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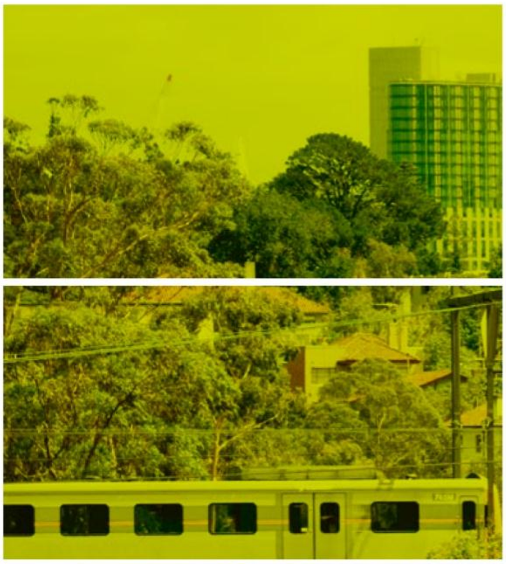

GEOTECHNICAL INVESTIGATION: NEW 11-FLOOR BUILDING AT LISMORE BASE HOSPITAL

Uralba Street, Lismore

New South Wales Health Infrastructure

GEOTALST01618AN-AF
8 March 2012

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SPECIALISTS MANAGING THE EARTH

8 March 2012

New South Wales Health Infrastructure
c/o Aurora Projects Pty Ltd
Level 6, 50 Berry Street
North Sydney, NSW, 2060

ATTN: Gavin Thompson

Dear Sir

RE: Geotechnical Investigation: New 11-Floor Building at Lismore Base Hospital

Coffey Geotechnics is pleased to present our revised report on the geotechnical investigation at the above site. The report includes minor edits and expanded comment on foundations near the soil nail wall located above the Mental Health Unit. This report supersedes report GEOTALST01618AN-AD.

We draw your attention to the attached sheet entitled “Important Information about Your Coffey Report” which should be read in conjunction with this report.

We trust that this report meets your requirements. If you require further information please contact the undersigned in our Alstonville office.

For and on behalf of Coffey Geotechnics Pty Ltd

R Vleggaar

RIAN VLEGGAAR

Geotechnical Engineer

Distribution:	1 electronic Copy – New South Wales Health Infrastructure c/o Aurora Projects
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1 INTRODUCTION

Coffey Geotechnics Pty Ltd (Coffey) has conducted a geotechnical investigation at the proposed location of a new 11-floor building at Lismore Base Hospital. The hospital is located at Uralba Street, Lismore. The investigation was commissioned by New South Wales Health Infrastructure.

Coffey conducted the work in accordance with proposal no. GEOTALST01618AN-AC, dated 30 November 2012. This report presents the results of the site investigation and our geotechnical recommendations.

This version of the report includes more detailed discussion of construction and foundations near the existing soil nails above the mental health unit.

2 SITE DESCRIPTION AND PROPOSED DEVELOPMENT

A site survey plan of existing features, prepared by Newton Denny Chapelle of Lismore, has been used as a base plan for this report (Figure 1).

The site of the proposed building will be located over the footprint of the existing Pathology Building (Block T) and Mortuary Building (Block H). A soil nail wall, sloping down and away from the site, is located to the north of the site, above the Mental Health Unit. To the west of the site, the main hospital building and the Mother’s Care Unit (Block J) bound the site. To the east and south, Little Uralba and Uralba Streets bound the site respectively.

The existing structures on the site will be demolished to make way for the new building.

Regionally the site is located near the crest of a Basalt ridgeline following the alignment of Uralba Street. The ground slopes down to the north from about RL 36m at Uralba Street to about RL27m at the top of the soil nail wall, with an average slope of about 1V:7H.

The proposed building will be an 11-floor structure, with the superstructure developed in three stages. Two levels of basement excavations will be undertaken, staggered across the site and set into the ground slope.

The depth of excavation for the basement levels will vary. Coffey estimates that excavations of up to 5.5m at the eastern boundary with Little Uralba Street and 4.5m at the southern boundary and step-up between excavation levels will be undertaken. The proposed excavation profiles are shown on Figures 2 and 3 and were based on sketches in the geotechnical brief.

Taylor Thomson Whitting (NSW) Pty Ltd (TTW) has advised that column loads may be up to 8,000 kN and that a structural grid of 8.4m by 8.4m would likely be adopted. The structure would also be a post-tensioned concrete frame or a conventionally reinforced concrete structure.

3 SCOPE OF WORK

3.1 Fieldwork

Fieldwork was carried out from 15 to 18 and 24 to 25 January 2013, inclusive. The field work comprised the drilling of three boreholes, BH1, BH2 and BH3 to depths of 20m, 20m and 25.7m respectively. The deeper borehole was undertaken to obtain information on the continuity of the lower basalt layer underlying the known tephra layer on the site that separates two basalt flows.

The locations of the boreholes are indicated on Figure 1.

Samples comprising Standard Penetration Test samples in soils and triple tube NMLC cores in rock were collected from the boreholes.

Fieldwork was conducted in the full-time presence of a geotechnical professional from Coffey who logged the materials observed, collected samples and recorded results of in-situ testing.

Engineering logs of the geotechnical conditions encountered are included in Appendix A.

3.2 Laboratory Testing

Samples collected during the fieldwork were submitted for laboratory testing at our NATA-accredited Coffs Harbour laboratory. The following testing was undertaken:

- 2 Atterberg Limits tests on near surface soil.
- 1 Atterberg Limits test on the Tephra layer.
- Point Load Index tests on rock cores at about 1.5m intervals.

CBR testing for pavement support could not be undertaken due to limited sample obtained from the augers.

Laboratory Test results are summarised in Section 4.3 and are attached in Appendix B. Point load index test results are included on the engineering logs and in Appendix B.

4 SUBSURFACE CONDITIONS

4.1 Geotechnical Conditions Observed

The Tweed Heads 1:250,000 Geological Map of NSW indicates that the site is underlain by the Lismore Basalts. This was further borne out by the subsurface investigation results.

In general, the observed geotechnical conditions are consistent with those from previous investigations by Coffey and others at the main Hospital building to the west of the proposed structure. Two Basalt flows, separated by a Tephra layer (a deposit of volcanic material ejected into the air), were observed in the boreholes. The depths of the boreholes were chosen to confirm the thickness, properties and base of the tephra to aid in assessing constraints to the support of building loads.

The Tephra layer was observed to be typically in the order of 2m to 3m thick, to dip less than 1m in elevation from the north to the south, and to reduce in thickness towards the east of the site. The extents of the layer were observed between RL 18m and RL 15m.

The weathering profile of the upper basalt is complex. It appears that extensive and variable weathering has occurred in the upper basalt at the north-western quadrant of the site (BH2). This weathering is consistent with observed cutting exposures above, and the footing exposures visible beneath the hospital, respectively. The upper basalt flow has undergone only minor weathering at the south-western and north-eastern quadrants of the site.

We infer that there will be a contact between the zones of different degrees of weathering of the rock mass. The location of this contact was not encountered in the boreholes. The delineation of this contact is an important geotechnical consideration for the project as different support requirements are likely on either side of the contact, both for foundations and for lateral support. Excavation conditions for the basement levels will also be different.

We recommend that the contact requires further investigation to reduce the risk of contract variation and variable building performance. We note that the south-eastern quadrant of the site was not accessible for a drilling rig at the time of the investigation.

The subsurface conditions encountered at the site is summarised in Table 1. The levels given correspond to those encountered in the boreholes. These are not necessarily minimum, maximum or average values of these units across the site.

Geotechnical Sections are shown on Figures 2 and 3. Further details of the materials encountered in the boreholes are provided on the Engineering Logs.

Table 1: Summary of Subsurface Conditions Encountered

Unit	**Description**	**Levels Encountered (RL, metres AHD)**		
		BH1	BH2	BH3
1	**FILL:** comprising a concrete pavement overlying gravelly clay, gravel and clay. This fill is expected to be non-compliant to the requirements for controlled fill per AS3798-2007.	33.2 – 33.7	26.8 – 27.5	31.0 – 32.2
2	**RESIDUAL SOIL AND SOIL-STRENGTH EXTREMELY WEATHERED (XW) BASALT:** comprising high plasticity, stiff to very stiff gravelly clay.	33.2 – 33.7	-	-
3A	**UPPER BASALT FLOW** **SLIGHTLY WEATHERED (SW) TO FRESH (FR) BASALT:** comprising very high to extremely high strength basalt. The upper 1m to 2m of the unit comprising Moderately Weathered (MW) basalt. The defect spacing within this unit is generally 30mm to 300mm to 5m depth and generally 100mm to 1,000mm below 5m depth.	17.5 – 32.8	-	17.8 – 31.0

Unit	Description	Levels Encountered (RL, metres AHD)		
		BH1	BH2	BH3
3B	**UPPER BASALT FLOW** **VARIABLY AND DISTINCTLY WEATHERED BASALT:** comprising a predominantly Highly Weathered (HW) rock mass in the upper 4m with a network of closely spaced XW seams some 10mm to 100mm apart. High strength, SW basalt pieces were observed between the seams. Below 4m the network of seams is less defined and the rock grades to a more homogenously weathered HW to MW basalt.	-	18.1 – 26.8	-
4	**TEPHRA LAYER:** comprising variably weathered Tephra, ranging from XW (very stiff to hard soil strength) at BH2 to HW to MW (very low to high rock strength) at BH1 and BH3	14.9 – 17.5	15.5 – 18.1	16.2 – 17.8
5	**LOWER BASALT FLOW** **HW to MW BASALT:** comprising low to medium strength basalt, defect spacing 30mm to 300mm.	-	13.3 – 15.5	-
6	**LOWER BASALT FLOW** **SW TO FR BASALT:** comprising high to extremely high strength basalt, with typical defect spacing greater than 300mm (up to 1,000mm) with minimum defect spacing around 100mm.	-	From below 8.3 to 13.3	From below 6.4 to 16.2
7	**SLIGHLTY WEATHERED PYROCLASTIC AGGLOMERATE:** comprising high to very strength rock, including basalt bombs in a tuff matrix. Defect spacing is typically 300mm to 1,000mm.	From below 13.7 to 14.9	-	-

4.2 Groundwater

Groundwater inflow was not observed in the borehole during drilling. Circulation of drilling fluid was introduced with the commencement of coring. As this level was high in each of the boreholes, the majority of the drilling was undertaken while groundwater inflows (if any) were obscured by the use of drilling fluids.

Standing water levels during the investigation were affected by the drilling fluid which remained in the holes overnight.

Groundwater conditions within the basalt rock observed may be highly variable, and would likely follow defects and seams. Groundwater flows within the rock may only be visible following significant rain events.

The greater weathering observed at the north-western quadrant (BH2) may indicate that groundwater flows may have influenced this area more than other parts of the site.. However, as the dating of the weathering is unknown, groundwater conditions may have changed over geological time.

For reference, groundwater seeps were not observed at the soil nail wall to the north of the site during construction in 2007. This indicates that standing, long term groundwater levels are likely to be below RL 23m on the site, not accounting for any perched water tables or short term groundwater flows during or after rainfall or otherwise.

4.3 Laboratory Test Results

The results of the laboratory testing are summarised in Table 2 (Material Classification tests).

Laboratory test results are provided in Appendix B.

Table 2: Material Classification Test Results Summary

Sample	Liquid Limit (%)	Plasticity Index
BH2, 0.5 – 0.95m, Clay fill	54	27
BH1, 0.45 – 0.55m, Residual Soil	55	29
BH3, 10.2 – 10.45m, Tephra	74	42

5 GEOTECHNICAL ASSESSMENT

5.1 Excavation Assessment

5.1.1 Proposed Excavations

Basement excavations on the site will take place through Units 1, 2 and 3A and 3B. The approximate extent of excavations is shown on the geotechnical sections on Figures 2 and 3.

The excavation conditions will be variable across the site due to the sloping surface and variable subsurface conditions. Some of the excavations will need to penetrate very high and extremely high strength massive rock. Consideration should be given to reduce the volume of excavations within these units.

5.1.2 Resistance to Excavation

Excavation of Units 1 and 2 should be feasible using typical earthmoving equipment such as backhoes or hydraulic excavators (say less than 15 tonnes).

Excavation of Units 3A and 3B will present greater challenges in terms of the plant required, speed and cost of excavation. Prospective excavation contractors should undertake their own assessment of appropriate excavation techniques and likely productivity of specific plant based on the engineering logs and recovered rock core samples stored at the Coffey office. Further testing specific to excavatability, such as abrasivity, drillability and indenter tests may assist in such a detailed assessment. Such tests should also include the mechanical action of excavation (e.g. drilling, hammering, toothed buckets, tynes etc.) for appropriate assessment. The point load index test is a simple indicator of intact rock strength but may not always be representative of the excavation properties of the rock mass.

Based on the existing proposal, excavation in Unit 3A will be through moderately and slightly weathered Basalt with Point Load Index test values of 4 to 8 MPa (BH1) and between 1 and 10 MPa (BH3). The intact rock strength of this unit may be in the range of 100 to 250 MPa. From the observed core the defects interlocked well and were generally clean and rough. It is therefore likely that excavation in this unit will need to be undertaken using splitting of rock from a working face using, for instance, slow chemical expanders in predrilled holes. Excavation productivity rates are expected to be low. If crushing of the excavated basalt can be undertaken economically, crushed basalt may be useful for gravel backfill or aggregate on site, or could be on-sold.

Excavation in Unit 3B will be through a highly weathered Basalt structure, being heavily fractured with developed seams and similar to the existing cuttings and footing excavations for the existing main hospital building. Defect spacings were generally 10mm to 100mm at the levels of the proposed investigation and comprised weathered seams. It is envisaged that relatively large (say greater than 20 tonne) excavators with toothed buckets and ripping tynes could be used to work loose this material. It is possible that a pneumatic rock hammer would be required for zones where less seams are present.

Rock mass properties may change with distance, and variable weathering (both a degree of more or lesser weathering) should be expected between borehole locations.

5.1.3 Vibration Impacts on Nearby Structures

Excavation in the basalt using equipment such as impact hammers could result in vibration damage to susceptible receptors. If such plant is proposed to be used then a vibration monitoring and contingency plan should be developed.

It is in the interest of the owner of the site and of the contractor undertaking the work, that a pre-work condition survey of nearby structures be undertaken. The use of vibration sensors with data logging will aid in the monitoring of the works and managing of risk due to vibrations.

5.1.4 Trafficability of the Excavated Site

The trafficability of Units 1 and 2 once exposed is expected to be poor, particularly after rainfall and on sloping sections. Where access is required over these units, a working platform of granular materials will aid vehicle and equipment movements.

The trafficability of Units 3A and 3B is expected to be good provided the running surface is kept free of debris and is drained well.

Coffey can assist in the assessment of working platforms for heavy equipment such as cranes, drilling rigs or piling rigs.

5.1.5 Excavation Slope Profile

The profile of unsupported excavations on the site will be compound due to the range of material the basements will transect. For unsupported slopes, relatively low angles will be required through the Unit 1 and 2 soil units, while steeper cuts should be feasible for Unit 3B. For the proposed depths of excavation (up to 5.5m), the Unit 3A slightly weathered and fresh Basalt unit is expected to be self-supporting barring the presence of any adversely oriented defects that may affect stability though wedge failures or block toppling.

Comments and recommendations regarding temporary and permanent slopes are summarised in Table 3. As the contact between Units 3A and 3B has not been delineated in detail, further infill drilling is recommended.

Table 3: Summary of Slope Profile Considerations

Unit	**Unsupported Slopes**		**Comments**
	Temporary Slopes	**Permanent Slopes**	
Controlled fill to AS3798-2007	1V:1.5H	1V:2H	Should be assessed on a case-by-case basis once specific available filling materials are known.
Unit 1 – Uncontrolled Fill	1V:2H	1V:3H	Steeper cuts may be feasible if soil nails or active anchors are incorporated.
Unit 2 – Residual soil and XW Basalt	1V:2H	1V:3H	
Unit 3A – MW to FR Basalt, VH to EH strength	Upper 1.5m: The top 1.5m of this unit shall be cut back at an angle of 1V:1H to manage the defects observed in this zone in the rock core. Below upper 1.5m: Self-supporting at vertical (provided good excavation techniques are used) to the heights proposed unless adverse defects exist.		A geotechnical professional should observe the exposure of this material for indications of adverse in-situ defects that may affect stability.
Unit 3B – HW Basalt	1V:1H	1V:1.5H	Cut through this material to the north of the site, and above the Mental Health unit became unstable at 60°. Passive or active anchoring would be required for steeper angles.

5.1.6 Retention or Shoring of Excavated Slopes/Faces

If space requirements dictate that the unsupported slope angles from Table 3 are not feasible, then retaining structures, shoring or anchoring (active or passive anchors) may be warranted.

It is considered feasible to undertake top-down excavation of the basement at steeper angles (up to vertical) provided support is provided to Units 1, 2, 3B and the top 1.5m of Unit 3A. Unit 3A below the level supported by anchors may be left vertical; however, progressive mapping by a geotechnical professional during each stage of excavation will be required to compare the observed conditions to the design intent. Spot bolting should be effective to manage risk from wedge failures or block toppling from the face of Unit 3A and it is likely that the necessary equipment for anchor installation from the same contractor could be used for spot bolting, if required.

The designer of anchors on the western boundary will need to ensure that the drilling and bond zone of anchors do not interfere with any existing foundations. Along the south and east of the site, utilities (such as water lines, stormwater lines and sewers) and pole foundations may be present in the upper 3m. Temporary or permanent relocation of these utilities may be necessary to allow installation of soil nails or anchors.

Coffey can assist in the development of a support design and specification for the above-mentioned top-down excavation method. Anchor design parameters have been provided in Table 5.

The use of bored pile walls (e.g. secant or soldier pile walls) could be problematic due to the high strength of the rock and associated difficult drilling the sockets needed to embed the piles. However, this option may be useful to achieve greater certainty in the extent of support requirements before the works commence as once the piles are installed, excavation could proceed without the need for standby should additional support requirements arise. It is also considered practicable that vertical building loads could be incorporated onto the lateral piles as needed, improving efficiency of the site area. Nominal shotcreting on the face between piles (say 100mm thick with reinforcement mesh SL81 for preliminary purposes) would be required for Units 1, 2 and 3B and the upper 1.5m of Unit 3A to reduce the risk of material spalling from between piles. Drainage should be provided behind the shotcrete.

Simple cantilever retaining walls (bottom up construction) are not considered suitable for the full height of the excavations, as the exposure of the full profile over slope angles steeper than those in Table 3 may present a high risk of instability. However, it could be feasible to construct retaining walls founded onto Unit 3A to support the upper Units 1, 2, and 3B, prior to further excavation into Unit 3A. This would not allow for a near vertical excavation profile for the full height, but could allow for steeper average slopes than in Table 3. Further consideration would be required in this case for the foundation requirements of the retaining wall as excavation would proceed below it. This could be managed by providing a minimum offset from the toe of the foundation to the crest of the rock excavation (say 2x the footing width in section) and/or providing tensioned anchors in the heel of the foundation or ground anchors to assist in resisting over-turning forces and to reduce bearing pressures.

Geotechnical parameters for design of lateral earth restraint are given in Table 4. Estimated Young's Moduli and lateral spring stiffnesses (Subgrade Reaction Modulus) for the materials are given in Table 7. Appropriate drainage measures must be incorporated into all retaining structures to control groundwater build-up.

Table 4: Lateral Earth Pressure Parameters

Material	Bulk Density, γ_b (kN/m^3)	Design Undrained Shear Strength (kPa), S_u	Effective Cohesion (kPa), c'	Effective Friction Angle ϕ'	Lateral Earth Pressure Parameters		
					K_a	K_0	K_p
Controlled fill to AS3798-2007 (Granular)	22	-	0	32°	0.31	0.47	3.3
Unit 1 – Uncontrolled Fill	20	50	5	24°	0.42	0.59	2.4
Unit 2 – Residual soil and XW Basalt	20	75	5	28°	0.36	0.53	2.8
Unit 3A – Top 1.5m of unit Note 1	26	-	120	63°	0.06	0.11	17
Unit 3A – Top 1.5m to 3.5m of unit Note 1	26	-	550	69°	0.03	0.07	29
Unit 3A – Below Top 3.5m of unit Note 1	26	-	4000	68°	0.04	0.07	26
Unit 3B – HW Basalt Note 1	24	-	40	48°	0.14	0.25	7.1

Note 1. Mohr-Coulomb parameters (c' and ϕ') have been provided for the rock materials based on a fit through the Hoek-Brown criteria (for the rock mass properties) and based on good workmanship in undertaking the excavations. The estimates were made over the pressure range of 0 – 0.3 MPa for the 5m slope. The inputs to the Hoek-brown classification are approximate. These Mohr-Coulomb parameters (and hence K_a, K_0 and K_p) for rock should be used with extreme caution and **do not allow for defects** which often control failure in a slope and often control lateral earth pressure onto retention structures.

5.1.7 Active and Passive Ground Anchor Geotechnical Design Parameters

Based on the assessment of appropriate slope support, pull-out bond stresses between grouted elements such as anchor or soil nail bond zones are given in Table 5. Appropriate reduction or safety factors should be used for the design method adopted (e.g. limit states or allowable stress design, respectively). A geotechnical reduction factor of 0.4 is considered appropriate for ultimate limit states design.

Table 5: Anchor/Nail Bond Stress

Unit	Ultimate Bond Stress, Pull-out
Controlled fill to AS3798-2007 (Granular)	40 kPa
Unit 1 – Fill	Do not use for anchor support
Unit 2 – Residual soil and XW Basalt	70 kPa
Unit 3A – MW to FR Basalt, VH to EH strength	• 0.4 MPa in the top 1.5m of the unit • 1 MPa between 1.5m and 3.5m into the unit • 2.4 MPa below the top 3.5m of the unit.
Unit 3B – HW Basalt	100 kPa

5.2 Comment on Presence of Existing Soil Nail Wall at North of Site

5.2.1 General Aspects

The existing soil nail wall to the north of the site, and supporting the slope above the mental health unit, will pose a constraint to the footprint of the basement floor and the foundation layout.

Based on the maximum nail length used in the design, the soil nails are up to 8m long, extending into the slope face. Coffey recommends that construction records be reviewed for actual nail installation depths.

It is recommended that the nearest in-ground structural elements along the northern side of the site be founded at least 10m back from the crest of the soil nail wall. Piles carrying lateral load near the soil nails will require careful consideration once pile layouts and loads are known. Coffey can assist with detailed analysis of these effects.

The impacts of surcharge loads on the soil nail wall should be considered in the design.

5.2.2 Construction Loads above Wall

The area above the soil nail wall is currently an access-way and car park to the rear of the Mortuary and eastern side of the main hospital building. Based on our discussions we understand that deliveries by heavy vehicles may be required in this area during construction.

The design of the Soil Nail Wall was documented in the Coffey Letter GEOTALST01618AE-AC dated 30 January 2007. The design includes and allowance of 10 kPa design load above the wall.

It is recommended that spread loads behind the wall from stockpiling or other loads be limited to 10 kPa where vehicle access is not planned. This would correspond to a loosely stockpiled mound 0.65m high or compacted fill of 0.5m high.

Traffic loads for deliveries should be limited to “General Access” vehicles as defined by the Roads and Maritime Services (RMS) with a reduction in maximum vehicle mass from 42.5 tonnes to 32 tonnes, i.e. Max Truck Lengths of 12.5m, Max tonnage 32 tonnes. This results in an aggregate load of about 10 kPa. Vehicles must be set back at least 3m from the crest of the soil nail wall. Access to the area may be difficult based on current arrangements. Design of retention systems for the excavations should include allowances for delivery vehicles.

Where filling and vehicle access is proposed, the vehicle mass should be reduced by the amount of load the fill imparts.

Where heavy construction equipment is proposed (e.g. pile boring equipment) the wall factor of safety should be re-assessed. This should be done once piling equipment requirements are known. It is envisaged that Pneumatic Drills for micro piles in this area could be installed using rigs with mass less than the vehicle limit above. Contractors should be consulted for available equipment during the design process.

5.2.3 Consideration of Piles near and over the Soil Nail Wall

Piles and micro piles near the soil nail wall should be designed based on the guidance in Section 5.4.2.

5.3 Site Filling

There are limited volumes of site soil available for re-use. Between 400mm and 1.2m thickness of soil strength material was observed in the three boreholes undertaken. It is likely that across the building footprints, most soil strength material would have been removed during the construction of the footings and slabs of the pathology and mortuary buildings. It should be feasible to re-use the gravelly clay from the residual soil or existing fill units, however, volumes are expected to be relatively small.

The proposed basement excavations would result in large volumes of spoil comprising rock and large particles (e.g. coarse gravel, cobble and boulders). The Unit 3B material may be able to be used as a coarse gravel fill. The product won from the excavation would need to be assessed on site as the excavation method may result in a product that is different than that suggested by the core photo. It is expected that the product would comprise a clayey gravel with fine to coarse grained granular fraction.

In order to utilise spoil on site from the Unit 3A excavations, it is likely that crushing plant would be required. It is considered feasible that clean gravel could be produced from a crushing stream. It may be feasible to on-sell excavated rock and any crushed product on the site to offset some cost of importing general fill.

Any fill supporting structures (e.g. beneath footings), services or pavement should be placed as controlled fill to AS3798-2007. Coffey recommends that Level 1 geotechnical inspection and testing be undertaken with testing frequencies as recommended in AS3798. .

Controlled fill should be placed to the provisions of AS3798 for commercial developments. It may be necessary to develop a method specification if fill comprising material with more than 20% of particles larger than 37.5mm is used. Coffey can assist in this regard during construction.

5.4 Foundations

5.4.1 Conventional Pad, Strip and Piled Footings

We have assessed that Unit 3A and 3B will be required to support the advised column loads (8,000 kN) below the excavation levels on the site. Foundation conditions will vary across the site. As such the building designer should consider whether articulation of the structure will be necessary.

High level footings have been used successfully for the main hospital building. Excavation and piling on the site will be difficult given the high to very high strength of the rock. High capacity piling rigs will be required if rock sockets are required.

The volcanic rock units at this site are more complex than sedimentary rocks, due to the dynamic nature of their deposition, structural formation and complex weathering. Interaction between the geotechnical and structural consultant during design and geotechnical involvement during construction is recommended, to provide economical foundation designs for the indicated column loads.

The bedrock quality varies across the site area and with depth. Footing performance will generally be governed by settlement rather than bearing capacity considerations. The settlement characteristics of the rock will be significantly influenced by defects such as clay seams. If the poorest rock quality is considered for each rock unit, then the resulting design parameters will be relatively conservative and impact on foundation costs.

We recommend that foundation parameters be assessed assuming defects such as clay seams within the zone of influence of the footings are not 'worst case'. However, verification works will be required during construction to confirm that defects are within tolerable limits. For shallow footings this may consist of additional cored boreholes or spoon testing. For bored piles, additional cored boreholes would be required. To this end we have provided typical and 'worst case' parameters for the Unit 3B material which exhibited the most variability across the site to allow a sensitivity analysis to be carried out.

We provide serviceability values for pad or strip footings in Table 6. If these values are adopted we would expect that settlements should be less than 1% of the footing width.

Table 6: Preliminary Design Parameters – Pad and Strip Footings

Unit	Maximum % Clay Seams (1)	Allowable Bearing Pressure (kPa)
Unit 2 – Residual Soil	No limit	100
Unit 3A – Top 1.5m of unit	25	1,000
Unit 3A – Below top 1.5m of unit	8	2,500
Unit 3A – Below top 3.5m of unit	4	5,000
Unit 3B (general, high level footings)	25	1,000

Unit	Maximum % Clay Seams (1)	Allowable Bearing Pressure (kPa)
Unit 3B (‘worst case’, high level footings)	50	500

Note: (1) Footings should be assessed by spoon testing or coring to a depth of at least 3 times the footing width or to 1.5m depth, whichever is greater.

For bored piles we recommend the preliminary ultimate limit state design parameters in Table 7. Due to the strength of the rock, achieving long rock sockets is likely to require high capacity piling rigs and low productivity should be expected. We provide parameters for the rock above RL18m on the basis that it is unlikely to be practicable to bore deeper piles, although calculations based on worst case conditions may indicate that deep piles are required. Further geotechnical advice should be sought during detailed design to assist with the assessment of piling for the relatively complex ground conditions.

Young’s modulus values are provided for the assessment of settlements at serviceability loads. Coffey would be pleased to carry out settlement analyses for specific pile dimensions to assist with detailed design, as an extension to our commission.

Table 7: Preliinary Design Parameters – Bored Piles

Unit	Maximum % Clay Seams	Ultimate End Bearing Pressure (MPa) (1)	Ultimate Shaft Adhesion/Friction (MPa) (1)	Ultimate Lateral Yielding Profile (2) (kPa)	Young’s Moduli (Vertical) (MPa)	Subgrade Reaction Modulus, k_s for Laterally Loaded Piles (3) (MPa/m)
Unit 3A (top 1.5m of unit)	25	3	0.15	0.75	75	33
Unit 3A (below top 1.5m of unit)	8	30	0.6	7.5	500	250
Unit 3A (below top 3.5m of unit)	4	60	1	12	1,000	540
Unit 3B (‘worst case’, piled footings)	25	3	0.15	0.75	100	45
Unit 3B (general, piled footings)	8	30	0.6	7.5	500	250

Note (1) The parameters for Unit 3A and 3B are appropriate for piles that terminate at least 3 pile diameters above the top of the Unit 4 Tephra layer (about RL18m AHD). If longer piles are required further geotechnical advice should be sought.

Note (2). These values apply for the top 1m or 1.5 pile diameters of the unit (whichever is greater). Below that level these values may be doubled.

Note (3). The subgrade reaction modulus is given for a pile size of up to 1.2m and concrete stiffness of 30 GPa. Higher values may apply for smaller piles. Coffey can assist in more detailed assessment once preliminary pile sizes have been assessed by the designer.

Pile designs should be undertaken according to the provisions of AS2159-2009: *Piling - Design and Construction*. When considering the ultimate limit state the use of the geotechnical strength reduction factor (ϕ_g) is required. As per AS2159-2009 the factor is a function of the basic geotechnical strength reduction factor (ϕ_{gb}) and the degree of testing undertaken. The basic factor is assessed from a subjective consideration of the risk at the site posed by the site conditions, design process, and installation quality control of the piles. Pile integrity, serviceability and/or strength testing is required by AS2159-2009 if a reduction factor of greater than 0.4 is to be used. If no testing is undertaken, a geotechnical reduction actor of 0.4 should be used.

If pile testing is specified, the assessment requires assignment of an Average Risk Rating (ARR) which is then used to determine a geotechnical strength reduction factor taking into account the redundancy of the pile system and quantity and type of pile testing to calculate geotechnical strength reduction factor. This process necessarily requires consideration of a number of factors which at this stage of the project Coffey are not in a position to assess.

In order for a recommendation to be made the following assumptions have been made about decisions that will be made by the structural designer. The terms used in AS2159-2009 have been used. In the event that these assumptions change, the design geotechnical strength reduction factor would need to be modified in accordance with the requirements of AS2159-2009 Clause 4.3.

Coffey has undertaken an assessment of the risks based on the following assumptions:

- The pile designer has more than limited experience with similar foundations in similar geological conditions.
- Design method adopted will be based on simplified methods with well-established basis, the methods recommended in this report or other mutually agreed methods.
- A limited degree of professional geotechnical involvement in supervision will be undertaken (or specified) and conventional construction techniques would be used.
- No monitoring of the level of performance of the supported structures during or after construction.

Coffey calculated an ARR of 3.5 to 4.0 (moderate to high risk) and therefore a basic geotechnical reduction factor (ϕ_{gb}) of 0.45 to 0.53 would be assigned to the site for low and high redundancy piling systems respectively.

Pile load testing may be used to increase the basic factor. For example, using dynamic load testing of other than preformed piles, and the guidelines of Clause 4.3.1 of the standard, the basic values discussed above could be increased to the following values:

- 3% of piles tested: $\phi_g = 0.61$.
- 10% of piles tested: $\phi_g = 0.70$.

However, at this site the rock is relatively high strength and the geotechnical strength criteria may be able to be met with a strength reduction factor of 0.4. This will be dependent on verifying the rock strength and that the defects (clays seams) below the pile base are less than 8%. Therefore, there may be more benefit in additional boreholes rather than extensive pile load testing. Strength testing of piles to failure is unlikely to be practical for rock piles as the load may be difficult to mobilise. Accordingly the use of dynamic testing of cast-in-place piles is recommended for confirmation of load carrying capacity of the piles.

5.4.2 Use of Micro Piles near or within extent of Soil Nails above Mental Health Unit

The project team has raised the possibility of using micro-piles founded through the reinforced block zone of the soil nail wall. In principal this concept may be practicable but will require detailed analysis to assess the possible impacts of pile loadings on embankment stability. Careful attention will be required to construction workmanship and contingencies will be needed in the event that complications arise. These factors and design of such micro piles are considered below.

5.4.2.1 Construction Issues

In order to construct micro-piles, the use of a reverse cycle pneumatic drill would likely be required to form the pile holes. The pile size would be limited to around 250mm. Given the small diameter, constructability problems may arise if groundwater is encountered and tremmie placement is required. Special concrete mixes may be required to allow installation of reinforcement post-casting of the pile.

If groups of micro piles are required to resist imparted loads, and the piles are spaced at closer than 5 pile diameters, then an equivalent pile diameter of the perimeter formed by the micro pile group should be used to assess offsets.

The soil nail design lengths were up to 8m, but varied in length. The construction record of the installation by Reed Constructions should be referenced for as-built locations and lengths.

Installation geometries of soil nails may neither be straight nor predictable. We expect that deviation of up to 5° could exist along the length of the nail. Maximum deviations of installed nails could be some 700mm at the bottom of an 8m long nail. Placement of micro piles should consider such potential deviations.

If a soil nail is struck during installation, replacement nails may be required to be installed. A top-down working approach will be required as access is not possible from below the wall.

5.4.2.2 Design of Micro Piles

The soil nail wall design was carried out for long-term conditions such as self-weight of the slope, groundwater and surcharge loads. No additional allowance was made for imparted lateral or vertical pile loads. The wall was designed with a long term calculated factor of safety of at least 1.5.

The degree to which the factor of safety would be affected would depend on the magnitude, location and nature of the lateral and vertical loads. Lower factors of safety than 1.5 may result if the soil nail block is surcharged by lateral or vertical loads. However, lower factors of safety may still be acceptable if the loads are transient (e.g. wind or earthquake actions).

Once details about the imparted lateral loadings are known, the effect on the soil nail wall could be further analysed. Cyclical load analysis may be required. If the analyses show that the reduction in factor of safety is small for the proposed pile locations and load distribution, it may be feasible to construct the micro piles with some surcharge on to the reinforced wall block.

If the effect is more pronounced, limits on the founding depth of construction aspects of the piles may be required, and/or the resistance in the soil nail wall will have to be increased. Vertical and lateral loads may then require foundation below the level of the toe of the wall with piles isolated from the ground in the upper sections.

Lateral loads in the east-west direction (i.e. along the wall) may be taken up by micro piles in the reinforced block zone provided lateral deflections are small and the lateral load bearing piles are spaced and loaded similarly to reduce stress concentrations on the nails. Such concentrations could lead to cracking of the nails and early deterioration of the nail bar through corrosion.

Directing north-south lateral loads to shear walls/diaphragms founded away from the soil nail extents (by at least 5m) is expected to prevent loading of the soil nail wall and would reduce the need for additional analysis of the load effects on the wall.

Coffey can assist in undertaking more detailed analysis of the effects of the proposed loads onto the soil nail wall, once loads have been assessed.

5.5 Earthquake Design

AS1170.4-2007 was referenced for the consideration of geotechnical inputs to the earthquake design.

- A site hazard factor (Z) for Lismore of 0.05 has been selected per Section 3 of AS1170.4-2007.
- A Site Class B_e – Rock – has been assessed per Section 4.2 of AS1170.4-2007.

The earthquake design should be undertaken to the provisions of AS1170.4-20007.

5.6 Mine Subsidence

Coffey contacted the New South Wales Government Mine Subsidence Board (MSB) regarding any past mine workings at the site. The MSB indicated that no records exist of any mine workings at the site.

5.7 Slope Stability and Landslide Hazards

Coffey reviewed the site conditions relating to overall slope stability with reference to the Australian Building Codes Board (ABCB) Landslide Hazards 2006 Handbook.

The site slopes on average about 8° down to the north. The site is located at the top of the slope with only a small rise (less than 2m) to the crest of the ridgeline to the south on Uralba Street.

No indications of past or present landslides were noted on the site during our walkover of the broader hospital site in 2012 or during the borehole drilling for this project.

In our opinion, the risk of natural landslide hazards on or off the site impacting the building is low due to:

- The shallow soil depth observed.
- The location of the site on the slope (near the crest).
- The history of the broader development of the site with no known instances of instability.

Provided the recommendations in this report are adhered to in the design and construction of the excavations and building, and the site is maintained, the risk should remain low.

5.8 Stress Relief due to Excavations

Coffey does not have data relating to the potential for high locked in horizontal stresses within the basalt rock at the site. The magnitude of excavations is relatively small and hence the potential impacts of horizontal stress relief are not expected to be a significant design issue where excavation precedes bottom up construction. As the Lismore Basalt is a geologically recent formation, it is anticipated that locked in stresses would be small due to the lack of past regional stress-related events such as plate tectonics or significant overburden.

Locked in stresses could be assessed further by installing rock stress monitoring equipment. However, such monitoring is expected to be costly relative to the anticipated low likelihood of the presence of locked in stresses.

In order to isolate the building from any stress relief movements it is considered prudent to:

- Monitor excavation surfaces regularly during construction for any movements.
- Confirm movements (if any) of the cutting faces have ceased prior to commencing construction of building elements.
- Isolate building elements from abutting the rock (i.e. leave an isolation gap between structural elements and the rock).

Where settlement of adjacent existing structures or services due to the excavations is of concern, consideration should be given to the potential for vertical and lateral movements of up to 0.3% in soil and 0.1% in rock (expressed relative to the vertical cutting height). Lateral movements may damage brittle services and buildings. The lateral extent of movements could extend up to 3 times the vertical height. In order to reduce vertical and lateral deflections, the geotechnical design may be undertaken using:

- For retaining walls installed prior to excavation: at-rest earth pressure parameters rather than active earth pressure parameters.
- For anchored systems installed prior to excavation: active anchors rather than passive anchors.

5.9 Pavements

5.9.1 Selection of Design Traffic

5.9.1.1 Pavement Design Life

Guidance from the Northern Rivers Design and Construction Manual (NRDCM) D2 specification notes that a design life of 20 years for the pavement structural layers (excluding the spray seal) is appropriate for flexible granular or bound pavements. This timeframe was adopted for the design traffic calculations and pavement thickness design.

5.9.1.2 Traffic Volumes

The proposed traffic volumes for the car park and delivery areas are not known. The NRDCM D2 specification notes a Design Equivalent Standard Axle (DESA) value of 3×10^5 for local access roads.

Once more information on the traffic volumes are known to the developer, the traffic should be compared to the DESA used above and the pavement design should then be reviewed.

5.9.2 Design CBR Value

The design CBR of 5% has been adopted for the gravelly clay on the site. Presumptive values from AUSTROADS and past experience have been assessed based on the nature of the materials encountered in this report.

5.9.3 Pavement Thickness Design

The pavement thickness design was based on the Empirical Design Method for granular pavements with thin bituminous surfacing less than 40mm thick, and Figure 8.2 from AGPT02/10.

The minimum pavement base thickness assessed from AGPT02/10 is about 120mm for a DESA of 3 x 10^5 with total pavement thickness of about 340mm. The NRDCM D2 specification requires a minimum pavement thickness of 300mm and minimum base thickness of 150mm. Hence, we recommend a 150mm base layer with 200mm subbase layer.

The pavement thickness design is summarised in Table 8.

For turning areas for heavy vehicles, the use of a rigid pavement using a Steel-Fibre Reinforced Concrete (SFRC) base layer should be considered.

- A lean mix sub-base of minimum 100mm lean mix concrete should be adopted (7 MPa after 28 days compressive strength (excluding flyash) or 5 MPa including flyash).
- A SFRC base layer of minimum 205mm thick should be adopted. The flexural strength of the base should be 5 MPa.
- These layer thicknesses do not include construction tolerances. Allowances will have to be made for appropriate slab dimensions and crack control.

Table 8: Flexible Pavement Thickness Design

Layer	Minimum Thickness, 20 year Design Life	Material Specification	Construction Specification
Primer and Two-coat Flush Seal	-	Primerseal (7mm) 1st Coat Flush Seal 14mm pre-coated aggregate 2nd Coat Flush Seal 7mm pre-coated aggregate	In accordance with NRDCM C-244. Bitumen Class 170. A 10mm primerseal and 10mm 2nd coat flush seal may be adopted if 7mm is impracticable.
Base Course	150mm	NRDCM - C242 DGB20 (20mm dense graded base)	100% SMDD 60-90% OMC Single Lift using appropriate compaction equipment In accordance with NRDCM C-242

Layer	Minimum Thickness, 20 year Design Life	Material Specification	Construction Specification
Subbase Course	200mm	NRDCM - C242 DGS40 (40mm dense graded subbase)	100% SMDD 60-90% OMC Single Lift using appropriate compaction equipment In accordance with NRDCM C-242
Subgrade	-	CBR 5%	Refer Engineering Drawings for Material Specification.

5.9.4 Site Preparation and Pavement drainage

Site preparation and earthworks for engineered/controlled fill to the pavement or footings should be undertaken as follows:

- Prior to placement of any fill, the proposed areas should be stripped to remove all vegetation, organic soil, topsoil, root affected or other potentially deleterious material;
- The profile should be benched to create steps no higher than 300mm where the existing ground level slopes at greater than 1V:10H.
- Following stripping, the exposed subgrade materials should be proof rolled in the presence of a suitably qualified and experienced geotechnical practitioner to identify any wet or excessively deflecting material. Proof rolling should involve:
    - Compaction of the subgrade using a minimum 8-tonne roller.
    - Trimming the rolled surface to level and clean finish.
    - Proof rolling with a minimum 8-tonne roller.
    - Areas indicating excessive deflection should be over excavated and backfilled with an approved select material or bridging layer.
- Approved, controlled general fill to form the embankment for access should be placed in layers not exceeding 150mm compacted thickness and compacted to a minimum density ratio of 98% Standard Maximum Dry Density (SMDD) (cohesive materials) or 75% Density Index (non-cohesive materials).
- Cohesive general fill should be placed and maintained at ±3% of Standard Optimum Moisture Content (SOMC).
- The top 300mm of natural subgrade below pavement layers should be compacted to a minimum density ratio of 100% SMDD or equivalent within -3% to 0% variance from SOMC.
- If machine access for compaction cannot be achieved due to soft subgrade conditions, a bridging layer at least 500mm thick shall be provided with appropriate separation geofabric top and bottom of the layer. A Bidim A39 or similar product may be used. The bridging layer material should comprise clean, durable rock with particle size less than 150mm and greater than 2.36mm.

- Consideration should be given to the permanent drainage of boxed construction if any fill is to be granular (e.g. pavement layers) and the subgrade cohesive, as water ponding at the top of the subgrade may lead to softening of the subgrade. This may be an issue if a bridging layer is required.

Earthworks should be undertaken to the provisions of AS3798-2007 *Guidelines for Earthworks for Commercial and Residential Developments.*

5.9.5 Pavement Seal and Maintenance

The design for flexible pavement includes the use of a sprayed bituminous seal with Primerseal and a Two-coat flush seal based on the requirements of the NRDCM D2 specification.

Coffey has not assessed pavement seal maintenance regimes or requirements. While the adopted design life for the pavement structure is 20 years, the sprayed seal is not considered to be part of the structural layers of the pavement. Seal deterioration may occur with time before the structural design life is met. This is particularly the case for heavy vehicle turning areas, where the use of a rigid pavement is recommended.

6 RECOMMENDED ADDITIONAL GEOTECHNICAL WORK

The delineation of the contact between Units 3A and 3B is recommended to manage construction risk of excavations, retention and the building foundations.

Accordingly we recommend the following additional investigations.

- A further borehole to 6m below the excavation floor, undertaken on the southern boundary for the excavation below Uralba Street.
- A further borehole to 6m below the excavation floor, undertaken on the eastern boundary for the excavation below Little Uralba Street.
- A further one foundation investigation borehole undertaken in the south-eastern corner.
- A further three boreholes across the site and coupled with the level change between the first and second basement levels to assess the Unit 3A/3B contact.

These boreholes would only be possible once demolition of the existing structures has been completed to provide drilling rig access. If boreholes are undertaken prior to demolition, access will be constrained and not all of the above investigations may then be possible.

The use of a geophysical survey may add information regarding the Unit 3B extents; however the limitations on the accuracy of such a survey would need to be considered. As a minimum at least a further two boreholes would be required on the site in conjunction with a geophysical survey compared to the larger extent of drilling outlined above.

7 CLOSING COMMENT

The findings in this report are the result of a limited number of boreholes and observation of the surface conditions. Subsurface conditions across the site may vary from those encountered within the boreholes. One quadrant of the site was not accessible for investigation. Further investigation work before or after demolition is recommended.

Should different subsurface conditions to those expected be encountered during construction, Coffey should be contacted immediately.

Our report has not considered environmental contamination aspects, constraints or investigations for the development. These aspects will be reported separately by Coffey.

Your attention is drawn to the document 'Important Information about Your Coffey Report', which is attached and should be read in conjunction with this report. Please do not hesitate to contact the undersigned if you require further information with respect to this report.

For and on behalf of Coffey Geotechnics Pty Ltd

R Vleggaar

RIAN VLEGGAAR

Geotechnical Engineer

8 REFERENCES

AS2159-2009: *Piling - Design and Construction*, Standards Australia

AS2870-2011: *Residential Slabs and Footings,* Standards Australia

AS3798-2007: *Guidelines on earthworks for residential and commercial developments,* Standards Australia

FHWA. *Geotechnical Engineering Circular No 7 – Soil Nail Walls*. Publication No FHWA-1F-03-017. USDOT, Washington DC. March 2003.

Vesic, A.B. *Beams on Elastic Subgrade and Winkler's Hypothesis*. Proc. 5th Int. Conf. on Soil Mechanics and Foundation Engineering, Paris, 1961, p845 -850.

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

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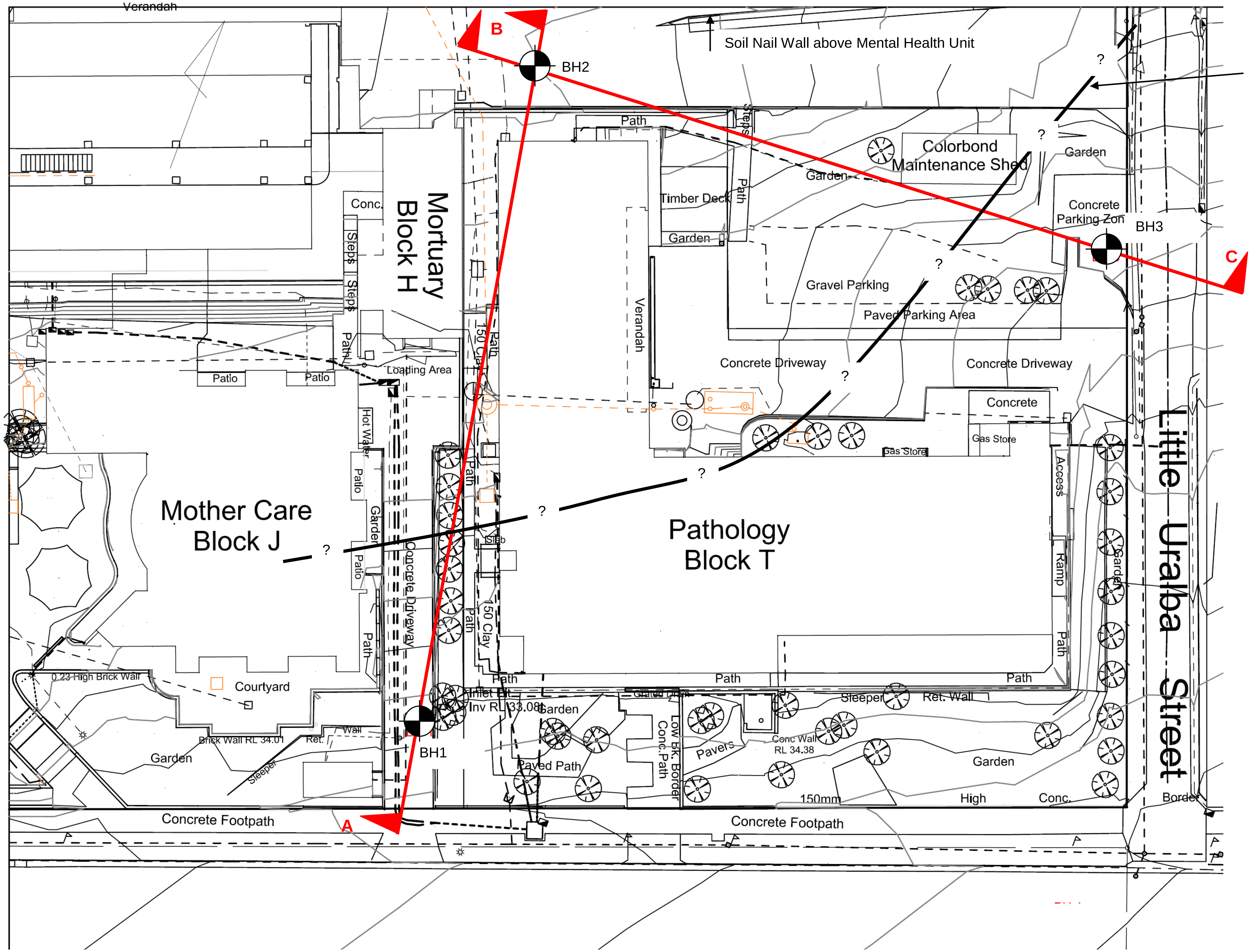
* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Figures



Inferred contact between Unit 3A and 3B (Alignment unknown). Further drilling required to delineate.

Surface Slopes down

revision	description	drawn	approved	date

Drawing based on survey drawing prepared by Newton Denny Chapelle.

0 3 6 9 12 15 18

Horizontal Scale (metres)

drawn	**RV**
approved	
date	**2013-02-14**
scale	**≈ 1:300**
original size	**A3**

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client: **NEW SOUTH WALES HEALTH INFRASTRUCTURE**

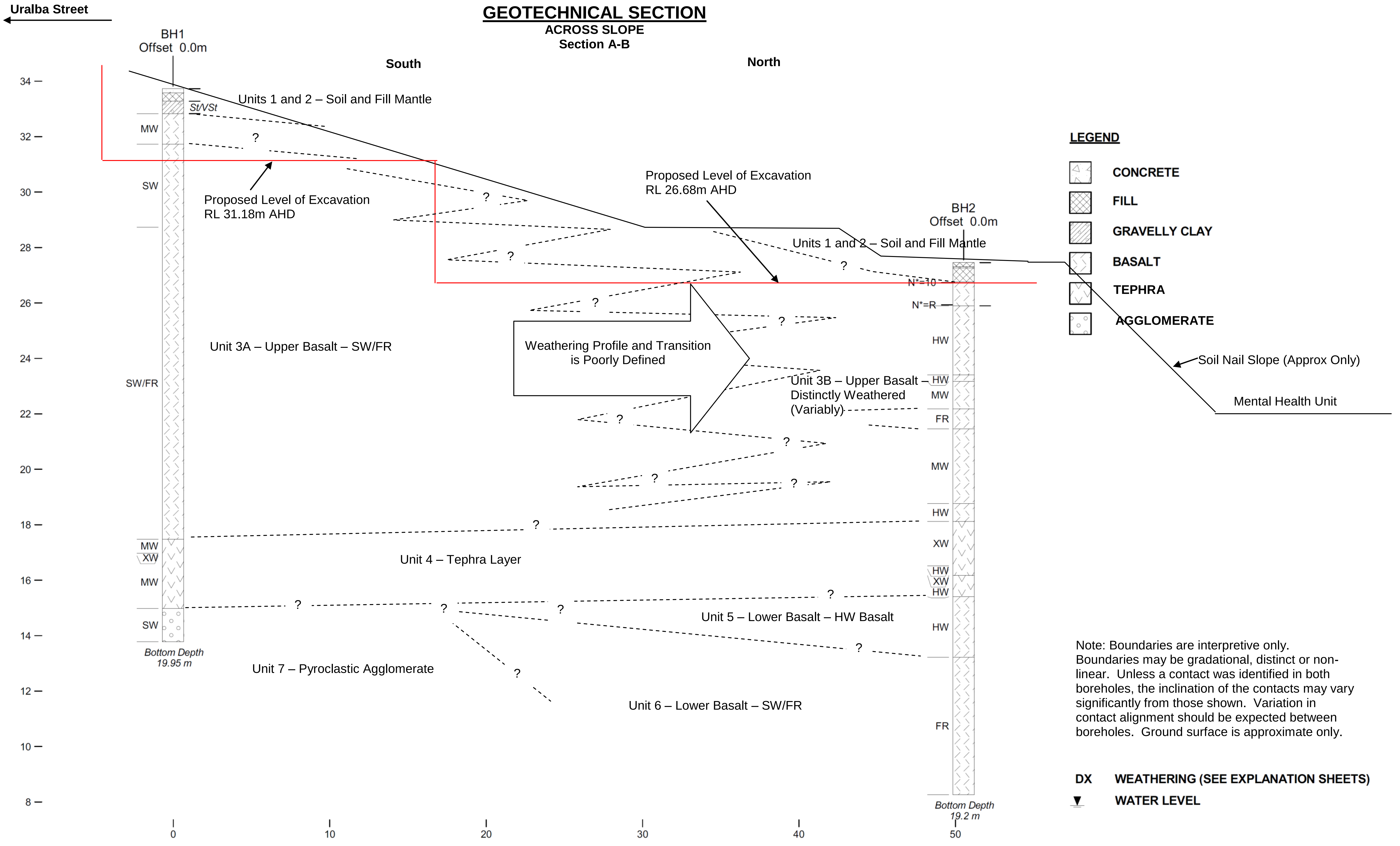
project: **LISMORE BASE HOSPITAL**
NEW 11 FLOOR STRUCTURE

title: **SITE PLAN WITH INVESTIGATION LOCATIONS**

project no: **GEOTALST01618AN-AD** figure no: **FIGURE 1**

GEOTECHNICAL SECTION

ACROSS SLOPE
Section A-B



LEGEND

- ◿ **CONCRETE**
- ▩ **FILL**
- ▨ **GRAVELLY CLAY**
- ▧ **BASALT**
- ▧ **TEPHRA**
- ⁘ **AGGLOMERATE**

Note: Boundaries are interpretive only. Boundaries may be gradational, distinct or non-linear. Unless a contact was identified in both boreholes, the inclination of the contacts may vary significantly from those shown. Variation in contact alignment should be expected between boreholes. Ground surface is approximate only.

DX **WEATHERING (SEE EXPLANATION SHEETS)**

▼ **WATER LEVEL**

revision	description	drawn	approved	date

drawn	**RV**
approved	
date	**2013-02-14**
scale	**As Indicated**
original size	**A3**

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client: **NEW SOUTH WALES HEALTH INFRASTRUCTURE**

project: **LISMORE BASE HOSPITAL**
NEW 11 FLOOR STRUCTURE

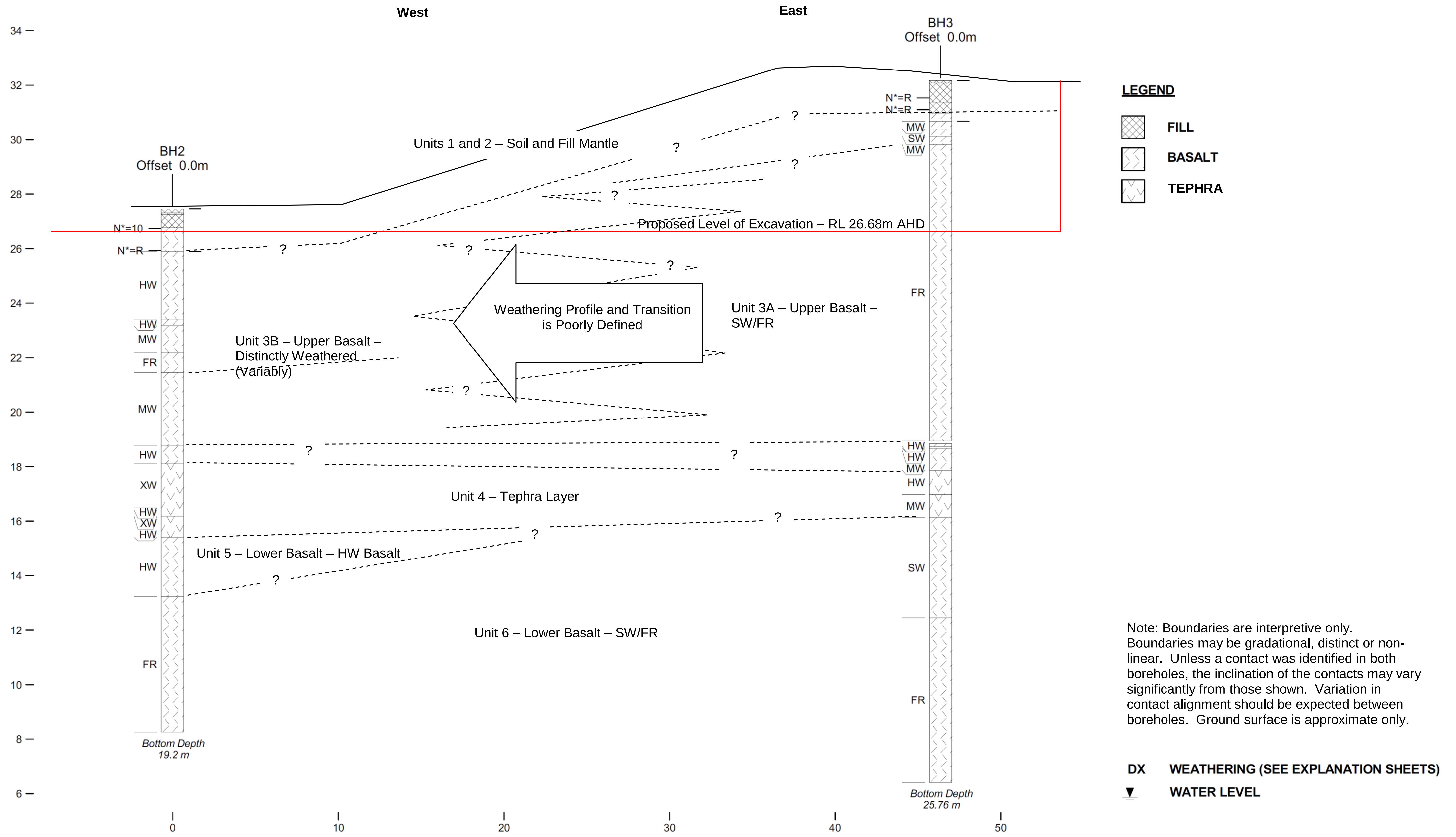
title: **GEOTECHNICAL SECTION**
SOUTH-NORTH

project no: **GEOTALST01618AN-AD** figure no: **FIGURE 2**

GEOTECHNICAL SECTION

ALONG SLOPE

Section B-C



Note: Boundaries are interpretive only. Boundaries may be gradational, distinct or non-linear. Unless a contact was identified in both boreholes, the inclination of the contacts may vary significantly from those shown. Variation in contact alignment should be expected between boreholes. Ground surface is approximate only.

revision	description	drawn	approved	date

drawn	RV
approved	
date	2013-02-14
scale	As Indicated
original size	A3

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client: **NEW SOUTH WALES HEALTH INFRASTRUCTURE**

project: **LISMORE BASE HOSPITAL**
NEW 11 FLOOR STRUCTURE

title: **GEOTECHNICAL SECTION**
WEST-EAST

project no: **GEOTALST01618AN-AD** figure no: **FIGURE 3**

drawn	RV	coffey geotechnics SPECIALISTS MANAGING THE EARTH	client:	NEW SOUTH WALES HEALTH INFRASTRUCTURE
approved			project:	LISMORE BASE HOSPITAL NEW 11 FLOOR STRUCTURE
date	2013-02-14			
scale	NTS		title:	CORE PHOTOGRAPHS – BH1
original size	A3		project no: GEOTALST01618AN-AD	figure no: FIGURE 4

drawn	RV
approved	
date	2013-02-14
scale	NTS
original size	A3

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SPECIALISTS MANAGING THE EARTH

client:	NEW SOUTH WALES HEALTH INFRASTRUCTURE
project:	LISMORE BASE HOSPITAL NEW 11 FLOOR STRUCTURE
title:	CORE PHOTOGRAPHS – BH2
project no: GEOTALST01618AN-AD	figure no: FIGURE 5

drawn	RV	coffey geotechnics SPECIALISTS MANAGING THE EARTH
approved		
date	2013-02-14	
scale	NTS	
original size	A3	

client: **NEW SOUTH WALES HEALTH INFRASTRUCTURE**

project: **LISMORE BASE HOSPITAL**
NEW 11 FLOOR STRUCTURE

title: **CORE PHOTOGRAPHS – BH3**

project no: **GEOTALST01618AN-AD**

figure no: **FIGURE 6**

Appendix A

Engineering Logs and Explanation Sheets

coffey geotechnics

Engineering Log - Borehole

Borehole No.	*BH1*
Sheet	1 of 4
Project No:	*GEOTALST01618AN*
Date started:	*24.1.2013*
Date completed:	*25.1.0213*
Logged by:	*TGN*
Checked by:	

Client: *NEW SOUTH WALES HEALTH INFRASTRUCTURE*

Principal:

Project: *LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*

Borehole Location: *MORTUARY DRIVEWAY*

drill model and mounting:	MD100 Track	Easting:	528517	slope:	-90°	R.L. Surface:	33.73
hole diameter:	100 mm	Northing	6813117.1	bearing:		datum:	AHD, MGA

drilling information | **material substance**

method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
DT									**CONCRETE:**	D			FILL: CONCRETE Pavement slopes @ 6.5° to N
ADT				E					**FILL:** GRAVELLY CLAY, high plasticity, orange brown, gravel, medium to coarse grained.	M			FILL
RR				E	33				**GRAVELLY CLAY:** High plasticity, orange brown and brown, gravel fine to coarse grained.		St/VSt		RESIDUAL SOIL/EXTREMELY WEATHERED BASALT? Difficult drilling due to coarse very high strength gravel.
						1			Borehole BH1 continued as cored hole				
					32	2							
					31	3							
			Water not observed		30	4							
					29	5							
					28	6							
					27	7							
					26	8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix
e.g. ADT

support

M	mud	N	nil
C	casing		

penetration
1 2 3 4
no resistance ranging to refusal

water
10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Cored Borehole

Borehole No.	**BH1**
Sheet	2 of 4
Project No:	*GEOTALST01618AN*
Client:	*NEW SOUTH WALES HEALTH INFRASTRUCTURE*
Date started:	*24.1.2013*
Principal:	
Date completed:	*25.1.0213*
Project:	*LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*
Logged by:	*TGN*
Borehole Location:	*MORTUARY DRIVEWAY*
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528517	slope:	-90°	R.L. Surface:	33.73
hole diameter:	100 mm	Drilling fluid:		Northing:	6813117.1	bearing:	datum: AHD, MGA

drilling information | **material substance** | **rock mass defects**

Columns: method; core-lift; water; RL; depth metres; graphic log core recovery; material – rock type; grain characteristics, colour, structure, minor components; weathering alteration; estimated strength (VL L M H VH EH); $Is_{(50)}$ MPa (D- diametral, A- axial); RQD %; defect spacing mm (30 100 300 1000 3000); defect description – type, inclination, planarity, roughness, coating, thickness (particular, general)

Water: Water not observed

RL marks: 33, 32, 31, 30, 29, 28, 27, 26

depth (m)	material	weathering	$Is_{(50)}$ D	$Is_{(50)}$ A
to 1	Continued from non-cored borehole			
1	**BASALT:** Dark grey, indistinct fabric with many clay seams, showing plastic deformation of flow banding.	MW	5.2	6.3
2	**BASALT:** Dark grey, indistinct fabric, showing plastic deformation of flow banding.	SW		
3.1	chalcedony infilled vuggs @ 3.1m depth			
3.5			7.8	3.9
5.1		SW/FR	7.6	10
7.3			8.1	9.7

RQD %: 27, 71, 100, 100, 100, 100

Defect description – particular:

- JT, 0-5°, PL, RO
- SM, 45°, HP clay, VSt, 110mm. PP>400
- SM, 0°, 2mm HP clay
- ST, 5°, IR, RO, CN
- ST, 5°, IR, RO, CN
- SM, gravel and clay 10mm
- JT, 10°, PL, CO fe
- JT, 25°, UN, RO
- JT, 15°, UN, RO
- DB, 2.95-3.05m
- JT, 90°, IR, RO, CO fe
- JT, 40°, SO, CO clay 1mm
- JT, 60, PL, RO, CN
- JT, 45°, UN, RO, CN
- DB
- DB
- JT, 30°, UN, RO, CO fe
- DB

Defect description – general: JT, 10-60°, PL, RO, CO (Fe stain)

CORED BOREHOLE 01618AN_LOGS_BH1_BH2_BH3.GPJ COFFEY.GDT 15.2.13

method	
DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift
- casing used
- barrel withdrawn

graphic log/core recovery
- core recovered - graphic symbols indicate material
- no core recovered

water
- 10/1/98 water level on date shown
- water inflow
- partial drill fluid loss
- complete drill fluid loss
- 25 water pressure test result (lugeons) for depth interval shown

weathering	
FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength	
VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type	
JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity	
PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness	
VR	very rough
RO	rough
SO	smooth
SL	slickensided

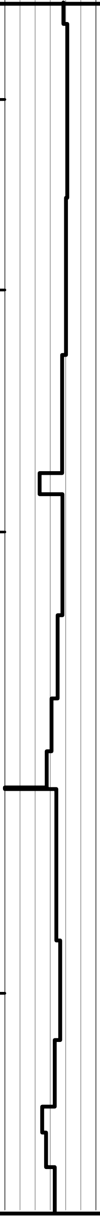
coating	
CN	clean
SN	stained
VN	veneer
CO	coating

Engineering Log - Cored Borehole

Borehole No.	**BH1**		
Sheet	3 of 4		
Project No:	**GEOTALST01618AN**		
Client:	**NEW SOUTH WALES HEALTH INFRASTRUCTURE**	Date started:	**24.1.2013**
Principal:		Date completed:	**25.1.0213**
Project:	**LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING**	Logged by:	**TGN**
Borehole Location:	**MORTUARY DRIVEWAY**	Checked by:	

drill model & mounting: MD100 Track	Easting: 528517	slope: -90°	R.L. Surface: 33.73		
hole diameter: 100 mm	Drilling fluid:	Northing: 6813117.1	bearing:	datum: AHD, MGA	

drilling information | **material substance** | **rock mass defects**



method	core-lift	water	RL	depth metres	graphic log core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength VL L M H VH EH	Is(50) MPa D- diametral A- axial	RQD %	defect description (type, inclination, planarity, roughness, coating, thickness) particular / general
						BASALT: Dark grey, indistinct fabric, showing plastic deformation of flow banding. *(continued)* becoming massive from 8.25m	SW/FR			100	JT, 30°, PL, RO, CN
			25			difficulty breaking core off in ground at end of run					
				9					D 7.6 A 10.3		
										100	JT, SO, UN, RO, CN
			24								
				10		indistinct flow banding near horizontal from 10m to 16.2m					
									D 8.1 A 6.6		JT, 20°, UN, RO, CN
			23							100	
				11							JT, 3°, UN, RO
											JT, 90°, IR-ST, RO, CO Chlorite from 11.05m
		Water not observed	22								
				12					D 6.2 A 10.2		JT, 5°, PL, SO, CO Chlorite
											JT, 0°, UN, SO, CO Chlorite
			21								
				13						99	JT, 60°, IR, RO, CN
											JT, 0°, PL, SO, CO Chlorite
			20						D 7.3 A 13.8		
				14							JT, 0°, PL, SO, CN
						difficulty breaking off core in ground.					
			19						D 5 A 9.4		SM, 0°, PL, SO, CN
				15						100	JT, 90°, IR, RO, CO Chlorite
											JT, 0°, PL, SO, CO
			18						D 4.5 A 3.7		
				16							JT, 0°, PL, RO, CN

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

casing used

barrel withdrawn

graphic log/core recovery

core recovered
- graphic symbols indicate material

no core recovered

water

10/1/98 water level on date shown

water inflow

partial drill fluid loss

complete drill fluid loss

25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

coating

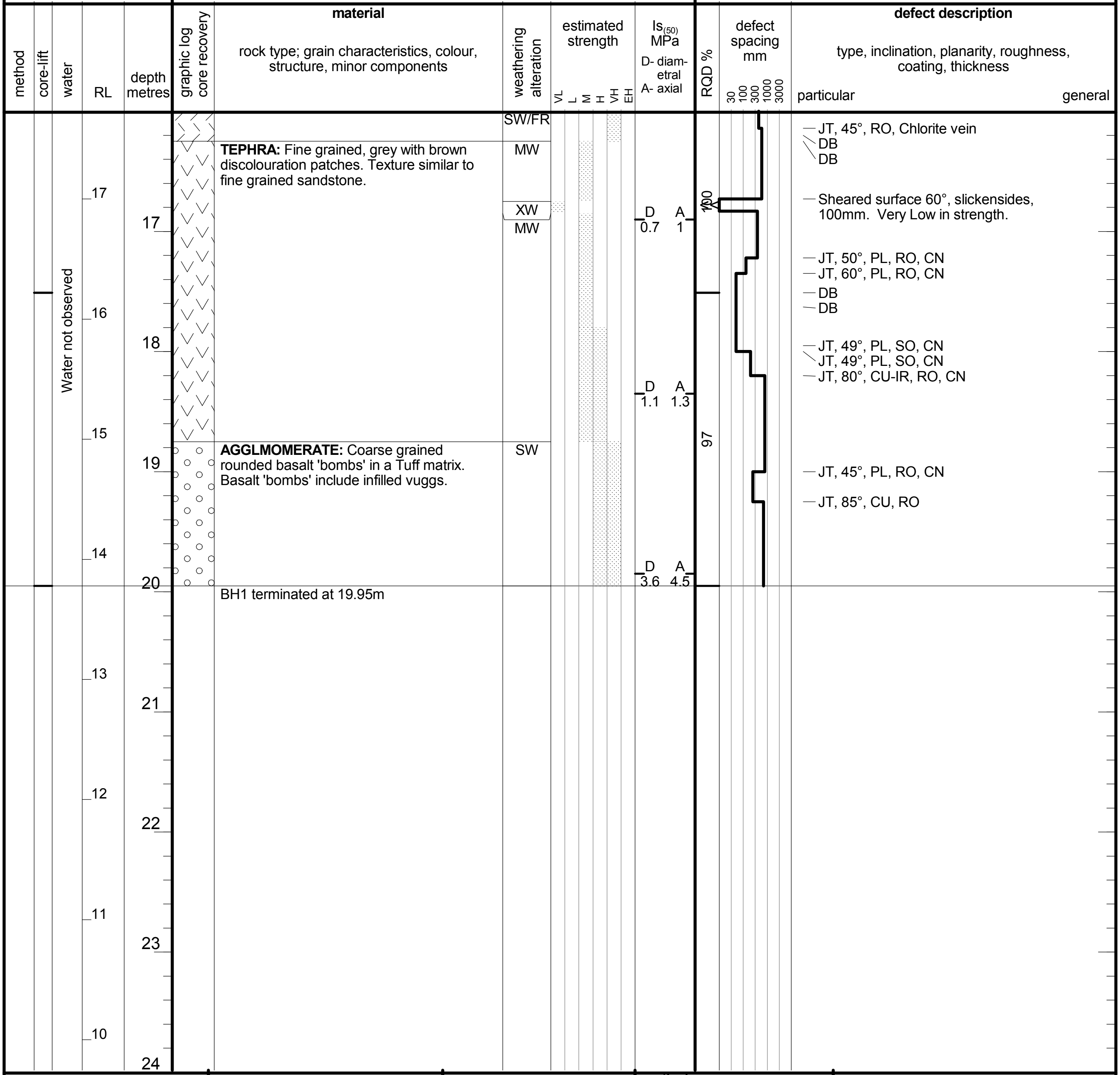
CN	clean
SN	stained
VN	veneer
CO	coating

coffey geotechnics

Engineering Log - Cored Borehole

Borehole No.	**BH1**
Sheet	4 of 4
Project No:	**GEOTALST01618AN**
Client:	***NEW SOUTH WALES HEALTH INFRASTRUCTURE***
Date started:	**24.1.2013**
Principal:	
Date completed:	**25.1.0213**
Project:	***LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING***
Logged by:	**TGN**
Borehole Location:	***MORTUARY DRIVEWAY***
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528517	slope:	-90°	R.L. Surface:	33.73
hole diameter:	100 mm	Drilling fluid:		Northing:	6813117.1	bearing:	
datum:	AHD, MGA						



material	weathering alteration	defect description (particular)
	SW/FR	JT, 45°, RO, Chlorite vein DB DB
TEPHRA: Fine grained, grey with brown discolouration patches. Texture similar to fine grained sandstone.	MW	
	XW	Sheared surface 60°, slickensides, 100mm. Very Low in strength.
	MW	JT, 50°, PL, RO, CN JT, 60°, PL, RO, CN DB DB JT, 49°, PL, SO, CN JT, 49°, PL, SO, CN JT, 80°, CU-IR, RO, CN
AGGLMOMERATE: Coarse grained rounded basalt 'bombs' in a Tuff matrix. Basalt 'bombs' include infilled vuggs.	SW	JT, 45°, PL, RO, CN JT, 85°, CU, RO
BH1 terminated at 19.95m		

method
- DT diatube
- AS auger screwing
- AD auger drilling
- RR roller/tricone
- CB claw or blade bit
- NMLC NMLC core
- NQ, HQ, PQ wireline core

core-lift
- casing used
- barrel withdrawn

graphic log/core recovery
- core recovered - graphic symbols indicate material
- no core recovered

water
- 10/1/98 water level on date shown
- water inflow
- partial drill fluid loss
- complete drill fluid loss
- 25 water pressure test result (lugeons) for depth interval shown

weathering
- FR fresh
- SW slightly weathered
- MW moderately weathered
- HW highly weathered
- XW extremely weathered
- DW distinctly weathered (covers MW and HW)

strength
- VL very low
- L low
- M medium
- H high
- VH very high
- EH extremely high

defect type
- JT joint
- PT parting
- SM seam
- SZ sheared zone
- SS sheared surface
- CS crushed seam

planarity
- PL planar
- CU curved
- UN undulating
- ST stepped
- IR irregular

roughness
- VR very rough
- RO rough
- SO smooth
- SL slickensided

coating
- CN clean
- SN stained
- VN veneer
- CO coating

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Engineering Log - Borehole

Borehole No.	**BH2**
Sheet	1 of 4
Project No:	**GEOTALST01618AN**
Date started:	**15.1.2013**
Date completed:	**16.1.2013**
Logged by:	**MH**
Checked by:	

Client: **NEW SOUTH WALES HEALTH INFRASTRUCTURE**

Principal:

Project: **LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING**

Borehole Location: **LANE N OF MORTUARY**

drill model and mounting:	MD100 Track	Easting:	528507.3	slope:	-90°	R.L. Surface:	27.46
hole diameter:	100 mm	Northing	6813166.7	bearing:		datum:	AHD, MGA

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
ADT		C							**FILL:**CONCRETE				CONCRETE
DT									**FILL:** Gravel, coarse, angular, trace clay.	>Wp			FILL
				Ex2	27				**FILL:**CLAY, high plasticity, brown and dark grey, some gravel.				
				SPT 3,3,7 N*=10									RODS ANGLED AWAY DURING SPT TEST - NOT REPRESENTATIVE
		M							**BASALT:** Black, dark grey and dark brown, with gravel and clay seams.				EXTREMELY WEATHERED TO MODERATELY WEATHERED BASALT
RR				Ex2		1							
					26								
			Water not observed	SPT 25/60mm N*=R					Borehole BH2 continued as cored hole				
						2							
					25								
						3							
					24								
						4							
					23								
						5							
					22								
						6							
					21								
						7							
					20								
						8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit

*bit shown by suffix
e.g. ADT

support

M	mud	N	nil
C	casing		

penetration
1 2 3 4
no resistance ranging to refusal

water

▼	10/1/98 water level on date shown
►	water inflow
◄	water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

Engineering Log - Cored Borehole

Borehole No. **BH2**
Sheet 2 of 4
Project No: **GEOTALST01618AN**

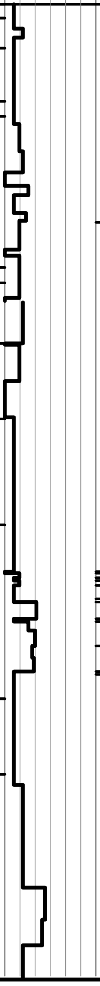
Client:	*NEW SOUTH WALES HEALTH INFRASTRUCTURE*
Principal:	
Project:	*LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*
Borehole Location:	*LANE N OF MORTUARY*
Date started:	*15.1.2013*
Date completed:	*16.1.2013*
Logged by:	*MH*
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528507.3	slope:	-90°	R.L. Surface:	27.46
hole diameter:	100 mm Drilling fluid:	Northing:	6813166.7	bearing:		datum:	AHD, MGA

drilling information | **material substance** | **rock mass defects**

RL	depth metres	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (VL L M H VH EH)	Is(50) MPa (D- diametral, A- axial)	RQD %
27 – 26	0 – 1.56	Continued from non-cored borehole				
26 – 23.4	1.56 – 4.1	**BASALT:** Dark grey and black FR pieces in matrix of weathered seams with brown-orange XW/HW fragmented rock. NOTE FR pieces are VH-EH strength (not shown in strength column), seams are Soil Strength. Point loads undertaken on intact FR pieces.	HW	VL	A 8.8 D 5.4 A 10.3	0 0 0 0 0 0 0 0
	4.1 – 4.4	**BASALT:** Orange and brown, decomposed and friable, some clay within structure.	HW	VL		
	4.4 – 5.4	**BASALT:** Orange-brown and grey, many closed joints at various angles, gravel sized pieces of SW/FR basalt.	MW	M – H	A 1 A 1.7	0
	5.4 – 6.1	**BASALT:** Dark grey to black, typical grain size <1mm.	FR	VH – EH	D 6.7 A 6.8	0
21 – 20	6.1 – 8	**BASALT:** Orange-brown and grey, many joints at various angles.	MW	H – VH		0 23

Water not observed



defect description (type, inclination, planarity, roughness, coating, thickness)

particular:

~~1.56-1.8 Many joints at various angles,~~ generally CU/UN, RO/VR, SN/CO. Thin seams with weathered rock grained.
1.8-2.35 rock broken to gravel thin seams with weathered rock grained clay.
2.35-4.05 Solid rock split by many seams of crushed weathered basalt. Seam thickness is generally 5-40mm at spacings of 20-50mm
SZ, 20mm, rock fragments and clay
SZ, 40mm, rock fragments and clay
SZ, 30mm, rock fragments and clay
SZ, 15mm, fragmented rock and clay
SZ, 10mm, fragmented rock and clay
JT, 70°, UN, RO, VN
JT, 30°, CU, RO, CO
JT, 30°, CU, RO, CO
JT, 30°, UN, RO, CO
JT, 10°, UN, RO, CO
4.9-5.1 Rock brocken by driling, 200mm
JT, 35°, PL, SO, CO, clay
JT, 30°, PL, SO, CO Clay
JT, 50°, PL, SO, CO, clay
JT, 50°, PL, SO, CO, clay
CS, 3mm, rock and clay
CR, SM, 4mm, rock and clay
6-6.15 Rock broken by driling, 150mm
6.16-8.51 Joints at 10-20°, typical spacing 5-40mm, IR, RO, SN/VN, interseted by curved joints at steepher (30-90°) angles.

general:

JT1= JT, 10 - 20°, PL/UN, RO, SN/VN

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

casing used
barrel withdrawn

graphic log/core recovery

core recovered - graphic symbols indicate material
no core recovered

water

10/1/98 water level on date shown
water inflow
partial drill fluid loss
complete drill fluid loss
25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

coating

CN	clean
SN	stained
VN	veneer
CO	coating

CORED BOREHOLE 01618AN_LOGS_BH1_BH2_BH3.GPJ COFFEY.GDT 15.2.13

Form GEO 5.5 Issue 3 Rev. 3

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Engineering Log - Cored Borehole

Borehole No. **BH2**

Sheet 3 of 4

Project No: **GEOTALST01618AN**

Client:	NEW SOUTH WALES HEALTH INFRASTRUCTURE	Date started:	15.1.2013
Principal:		Date completed:	16.1.2013
Project:	LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING	Logged by:	MH
Borehole Location:	LANE N OF MORTUARY	Checked by:	

drill model & mounting:	MD100 Track	Easting:	528507.3	slope:	-90°	R.L. Surface:	27.46
hole diameter:	100 mm	Drilling fluid:	Northing: 6813166.7	bearing:		datum:	AHD, MGA

drilling information

method | core-lift | water | RL | depth metres

water: Water not observed

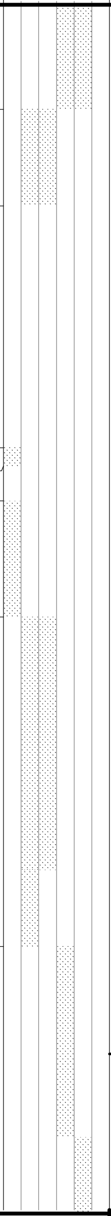
RL: 19, 18, 17, 16, 15, 14, 13, 12

depth metres: 9, 10, 11, 12, 13, 14, 15, 16

material substance

material: rock type; grain characteristics, colour, structure, minor components	weathering alteration
BASALT: Orange-brown and grey, many joints at various angles. *(continued)*	MW
BASALT: Orange, orange-brown and dark grey, massive.	HW
TEPHRA: Purple-grey, red-brown and orange. As clay, high plasticity, hard consistency. Red-brown sections approaching very low rock strength.	XW HW XW
TEPHRA: Orange with some purple-grey, approx. 10-20% as hard clay.	HW
BASALT: Yellow-grey, brown and orange, grain size is typically <1mm.	HW
BASALT: Dark grey and black, typical grain size <1mm.	FR

estimated strength: VL L M H VH EH

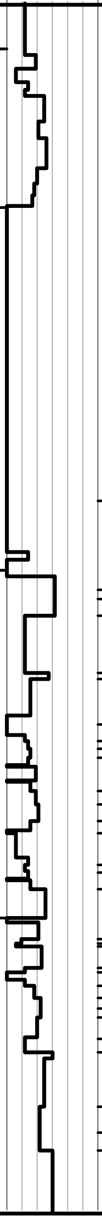


Is(50) MPa, D- diametral, A- axial: D 2.8, A 2.2

rock mass defects

RQD %: 23, 0, 12, 35, 79

defect spacing mm: 30 100 300 1000 3000



defect description: type, inclination, planarity, roughness, coating, thickness

particular:

- JT, 10°, UN, SO, CO clay
- JT, 15°, UN, SO VN CLAY
- SM, 4mm, clay
- SM, 5mm, clay
- SM, 10mm, clay
- JT, 15°, PL, SO, CO CLAY
- JT, 60°, ST, SO, CO CLAY
- PP=<500 kPA
- PP=>500 kPa
- PP=>500 kPa
- PP=>500 kpa
- XW SM, clay 40mm
- XW SM, hard clay 110mm
- XW SM, CLAY 3mm
- XW SM, clay 3MM
- XW SM, CLAY 5mm
- XW SM, CLAY 5mm
- 13.54 to 13.65 rock broken to clay and gravel, 110mm
- XW SM, CLOY 5mm
- XW SM, CLAY 30MM
- XW SM, CLAY 4mm
- JT, 45°, UN, SO, CN

general:

JT2= JT, 0 - 20°, UN, SO, VN-CO clay

method		core-lift	water	weathering		defect type		roughness	
DT	diatube	casing used	10/1/98 water level on date shown	FR	fresh	JT	joint	VR	very rough
AS	auger screwing	barrel withdrawn	water inflow	SW	slightly weathered	PT	parting	RO	rough
AD	auger drilling		partial drill fluid loss	MW	moderately weathered	SM	seam	SO	smooth
RR	roller/tricone		complete drill fluid loss	HW	highly weathered	SZ	sheared zone	SL	slickensided
CB	claw or blade bit			XW	extremely weathered	SS	sheared surface		
NMLC	NMLC core			DW	distinctly weathered (covers MW and HW)	CS	crushed seam		

graphic log/core recovery: core recovered - graphic symbols indicate material; no core recovered

NQ, HQ, PQ wireline core

water pressure test result (lugeons) for depth interval shown: 25

strength		planarity		coating	
VL	very low	PL	planar	CN	clean
L	low	CU	curved	SN	stained
M	medium	UN	undulating	VN	veneer
H	high	ST	stepped	CO	coating
VH	very high	IR	irregular		
EH	extremely high				

CORED BOREHOLE 01618AN_LOGS_BH1_BH2_BH3.GPJ COFFEY.GDT 15.2.13

Engineering Log - Cored Borehole

Borehole No.	**BH2**
Sheet	4 of 4
Project No:	*GEOTALST01618AN*
Client:	*NEW SOUTH WALES HEALTH INFRASTRUCTURE*
Date started:	*15.1.2013*
Principal:	
Date completed:	*16.1.2013*
Project:	*LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*
Logged by:	*MH*
Borehole Location:	*LANE N OF MORTUARY*
Checked by:	

drill model & mounting: MD100 Track — Easting: 528507.3 — slope: -90° — R.L. Surface: 27.46

hole diameter: 100 mm — Drilling fluid: — Northing: 6813166.7 — bearing: — datum: AHD, MGA

drilling information / material substance / rock mass defects

method	core-lift	water	RL	depth metres	graphic log core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength (VL L M H VH EH)	Is(50) MPa (D- diametral, A- axial)	RQD %	defect spacing mm (30 100 300 1000 3000)	defect description: type, inclination, planarity, roughness, coating, thickness — particular	general
		Water not observed	11			**BASALT:** Dark grey and black, typical grain size <1mm. *(continued)*	FR		D 7.3 A 9	79			JT3=JT, 0 - 10°, PL/UN, SO, CN
			10	17					D 10 A 8	100			
				18								JT, 50°, UN, SO, CN	
			9									JT, 20°, PL, SO, CN	
				19					D 8.1 A 9.1			JT, 25°, PL, SO, CN	
												JT, 50°, PL, SO, CN	
			8			BH2 terminated at 19.2m							
			7	20									
			6	21									
			5	22									
			4	23									
				24									

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

- casing used
- barrel withdrawn

graphic log/core recovery

- core recovered - graphic symbols indicate material
- no core recovered

water

- 10/1/98 water level on date shown
- water inflow
- partial drill fluid loss
- complete drill fluid loss
- 25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

coating

CN	clean
SN	stained
VN	veneer
CO	coating

coffey geotechnics

Engineering Log - Borehole

Borehole No.	***BH3***
Sheet	1 of 5
Project No:	***GEOTALST01618AN***
Client:	***NEW SOUTH WALES HEALTH INFRASTRUCTURE***
Date started:	***17.1.2013***
Principal:	
Date completed:	***18.1.2013***
Project:	***LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING***
Logged by:	***MH***
Borehole Location:	***LITTLE URALBA ST. CARPARK***
Checked by:	

drill model and mounting:	MD100 Track	Easting:	528553.6	slope:	-90°	R.L. Surface:	32.17
hole diameter:	100 mm	Northing	6813169.3	bearing:		datum:	AHD, MGA

drilling information							material substance						
method	penetration 1 2 3	support	water	**notes** samples, tests, etc	RL	depth metres	graphic log	classification symbol	**material** soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	**structure and additional observations**
ADDT					32				**FILL:**CONCRETE				CONCRETE
				Ex2 SPT 13,25/130mm N*=R					**FILL:** GRAVELLY CLAY, medium plasticity, dark brown, gravel is generally coarse angular basalt.	M			FILL
RR				Ex2 SPT 20/140mm N*=R	31	1			**FILL:** CLAYEY GRAVEL, fine to medium, angular, possibly some cement content.	D			SPT REFUSED ON HARD LAYER
									BASALT: Black and orange-brown, moderately weathered to fresh.				MODERATELY WEATHERED TO FRIABLE BASALT
			Water not observed						Borehole BH3 continued as cored hole				
						2							
					30								
						3							
					29								
						4							
					28								
						5							
					27								
						6							
					26								
						7							
					25								
						8							

method

AS	auger screwing*
AD	auger drilling*
RR	roller/tricone
W	washbore
CT	cable tool
HA	hand auger
DT	diatube
B	blank bit
V	V bit
T	TC bit
*bit shown by suffix	
e.g.	ADT

support

M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

water

▼ 10/1/98 water level on date shown
► water inflow
◄ water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
N	standard penetration test (SPT)
N*	SPT - sample recovered
Nc	SPT with solid cone
V	vane shear (kPa)
P	pressuremeter
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

coffey geotechnics

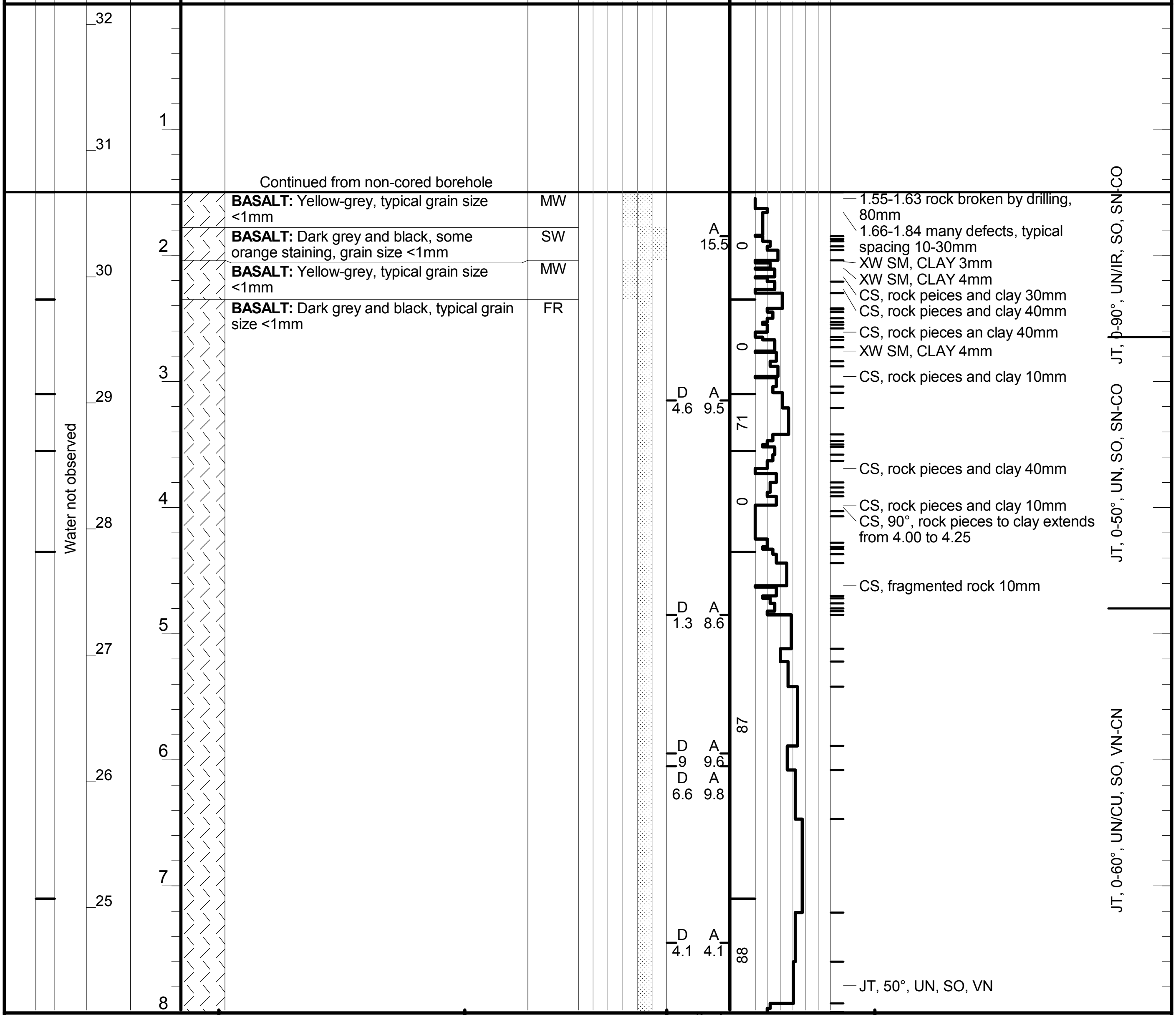
Engineering Log - Cored Borehole

Borehole No.	**BH3**
Sheet	2 of 5
Project No:	**GEOTALST01618AN**
Client:	**NEW SOUTH WALES HEALTH INFRASTRUCTURE**
Date started:	**17.1.2013**
Principal:	
Date completed:	**18.1.2013**
Project:	**LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING**
Logged by:	**MH**
Borehole Location:	**LITTLE URALBA ST. CARPARK**
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528553.6	slope:	-90°
R.L. Surface:	32.17				
hole diameter:	100 mm	Drilling fluid:		Northing:	6813169.3
bearing:		datum:	AHD, MGA		

drilling information | **material substance** | **rock mass defects**

method | core-lift | water | RL | depth metres | graphic log core recovery | material: rock type; grain characteristics, colour, structure, minor components | weathering alteration | estimated strength (VL L M H VH EH) | $Is_{(50)}$ MPa (D- diametral, A- axial) | RQD % | defect spacing mm (30 100 300 1000 3000) | defect description: type, inclination, planarity, roughness, coating, thickness (particular, general)



Continued from non-cored borehole

material	weathering alteration
BASALT: Yellow-grey, typical grain size <1mm	MW
BASALT: Dark grey and black, some orange staining, grain size <1mm	SW
BASALT: Yellow-grey, typical grain size <1mm	MW
BASALT: Dark grey and black, typical grain size <1mm	FR

$Is_{(50)}$ MPa	
D	A
	15.5
4.6	9.5
1.3	8.6
9	9.6
6.6	9.8
4.1	4.1

RQD %: 0, 0, 71, 0, 87, 88

Defect description – particular:

- 1.55-1.63 rock broken by drilling, 80mm
- 1.66-1.84 many defects, typical spacing 10-30mm
- XW SM, CLAY 3mm
- XW SM, CLAY 4mm
- CS, rock peices and clay 30mm
- CS, rock pieces and clay 40mm
- CS, rock pieces an clay 40mm
- XW SM, CLAY 4mm
- CS, rock pieces and clay 10mm
- CS, rock pieces and clay 40mm
- CS, rock pieces and clay 10mm
- CS, 90°, rock pieces to clay extends from 4.00 to 4.25
- CS, fragmented rock 10mm
- JT, 50°, UN, SO, VN

Defect description – general:

- JT, 0-90°, UN/IR, SO, SN-CO
- JT, 0-50°, UN, SO, SN-CO
- JT, 0-60°, UN/CU, SO, VN-CN

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

casing used

barrel withdrawn

graphic log/core recovery

core recovered - graphic symbols indicate material

no core recovered

water

10/1/98 water level on date shown

water inflow

partial drill fluid loss

complete drill fluid loss

25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

coating

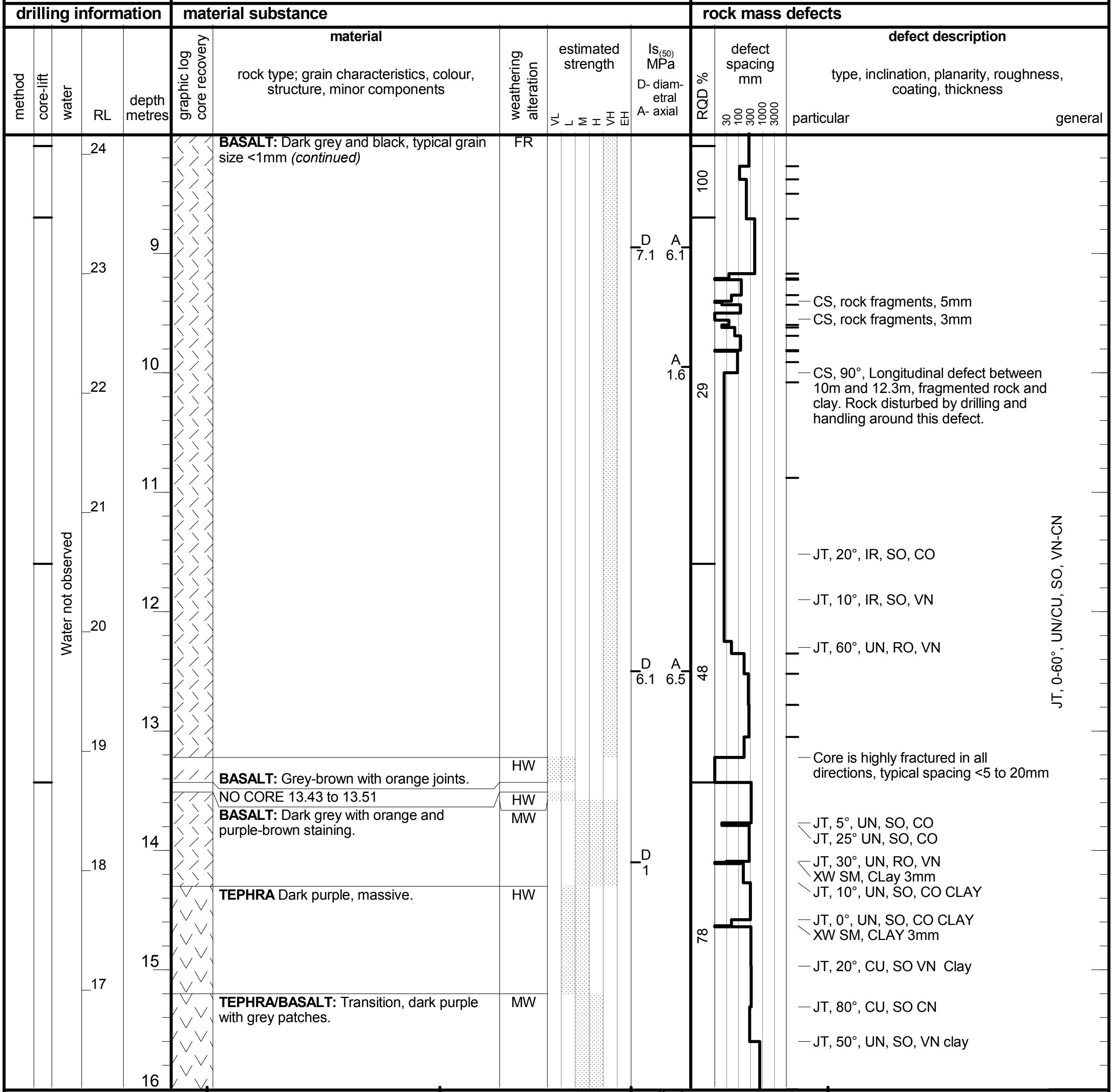
CN	clean
SN	stained
VN	veneer
CO	coating

coffey geotechnics

Engineering Log - Cored Borehole

Client:	*NEW SOUTH WALES HEALTH INFRASTRUCTURE*	Borehole No.	***BH3***
		Sheet	3 of 5
		Project No:	***GEOTALST01618AN***
		Date started:	***17.1.2013***
Principal:		Date completed:	***18.1.2013***
Project:	*LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*	Logged by:	***MH***
Borehole Location:	*LITTLE URALBA ST. CARPARK*	Checked by:	

drill model & mounting:	MD100 Track	Easting:	528553.6	slope:	-90°	R.L. Surface:	32.17
hole diameter:	100 mm Drilling fluid:	Northing:	6813169.3	bearing:		datum:	AHD, MGA



BASALT: Dark grey and black, typical grain size <1mm *(continued)*

BASALT: Grey-brown with orange joints.

NO CORE 13.43 to 13.51

BASALT: Dark grey with orange and purple-brown staining.

TEPHRA Dark purple, massive.

TEPHRA/BASALT: Transition, dark purple with grey patches.

CS, rock fragments, 5mm

CS, rock fragments, 3mm

CS, 90°, Longitudinal defect between 10m and 12.3m, fragmented rock and clay. Rock disturbed by drilling and handling around this defect.

JT, 20°, IR, SO, CO

JT, 10°, IR, SO, VN

JT, 60°, UN, RO, VN

Core is highly fractured in all directions, typical spacing <5 to 20mm

JT, 5°, UN, SO, CO

JT, 25° UN, SO, CO

JT, 30°, UN, RO, VN

XW SM, CLay 3mm

JT, 10°, UN, SO, CO CLAY

JT, 0°, UN, SO, CO CLAY

XW SM, CLAY 3mm

JT, 20°, CU, SO VN Clay

JT, 80°, CU, SO CN

JT, 50°, UN, SO, VN clay

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

casing used

barrel withdrawn

graphic log/core recovery

core recovered
- graphic symbols indicate material

no core recovered

water

▼ 10/1/98 water level on date shown

► water inflow

◁ partial drill fluid loss

◀ complete drill fluid loss

25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

coating

CN	clean
SN	stained
VN	veneer
CO	coating

coffey geotechnics

Engineering Log - Cored Borehole

Borehole No.	**BH3**
Sheet	4 of 5
Project No:	*GEOTALST01618AN*
Client:	*NEW SOUTH WALES HEALTH INFRASTRUCTURE*
Principal:	
Project:	*LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING*
Borehole Location:	*LITTLE URALBA ST. CARPARK*
Date started:	*17.1.2013*
Date completed:	*18.1.2013*
Logged by:	*MH*
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528553.6	slope:	-90°	R.L. Surface:	32.17
hole diameter:	100 mm	Drilling fluid:		Northing:	6813169.3	bearing:	datum: AHD, MGA

drilling information / material substance / rock mass defects

method | core-lift | water | RL | depth metres | graphic log core recovery | material: rock type; grain characteristics, colour, structure, minor components | weathering alteration | estimated strength VL L M H VH EH | Is(50) MPa D- diametral A- axial | RQD % | defect spacing mm 30 100 300 1000 3000 | defect description: type, inclination, planarity, roughness, coating, thickness — particular / general

Water: Water not observed

RL: 16, 15, 14, 13, 12, 11, 10, 9

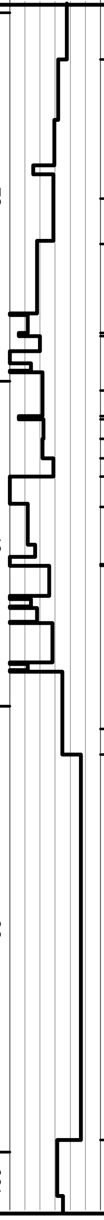
Depth metres: 17, 18, 19, 20, 21, 22, 23, 24

depth metres	material	weathering alteration
to 19.8	**BASALT:** Dark grey, some dark purple veins.	SW
19.8 – 24	**BASALT:** Dark grey and black, typical grain size <1mm.	FR

Is(50) MPa:

D	A
1.3	
5.7	5
8.4	7.8
6.6	7.2

RQD %: 82, 67, 96, 100



Defect description – particular:

- JT, 50°, ST< SL, VN
- JT, 80°, IR, SO, VN
- JT, 40°, UN, SL, VN
- JT, 30°, UN, SO, CO clay
- JT, 20°, UN, SO, CO clay
- JT, 10°, UN, SO, CO clay
- JT, 90°, UN, SO, VN extends from 18.14 to 18.20
- SZ, rock fragments 80mm
- SZ, rock fragments to 10mm
- SZ, fragmented rock and silt, 280mm
- SZ, fragmented rock 20mm
- SZ, fragmented rock 20mm
- JT, 30°, PL, SO, CO
- JT, 30°, PL, SO, CO
- CS, fragmented rock 3mm
- CS fragremnted rock 5mm
- JT, 70°, UN, SO VN clay

Defect description – general:

- JT, 0-70°, PL/UN, SO, CN-VN
- JT,0-30°, UN/CU, SO, CN

method

DT	diatube
AS	auger screwing
AD	auger drilling
RR	roller/tricone
CB	claw or blade bit
NMLC	NMLC core
NQ, HQ, PQ	wireline core

core-lift

casing used

barrel withdrawn

graphic log/core recovery

core recovered - graphic symbols indicate material

no core recovered

water

10/1/98 water level on date shown

water inflow

partial drill fluid loss

complete drill fluid loss

25 water pressure test result (lugeons) for depth interval shown

weathering

FR	fresh
SW	slightly weathered
MW	moderately weathered
HW	highly weathered
XW	extremely weathered
DW	distinctly weathered (covers MW and HW)

strength

VL	very low
L	low
M	medium
H	high
VH	very high
EH	extremely high

defect type

JT	joint
PT	parting
SM	seam
SZ	sheared zone
SS	sheared surface
CS	crushed seam

planarity

PL	planar
CU	curved
UN	undulating
ST	stepped
IR	irregular

roughness

VR	very rough
RO	rough
SO	smooth
SL	slickensided

coating

CN	clean
SN	stained
VN	veneer
CO	coating

Engineering Log - Cored Borehole

Borehole No.	***BH3***
Sheet	5 of 5
Project No:	***GEOTALST01618AN***
Client:	***NEW SOUTH WALES HEALTH INFRASTRUCTURE***
Date started:	***17.1.2013***
Principal:	
Date completed:	***18.1.2013***
Project:	***LISMORE BASE HOSPITAL - NEW 11 FLOOR BUILDING***
Logged by:	***MH***
Borehole Location:	***LITTLE URALBA ST. CARPARK***
Checked by:	

drill model & mounting:	MD100 Track	Easting:	528553.6	slope:	-90°	R.L. Surface:	32.17
hole diameter:	100 mm	Drilling fluid:		Northing: 6813169.3	bearing:	datum:	AHD, MGA

drilling information | **material substance** | **rock mass defects**

method	core-lift	water	RL	depth metres	graphic log core recovery	material: rock type; grain characteristics, colour, structure, minor components	weathering alteration	estimated strength VL L M H VH EH	Is(50) MPa D- diametral A- axial	RQD %	defect spacing mm 30 100 300 1000 3000	defect description: type, inclination, planarity, roughness, coating, thickness — particular	general
		Water not observed	8 7	25	╱╲	**BASALT:** Dark grey and black, typical grain size <1mm. *(continued)*	FR	VH–EH	D 8.4 A 10.6	100			JT,0-30°, UN/CU, SO, CN
			6 5 4 3 2 1	26 27 28 29 30 31 32		BH3 terminated at 25.76m							

method		core-lift	water	weathering		defect type		roughness	
DT	diatube	casing used	10/1/98 water level on date shown	FR	fresh	JT	joint	VR	very rough
AS	auger screwing	barrel withdrawn	water inflow	SW	slightly weathered	PT	parting	RO	rough
AD	auger drilling		partial drill fluid loss	MW	moderately weathered	SM	seam	SO	smooth
RR	roller/tricone		complete drill fluid loss	HW	highly weathered	SZ	sheared zone	SL	slickensided
CB	claw or blade bit			XW	extremely weathered	SS	sheared surface		
NMLC	NMLC core			DW	distinctly weathered (covers MW and HW)	CS	crushed seam		
NQ, HQ, PQ	wireline core								

graphic log/core recovery
- core recovered - graphic symbols indicate material
- no core recovered

water pressure test result (lugeons) for depth interval shown (25)

strength		planarity		coating	
VL	very low	PL	planar	CN	clean
L	low	CU	curved	SN	stained
M	medium	UN	undulating	VN	veneer
H	high	ST	stepped	CO	coating
VH	very high	IR	irregular		
EH	extremely high				

Soil Description Explanation Sheet (1 of 2)

DEFINITION:

In engineering terms soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material can be remoulded or disintegrated by hand in its field condition or in water it is described as a soil. Other materials are described using rock description terms.

CLASSIFICATION SYMBOL & SOIL NAME

Soils are described in accordance with the Unified Soil Classification (UCS) as shown in the table on Sheet 2.

PARTICLE SIZE DESCRIPTIVE TERMS

NAME	SUBDIVISION	SIZE
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

MOISTURE CONDITION

Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.
Moist	Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

TERM	UNDRAINED STRENGTH s_u (kPa)	FIELD GUIDE
Very Soft	<12	A finger can be pushed well into the soil with little effort.
Soft	12 - 25	A finger can be pushed into the soil to about 25mm depth.
Firm	25 - 50	The soil can be indented about 5mm with the thumb, but not penetrated.
Stiff	50 - 100	The surface of the soil can be indented with the thumb, but not penetrated.
Very Stiff	100 - 200	The surface of the soil can be marked, but not indented with thumb pressure.
Hard	>200	The surface of the soil can be marked only with the thumbnail.
Friable	–	Crumbles or powders when scraped by thumbnail.

DENSITY OF GRANULAR SOILS

TERM	DENSITY INDEX (%)
Very loose	Less than 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	Greater than 85

MINOR COMPONENTS

TERM	ASSESSMENT GUIDE	PROPORTION OF MINOR COMPONENT IN:
Trace of	Presence just detectable by feel or eye, but soil properties little or no different to general properties of primary component.	Coarse grained soils: <5% Fine grained soils: <15%
With some	Presence easily detected by feel or eye, soil properties little different to general properties of primary component.	Coarse grained soils: 5 - 12% Fine grained soils: 15 - 30%

SOIL STRUCTURE

ZONING		CEMENTING	
Layers	Continuous across exposure or sample.	Weakly cemented	Easily broken up by hand in air or water.
Lenses	Discontinuous layers of lenticular shape.	Moderately cemented	Effort is required to break up the soil by hand in air or water.
Pockets	Irregular inclusions of different material.		

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

Extremely weathered material	Structure and fabric of parent rock visible.
Residual soil	Structure and fabric of parent rock not visible.

TRANSPORTED SOILS

Aeolian soil	Deposited by wind.
Alluvial soil	Deposited by streams and rivers.
Colluvial soil	Deposited on slopes (transported downslope by gravity).
Fill	Man made deposit. Fill may be significantly more variable between tested locations than naturally occurring soils.
Lacustrine soil	Deposited by lakes.
Marine soil	Deposited in ocean basins, bays, beaches and estuaries.

Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 60 mm and basing fractions on estimated mass)						USC	PRIMARY NAME
COARSE GRAIINED SOILS More than 50% of materials less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.0 mm	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.		GW	GRAVEL
				Predominantly one size or a range of sizes with more intermediate sizes missing.		GP	GRAVEL
			GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)		GM	SILTY GRAVEL
				Plastic fines (for identification procedures see CL below)		GC	CLAYEY GRAVEL
		SANDS More than half of coarse fraction is smaller than 2.0 mm	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes		SW	SAND
				Predominantly one size or a range of sizes with some intermediate sizes missing.		SP	SAND
			SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).		SM	SILTY SAND
				Plastic fines (for identification procedures see CL below).		SC	CLAYEY SAND
FINE GRAINED SOILS More than 50% of material less than 63 mm is smaller than 0.075 mm			IDENTIFICATION PROCEDURES ON FRACTIONS <0.2 mm.				
			DRY STRENGTH	**DILATANCY**	**TOUGHNESS**		
		SILTS & CLAYS Liquid limit less than 50	None to Low	Quick to slow	None	ML	SILT
			Medium to High	None	Medium	CL	CLAY
			Low to medium	Slow to very slow	Low	OL	ORGANIC SILT
		SILTS & CLAYS Liquid limit greater than 50	Low to medium	Slow to very slow	Low to medium	MH	SILT
			High	None	High	CH	CLAY
			Medium to High	None	Low to medium	OH	ORGANIC CLAY
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture.					Pt	PEAT

- Low plasticity – Liquid Limit W_L less than 35%.
- Medium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

TERM	DEFINITION	DIAGRAM
PARTING	A surface or crack across which the soil has little or no tensile strength. Parallel or sub parallel to layering (eg bedding). May be open or closed.	
JOINT	A surface or crack across which the soil has little or no tensile strength but which is not parallel or sub parallel to layering. May be open or closed. The term 'fissure' may be used for irregular joints <0.2 m in length.	
SHEARED ZONE	Zone in clayey soil with roughly parallel near planar, curved or undulating boundaries containing closely spaced, smooth or slickensided, curved intersecting joints which divide the mass into lenticular or wedge shaped blocks.	
SHEARED SURFACE	A near planar curved or undulating, smooth, polished or slickensided surface in clayey soil. The polished or slickensided surface indicates that movement (in many cases very little) has occurred along the defect.	

TERM	DEFINITION	DIAGRAM
SOFTENED ZONE	A zone in clayey soil, usually adjacent to a defect in which the soil has a higher moisture content than elsewhere.	
TUBE	Tubular cavity. May occur singly or as one of a large number of separate or inter-connected tubes. Walls often coated with clay or strengthened by denser packing of grains. May contain organic matter	
TUBE CAST	Roughly cylindrical elongated body of soil different from the soil mass in which it occurs. In some cases the soil which makes up the tube cast is cemented.	
INFILLED SEAM	Sheet or wall like body of soil substance or mass with roughly planar to irregular near parallel boundaries which cuts through a soil mass. Formed by infilling of open joints.	

Rock Description Explanation Sheet (1 of 2)

The descriptive terms used by Coffey are given below. They are broadly consistent with Australian Standard AS1726-1993.

DEFINITIONS:	Rock substance, defect and mass are defined as follows:
Rock Substance	In engineering terms roch substance is any naturally occurring aggregate of minerals and organic material which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Effectively homogenous material, may be isotropic or anisotropic.
Defect	Discontinuity or break in the continuity of a substance or substances.
Mass	Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

SUBSTANCE DESCRIPTIVE TERMS:

ROCK NAME	Simple rock names are used rather than precise geological classification.
PARTICLE SIZE	Grain size terms for sandstone are:
Coarse grained	Mainly 0.6mm to 2mm
Medium grained	Mainly 0.2mm to 0.6mm
Fine grained	Mainly 0.06mm (just visible) to 0.2mm
FABRIC	Terms for layering of penetrative fabric (eg. bedding, cleavage etc.) are:
Massive	No layering or penetrative fabric.
Indistinct	Layering or fabric just visible. Little effect on properties.
Distinct	Layering or fabric is easily visible. Rock breaks more easily parallel to layering of fabric.

CLASSIFICATION OF WEATHERING PRODUCTS

Term	Abbreviation	Definition
Residual Soil	**RS**	Soil derived from the weathering of rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely Weathered Material	**XW**	Material is weathered to such an extent that it has soil properties, ie, it either disintegrates or can be remoulded in water. Original rock fabric still visible.
Highly Weathered Rock	**HW**	Rock strength is changed by weathering. The whole of the rock substance is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Some minerals are decomposed to clay minerals. Porosity may be increased by leaching or may be decreased due to the deposition of minerals in pores.
Moderately Weathered Rock	**MW**	The whole of the rock substance is discoloured, usually by iron staining or bleaching , to the extent that the colour of the fresh rock is no longer recognisable.
Slightly Weathered Rock	**SW**	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance (usually by limonite) has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
Fresh Rock	**FR**	Rock substance unaffected by weathering.

Notes on Weathering:

1. AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between XW and SW. For projects where it is not practical to delineate between HW and MW or it is judged that there is no advantage in making such a distinction. DW may be used with the definition given in AS1726.
2. Where physical and chemical changes were caused by hot gasses and liquids associated with igneous rocks, the term "altered" may be substituted for "weathering" to give the abbreviations XA, HA, MA, SA and DA.

ROCK SUBSTANCE STRENGTH TERMS

Term	Abbreviation	Point Load Index, I_S50 (MPa)	Field Guide
Very Low	**VL**	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
Low	**L**	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show with firm bows of a pick point; has a dull sound under hammer. Pieces of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	**M**	0.3 to 1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High	**H**	1 to 3	A piece of core 150mm long by 50mm can not be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High	**VH**	3 to 10	Hand specimen breaks after more than one blow of a pick; rock rings under hammer.
Extremely High	**EH**	More than 10	Specimen requires many blows with geological pick to break; rock rings under hammer.

Notes on Rock Substance Strength:

1. In anisotropic rocks the field guide to strength applies to the strength perpendicular to the anisotropy. High strength anisotropic rocks may break readily parallel to the planar anisotropy.
2. The term "extremely low" is not used as a rock substance strength term. While the term is used in AS1726-1993, the field guide therein makes it clear that materials in that strength range are soils in engineering terms.
3. The unconfined compressive strength for isotropic rocks (and anisotropic rocks which fall across the planar anisotropy) is typically 10 to 25 times the point load index (Is50). The ratio may vary for different rock types. Lower strength rocks often have lower ratios than higher strength rocks.

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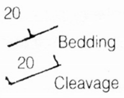
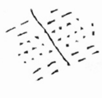
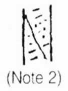
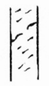
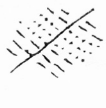
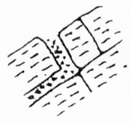
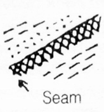
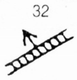
Rock Description Explanation Sheet (2 of 2)

COMMON DEFECTS IN ROCK MASSES

Term	Definition	Diagram	Map Symbol	Graphic Log (Note 1)
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or sub parallel to layering (eg bedding) or a planar anisotropy in the rock substance (eg, cleavage). May be open or closed.			
Joint	A surface or crack across which the rock has little or no tensile strength. but which is not parallel or sub parallel to layering or planar anisotropy in the rock substance. May be open or closed.			
Sheared Zone (Note 3)	Zone of rock substance with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge shaped blocks.			
Sheared Surface (Note 3)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided.			
Crushed Seam (Note 3)	Seam with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock substance which may be more weathered than the host rock. The seam has soil properties.			
Infilled Seam	Seam of soil substance usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1mm thick may be described as veneer or coating on joint surface.			
Extremely Weathered Seam	Seam of soil substance, often with gradational boundaries. Formad by weathering of the rock substance in place.			

DEFECT SHAPE

	TERMS
Planar	The defect does not vary in orientation
Curved	The defect has a gradual change in orientation
Undulating	The defect has a wavy surface
Stepped	The defect has one or more well defined steps
Irregular	The defect has many sharp changes of orientation

Note: The assessment of defect shape is partly influenced by the scale of the observation.

ROUGHNESS TERMS

Slickensided	Grooved or striated surface, usually polished
Polished	Shiny smooth surface
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.

COATING TERMS

Clean	No visible coating
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	A visible coating up to 1mm thick. Thicker soil material is usually described using appropriate defect terms (eg, infilled seam). Thicker rock strength material is usually described as a vein.

BLOCK SHAPE TERMS

Blocky	Approximately equidimensional
Tabular	Thickness much less than length or width
Columnar	Height much greate than cross section

Notes on Defects:

1. Usually borehole logs show the true dip of defects and face sketches and sections the apparent dip.
2. Partings and joints are not usually shown on the graphic log unless considered significant.
3. Sheared zones, sheared surfaces and crushed seams are faults in geological terms.

Appendix B

Laboratory Test Result Sheets

Coffs Harbour Laboratory

Coffey Information Pty Ltd
ABN 92 114 364 046
1/18 Hurley Drive
Coffs Harbour NSW 2450

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Fax: +61 2 6651 5194

coffey information
SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: COFH13S-00222-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd
1/18 Hurley Drive
Coffs Harbour NSW 2450

Principal:
Project No.: INFOCOFH00387AA
Project Name: GEOTALSO01618AN- Lismore Base Hospital
Lot No.: TRN:

Accredited for compliance with ISO/IEC 17025.

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

NATA
WORLD RECOGNISED ACCREDITATION

Ben Morton
Approved Signatory: Ben Morton
(Senior Geotechnician)
NATA Accredited Laboratory Number:431
Date of Issue: 11/02/2013

Sample Details

Sample ID:	COFH13S-00222
Client Sample:	1
Date Sampled:	15/01/2013
Source:	Not Specified
Material:	Not Specified
Specification:	No Specification
Sampling Method:	Submitted by client
Project Location:	Lismore
Sample Location:	Lismore Base Hospital BH2 - 0.5-0.95

Other Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	N/A	
Mould Length (mm)		0	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	54	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	27	
Plasticity Index (%)	AS 1289.3.3.1	27	
Date Tested		6/02/2013	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A

Coffs Harbour Laboratory

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SPECIALISTS IN SCIENTIFIC TESTING SOLUTIONS

Report No: COFH13S-00223-1
Issue No: 1

Material Test Report

Client: Coffey Geotechnics Pty Ltd
1/18 Hurley Drive
Coffs Harbour NSW 2450

Principal:
Project No.: INFOCOFH00387AA
Project Name: GEOTALSO01618AN- Lismore Base Hospital
Lot No.: TRN:

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025.

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Ben Morton

Approved Signatory: Ben Morton
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NATA Accredited Laboratory Number:431
Date of Issue: 11/02/2013

Sample Details

Sample ID:	COFH13S-00223
Client Sample:	2
Date Sampled:	15/01/2013
Source:	Not Specified
Material:	Not Specified
Specification:	No Specification
Sampling Method:	Submitted by client
Project Location:	Lismore
Sample Location:	Lismore Base Hospital BH1 - 0.45-0.55

Other Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	N/A	
Mould Length (mm)		0	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	55	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	26	
Plasticity Index (%)	AS 1289.3.3.1	29	
Date Tested		6/02/2013	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A

coffey information
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Material Test Report

Report No: COFH13S-00224-1
Issue No: 1

Client:	Coffey Geotechnics Pty Ltd 1/18 Hurley Drive Coffs Harbour NSW 2450
Principal:	
Project No.:	INFOCOFH00387AA
Project Name:	GEOTALSO01618AN- Lismore Base Hospital
Lot No.:	TRN:

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025.

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Ben Morton

Approved Signatory: Ben Morton
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NATA Accredited Laboratory Number:431
Date of Issue: 11/02/2013

Sample Details

Sample ID:	COFH13S-00224
Client Sample:	3
Date Sampled:	15/01/2013
Source:	Not Specified
Material:	Not Specified
Specification:	No Specification
Sampling Method:	Submitted by client
Project Location:	Lismore
Sample Location:	Lismore Base Hospital BH2 - 10.2-10.45

Other Test Results

Description	Method	Result	Limits
Sample History	AS 1289.1.1	Oven-dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	N/A	
Mould Length (mm)		0	
Crumbling		No	
Curling		No	
Liquid Limit (%)	AS 1289.3.1.1	74	
Method		Four Point	
Plastic Limit (%)	AS 1289.3.2.1	32	
Plasticity Index (%)	AS 1289.3.3.1	42	
Date Tested		6/02/2013	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A