4.3							4.3
		4.4							4.4
		4.5							4.5
		4.6							4.6
		4.7							4.7
		4.8							4.8
		4.9							4.9
		5.0							5.0
		5.1							5.1
		5.2							5.2
		5.3							5.3
		5.4							5.4
		5.5							5.5
		5.6							5.6
		5.7							5.7
		5.8							5.8
		5.9							5.9
		6.0							6.0
		6.1							6.1
		6.2		-					6.2
		6.3							6.3
		6.4							6.4
		6.5							6.5
		6.6							6.6
		6.7							6.7
		6.8							6.8
		6.9							6.9
		7.0							7.0

Continued on Sheet 3 of 3

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH2
Sheet	3 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: RL 19.606	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		7.1		-	SHALE, fine grained, dark grey, low strength, slightly weathered, Class IV SHALE	M	H/VD	High Core Bit Resistance	7.1
		7.2							7.2
		7.3							7.3
		7.4							7.4
		7.5							7.5
		7.6							7.6
		7.7							7.7
		7.8							7.8
		7.9							7.9
		8.0			Borehole BH2 terminated at 8.00m				8.0
		8.1							8.1
		8.2							8.2
		8.3							8.3
		8.4							8.4
		8.5							8.5
		8.6							8.6
		8.7							8.7
		8.8							8.8
		8.9							8.9
		9.0							9.0
		9.1							9.1
		9.2							9.2
		9.3							9.3
		9.4							9.4
		9.5							9.5
		9.6							9.6
		9.7							9.7
		9.8							9.8
		9.9							9.9
		10.0							10.0
		10.1							10.1
		10.2							10.2
		10.3							10.3
		10.4		-					10.4
		10.5							10.5

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

Job No:	G186
Hole No:	BH3
Sheet	1 of 3

ENGINEERING LOG OF DRILLED BOREHOLE

Client:	Ventus Group Pty Ltd	Test Location: Refer to Figure 1	
Project:	Proposed Residential Development	Test Method: Tracked Drill Rig	
Project Location:	9-13 Goulburn Street, Warwick Farm NSW	Date: 28/09/2016	Logged by: BB
		Surface Level: 19.923	

Groundwater	Samples/ Field Tests	Depth (m)	Graphic Log	Unified Classification	Description	Moisture Condition	Consistency/ Rel. Density	Additional Comments	Depth (m)
		0.1		SM	Silty SAND, coarse grained, dark brown, trace with some gravels	D	L		0.1
		0.2							0.2
		0.3							0.3
		0.4		CL	Silty CLAY, fine grained, medium plasticity, yellow/brown, trace of sand	M	S	Low V-bit Resistance	0.4
		0.5							0.5
	SPT	0.6							0.6
	3,6,7	0.7							0.7
	N=13	0.8							0.8
		0.9							0.9
		1.0							1.0
		1.1		SM	Silty CLAY, coarse grained, red/brown, trace with mottled grey gravels	D	L	Low V-bit Resistance	1.1
		1.2							1.2
		1.3							1.3
		1.4							1.4
		1.5							1.5
	SPT	1.6							1.6
	5,10,21	1.7							1.7
	N=31	1.8							1.8
		1.9							1.9
		2.0							2.0
		2.1							2.1
		2.2							2.2
		2.3							2.3
		2.4							2.4
		2.5							2.5
		2.6							2.6
		2.7							2.7
		2.8							2.8
		2.9							2.9
		3.0							3.0
	SPT	3.1		CI	Shaley CLAY, fine grained, medium plasticity, red/brown, mottled grey, trace with gravels	M	H	Medium to High V-bit Resistance	3.1
	8,15,30	3.2							3.2
	N=45	3.3							3.3
		3.4							3.4
		3.5							3.5
					End of Borehole				

Explanatory Notes:

Consistency		Density Index		Samples		Moisture	
VS	Very Soft	**VL**	Very Loose	**B**	Bulk Sample	**D**	Dry
S	Soft	**L**	Loose	**D**	Disturbed Sample	**M**	Moist
F	Firm	**MD**	Medium Dense	**U50**	Undisturbed Sample (50mm diam.)	**W**	Wet
St	Stiff	**D**	Dense			**Wp**	Plastic Limit
VSt	Very Stiff	**VD**	Very Dense	**N**	S.P.T. Value	**Wl**	Liquid Limit
H	Hard						

APPENDIX B – CSIRO FACT SHEET

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 perpends).

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

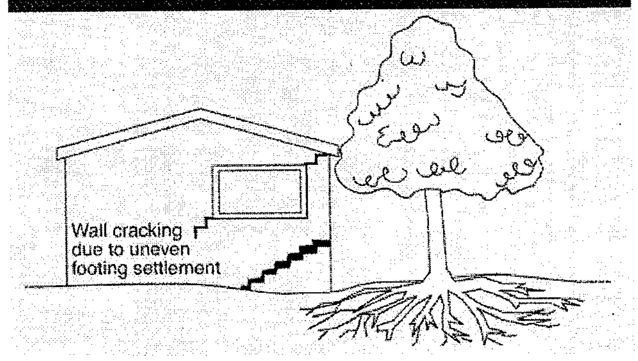
Seasonal swelling/shrinkage in clay

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

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

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

Trees can cause shrinkage and damage



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

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

Movement caused by tree roots

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

Complications caused by the structure itself

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

Effects on full masonry structures

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

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

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

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

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

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

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

Effects on framed structures

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

Effects on brick veneer structures

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

Water Service and Drainage

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

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

Plumbing

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

Ground drainage

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

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

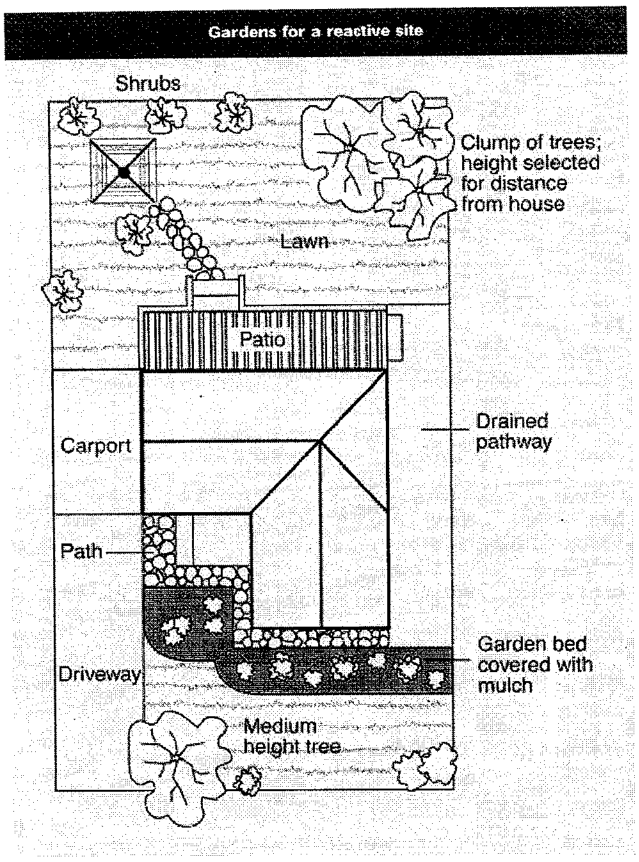
Protection of the building perimeter

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

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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