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FORBES RIGBY PTY LTD

PROPOSED VINCENTIA COASTAL VILLAGE NAVAL COLLEGE ROAD, VINCENTIA

ALTERNATIVE SHOPPING CENTRE & COMMERCIAL PRECINCT

GEOTECHNICAL ASSESSMENT

REPORT G24048/1-A JUNE 2004

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G24048/1-A GP:KW
8th June 2004

Forbes Rigby Pty Ltd
278 Kiera Street
WOLLONGONG NSW 2500

Attention: Mr Martin Wells

Dear Sir

Re: Proposed Vincentia Coastal Village, Naval College Road, Vincentia, Alternative Shopping Centre and Commercial Precinct: Geotechnical Assessment for Masterplanning Study.

Find enclosed our geotechnical assessment report for the above project site.

This report presents the results of field and laboratory testing and describes surface, subsurface and geotechnical conditions. The report provides an assessment of geotechnical constraints and guidelines on earthworks, footings, pavements and drainage.

Please contact Mr Gary Peake or the undesigned if you require further assistance.

For and on behalf of
Network Geotechnics Pty Ltd

for: R J King *BE(Civil)*
Principal Geotechnical Engineer

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APPENDIX A Field Investigation Results

APPENDIX B Laboratory Test Results

DRAWING No. G24048/1-1 Site Plan

1.0 INTRODUCTION

As requested, Network Geotechnics Pty Ltd has carried out geotechnical studies at an alternative site for a proposed shopping centre and commercial precinct fronting Naval College Road (Jervis Bay Road), Vincentia.

The alternative commercial precinct is identified as part of Lot 802 Jervis Bay Road and occupies an area of about 10 hectares bound by Naval College Road to the south-west and elsewhere by undeveloped bushland. The Bay and Basin Leisure Centre is situated about 400m further to the east. The site extends about 300 to 400m north-south and 300 to 350m east-west. A proposed layout plan of the site is shown on the attached Drawing No. G24048/1-1.

We have recently completed a Geotechnical Assessment on behalf of The Riverview Group for the originally proposed shopping centre and commercial precinct site adjacent to the Bay and Basin Leisure Centre (our Report G23129/1-A of 14/1/04). Prior to that, we had completed a Geotechnical Masterplanning Study on behalf of Forbes Rigby Pty Ltd for a larger 115 hectare site which includes both the original and alternate commercial precincts and undeveloped bushland to the north-west (our Report G23085/1-D of 16/12/03).

Based on review of the latest masterplan by Annand Alcock and B & N Architects, key elements of the proposed development are understood to be as follows:

- Stage 1 of the shopping centre/commercial precinct occupies the southern half of the site and includes carparking (974 spaces), supermarket, bulky goods building, medical centre, food outlets and specialty retail.

- Stage 2 of the shopping centre/commercial precinct occupies the northern half of the site and includes carparking for about 401 vehicles, supermarket, bulky goods buildings, food outlets, specialty retail and a 4950m^2 pond/water feature.

The aims of this study were to assess surface, subsurface and geotechnical conditions at the site in order to provide recommendations and advice on shallow and deep footing options, earthworks, surface/subsurface drainage, retaining walls and pavements.

We are currently conducting ongoing groundwater monitoring, the results of which will be presented in a subsequent report.

This report should be read in conjunction with the attached General Notes.

2.0 FIELDWORK

Fieldwork from previous studies considered of relevance to the current site included four machine excavated test pits (TPG1, TPG2, TPF8 and TP10) and four machine auger borehole (BHI3 and TH11 to TH13) taken to depths of 2.4m to 4.0m. A slotted standpipe piezometer was installed within BHI3 to allow ongoing measurement of groundwater levels.

Fieldwork for this current study was undertaken on 20th, 21st, 22nd and 30th April and 2nd June, 2004 and comprised:

- Seven truck mounted auger boreholes (BH1 to BH7) to depths ranging from 2.45 to 8.5m; three skid steer auger boreholes (BH8 to BH10) to 2.6m to 6.0m depth. BH1 to BH7 were continued by NMLC coring to depths ranging from 10.0m to 10.2m. BH8 and BH9 were positioned within a central gully between two proposed residential areas to the west.

- Dynamic Cone Penetrometer (DCP) soundings adjacent to BH1 to BH7 to depths ranging from 0.9m to 1.5m and Standard Penetration Tests (SPT's) within BH1 to BH7 to depths ranging from 1.95 to 3.45m.

- Slotted standpipe piezometers installed within eight boreholes (BH2 to BH5 and BH7 to BH10) and within five shallow (1.5m) boreholes adjacent to BH2 to BH5 and BH7. The upper 3 to 4m of the deep piezometers were backfilled with bentonite to allow measurement of deep groundwater table. The upper 0.5 to 0.75m of the shallow boreholes were backfilled with bentonite to allow measurement of a possible perched water table.

- Groundwater measurement within the thirteen piezometers on 20/4, 21/4, 22/4, 30/4 and 2/6/04.

The fieldwork was carried out by one of our Senior Geotechnical Engineers, one of our Geotechnical Engineers and our Principal Geotechnician, who located the nominated boreholes by hand held GPS (reported sub 5m accuracy), carried out insitu testing, sampling and groundwater measurements and prepared field logs of the boreholes.

Engineering logs of the boreholes from the current site and boreholes/test pits from the original site (considered relevant to this) are presented in Appendix A, together with an explanation sheet defining the terms and symbols used. The borehole/test pit locations are shown on the attached Drawing No. G24048/1-1. A summary of groundwater levels is presented in Attachment C.

3.0 LABORATORY TESTING

Laboratory testing carried out on samples obtained during this study included:

- Atterberg Limits (2) and Gradings (2) to aid assessment of soil classification;

- California Bearing Ratio (CBR) including Standard Compaction (3) to aid assessment of field and optimum soil moisture conditions, subgrade strength and pavement thickness requirements;

- Shrink-Swell (3) to aid assessment of soil volume change characteristics with changes in soil moisture (reactivity) and AS2870 classifications;

- Chemical analysis (2) to aid assessment of soil aggression to buried concrete and steel elements; and

- Point Load Strength Index (57) on selected rock core specimens to aid assessment of rock strength.

The Point Load Strength Index (I_{S50}) results are indicated on the engineering logs. The balance of the test results are presented in Appendix B, summarised in Attachment B and are discussed in Section 5.0.

4.0 SITE CONDITIONS

4.1 Surface

Site topography includes a broad north-east draining valley and the lower to mid slopes of two similar trending ridges. Surface slopes generally range from about 3° to 6°. Vegetation comprises native scrubland on the western slope and sedgeland vegetation within the valley and eastern slope. Surface soils are predominantly Silty SAND.

Mona Creek Road (unformed) extends north from Jervis Bay Road along the western site boundary.

An electricity easement extends through the south-west portion of the site and is defined by a bare access track. The access track is trafficable by most vehicles in dry weather, however soft wet soils may prevent access across the valley after wet weather.

4.2 Subsurface

Geological maps of the area indicate the site to be underlain by mainly Wandrawandian Siltstone. The valley extends to a low lying area to the north of the site underlain by Quaternary Alluvium.

Subsurface conditions encountered at the **boreholes/test pits within/near the shopping centre and commercial precinct** may be summarised as follows:

Layer	Description	Depth to Base of Layer (m)
TOPSOIL:	Silty SAND, fine to medium grained, grey-brown, low plasticity fines, some roots, dry to moist	0.1 to 0.6 (typically 0.25)
ALLUVIUM/ SLOPEWASH:	Sandy CLAY, Clayey SAND, Silty SAND, Silty Clayey SAND, SAND/Clayey SAND & SAND at BH1, BH2, BH3, TPG2, TPF8, TP10, BHI3 & TH11 to TH13; fine to medium grained, brown and pale grey mottled yellow-brown, medium dense: low and medium plasticity, brown and grey, fine to medium sand, firm/stiff (BH1 & BH3)	0.6 to 2.2
RESIDUAL:	CLAY, Sandy CLAY, Sandy Silty CLAY and Clayey SAND, low and medium and medium to high plasticity, brown and grey and grey mottled red/orange, fine to medium sand, M≤Wp becoming M>Wp with depth (west side of valley) and M>Wp becoming M<Wp with depth (east side of valley), stiff/very stiff becoming very stiff/hard with depth: the soil profile thickness generally increases northwards and towards the valley.	1.5 to 8.5
ROCK:	CLAYSTONE and SANDSTONE at BH1, BH2, BH5, TPG1, TPG2, TP10 & TH12; extremely to highly weathered, fine to medium grained, brown-grey-orange, very low to low rock strength	>2.4 to 6.0
	SILTSTONE at BH1 to BH7, distinctly to slightly weathered, dark grey, low and low to medium rock strength	>10.0

Subsurface conditions encountered **at Boreholes BH8 and BH9 within the central valley** may be summarised as follows:

Layer	Description	Depth to Base of Layer (m)	
		BH8	BH9
TOPSOIL:	Clayey SILT (BH8) : Silty CLAY (BH9)	0.2	0.1
SLOPEWASH/ ALLUVIUM:	Clayey SAND (BH8), dry/moist becoming moist/wet, est. medium dense : SAND, Sandy CLAY (BH9), dry/moist becoming wet, est loose/medium dense and stiff/very stiff	1.0	5.0
RESIDUAL:	Sandy CLAY and Clayey SAND, wet becoming dry with depth, stiff/very stiff and medium dense/dense	2.2	6.0+
Rock:	SANDSTONE (BH8 only), moderately weathered, brown, est. low rock strength, auger refusal on rock	2.6+	-

Groundwater was measured at depths of 0.8m to 4.0m after installation of boreholes within the alternative site. The depths at this time are affected by water used for coring. The latest readings (2/6/04) range from 1.38m to 5.25m within the deep piezometers and the shallow piezometers were dry. Groundwater depths from existing surface levels within the alternative site generally increase to the east and west from the valley.

Groundwater was measured at depths of 2.0m and 1.9m within the central valley at BH8 & BH9 after installation. The latest readings (2/6/04) were 1.38m and 2.17m.

The initial groundwater readings and ongoing monitoring readings to date are presented in Attachment C. Groundwater levels and seepages may vary with fluctuations in rainfall, temperature and other factors. The results of water aggression testing and ongoing groundwater monitoring will be presented in a subsequent report.

5.0 DISCUSSION & RECOMMENDATIONS

5.1 General

Survey long sections of proposed roads/carparks and design elevation of buildings were not available at the time of reporting. However, it is anticipated that earthworks will involve a balanced cut to fill of up to about 3m. It is anticipated that pavement subgrade materials close to cut/fill transitions will generally comprise loose/medium dense and dense SAND/Clayey SAND slopewash/alluvium, stiff Sandy CLAY slopewash or stiff/very stiff residual CLAY and Sandy CLAY. It is anticipated that subgrade materials within areas of significant (>1.5 to 3.0m) cut may include extremely to highly weathered CLAYSTONE or SANDSTONE. Pavement subgrade in areas of fill may include a combination of the above.

Laboratory tests indicate the Sandy CLAY slopewash to be low plasticity (LL 26%, PI 12%), and the residual Sandy CLAY to be low to medium plasticity (LL 32 to 43%, PI 20 to 30%). Laboratory tests have also indicated CBR values of 25% for SAND/Clayey SAND slopewash, 11% for Sandy CLAY slopewash, and 6%, 7%, 8% and 10% for residual Sandy CLAY at the current site.

Field moisture for the CBR samples ranged from about 1% to 7% wet of Standard Optimum Moisture Content (SOMC) for the Sandy CLAY and SAND/Clayey SAND slopewash and 1% dry to 4.5% wet of SOMC for the residual Sandy CLAY. It is noted that samples obtained from the east side of the valley at the original commercial site were 3.5% to 7% wet of SOMC and samples obtained from the west side of the valley during the current study were 1% dry to 2% wet of SOMC.

Laboratory Shrink-Swell tests have indicated the Clayey SAND alluvium/slopewash and residual Sandy CLAYS to be of low to moderate reactivity with Iss values of 1.1%, 1.2% and 1.2%.

Chemical analysis on samples of Clayey SAND alluvium/slopewash and residual Sandy CLAY and Gravelly Sandy CLAY indicate the soils to be: acidic with pH values in water (1:2) of 4.9, 4.5 and 5.2; low salinity with EC mS/cm (1:2) of 0.07, 0.19 and 0.05; non-aggressive to concrete structures with sulphate (1:2) of 350, 40 and 150 mgSO_4/kg and non-aggressive to steel structures with chloride (1:2) of 99.5, 34.7 and 111.5 Ωm.

The I_{S50}results are indicated on the engineering logs. The remaining laboratory results are summarised in Attachment B.

5.2 Pavements

Laboratory CBR values of 6%, 7%, 8% and 10% have been obtained for residual Sandy CLAYS, 11% for Sandy CLAY slopewash and 25% for SAND/Clayey SAND slopewash. However, there is likely to be the need for insitu lime stabilisation or extensive replacement of excessively wet subgrade unless construction is undertaken following a period of extended dry weather. A CBR value of 10% has been assumed for the design of pavements on lime stabilised subgrade or on select subgrade replacement. As a guide, we have considered a CBR value of 6% for the design of pavements on natural subgrade. If exposed, areas of insitu rock should be ripped and recompacted to a depth of not less than 300mm below subgrade level. CBR strength of these materials and the required pavement thickness should be confirmed during earthworks or when road/carpark design levels are known.

Three other potential benefits of lime stabilisation are decreased excavation volumes (due to thinner pavements), lime effectively "dries" wet subgrade, ie. the need for subgrade replacement may be avoided or significantly reduced and that subgrade and pavement deflections should be reduced.

Indicative pavement thickness designs are presented in Attachment A, together with notes covering design assumptions, compaction criteria, pavement material quality, drainage and other construction issues. The recommended pavement designs are in accordance with Austroads (1992) and APRG Report No 21.

5.3 Footings

5.3.1 Shopping Centre/Supermarkets/Bulky Goods Buildings

It is recommended that building footings extend into very stiff residual clay or dense residual clayey sand or to rock in order to reduce the effects of potential differential movement. If rock is encountered beneath part of a building footing system, it may be

necessary to extend all footings for that building to rock in order to reduce the potential for excessive differential settlements.

Conventional strip and pad footings may be used within the mid to upper, western portion of the site where it is anticipated that very stiff residual CLAY will be encountered close to the excavated level. Within the valley and eastern side of the site where fill is anticipated, pier & beam and pier footings may be required, with the depth to very stiff clay or dense Clayey SAND expected to range up to about 0.5 to 2.5m below existing surface levels.

Pad, strip and shallow pier footings founded within very stiff/dense residual CLAY/Clayey SAND or controlled fill (discussed in Section 5.4 Earthworks) may be proportioned for a maximum allowable bearing pressure of up to 100kPa. Settlements for footings not wider that 1m, founded in this strata are estimated to be in the range of about 10mm to 40mm. Bored piers placed at depths >4D (where D is the pier diameter) may be proportioned for a maximum allowable bearing pressure of 300kPa. Based on results of point load strength tests carried out on core samples from BH1 to BH7, it is assessed that footings founded in highly weathered CLAYSTONE or SANDSTONE may be proportioned for a maximum allowable bearing pressure of up to 700kPa and footings founded in distinctly weathered SILTSTONE, up to 1000kPa. Footings founded within either of these strata may be designed for allowable side shear of up to 75kPa within the rock socket.

Shallow groundwater is known to have been an issue during the design and construction of the Bay and Basin Leisure Centre and also appears to be present within anticipated footing depths over much of the low part of this site. If groundwater levels cannot be sufficiently lowered locally by stormwater or subsoil drainage or similar, techniques such as temporary liners, dewatering and rapid blinding of the drilled cleaned base with about 0.1m thickness of concrete could be considered. Alternatively, consideration should be given to insitu grout injected piles, driven timber piles or steel screw piles instead of bored piers.

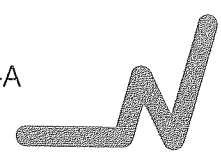
Timber piles of 300mm dia driven to an effective set within very stiff/dense residual CLAY/Clayey SAND have an allowable capacity of about 50kN. Screw piles of typically 90mm shaft dia and 250mm helix diameter, founded within strata of similar stiffness have an allowable capacity of about 75kN to 95kN. Higher capacities should be achievable with deeper installation.

Footings should be designed by a Structural Engineer and should be inspected and approved by a Structural or Geotechnical Consultant prior to placement of concrete.

Footings should be founded below the zone of influence of all sewer and drainage easements (ie a line that extends up at 45° from invert) unless the service is concrete encased. The zone of influence of possible future open table drains should be considered as a line that extends up at 2H:1V from the toe of batter.

5.3.2 Other Buildings

Based on the laboratory Shrink Swell results discussed in Section 5.1, an Iss value of 1.2% has been adopted for design.



Adopting a soil surface suction change (Δu)pF of 1.5 and a suction depth (H_s)m of 1.5 (suitable for a wet coastal climate such as Vincentia) site classification in accordance with AS2870-1996 "Residential Slabs and Footings" is assessed as follows:

. Existing Undisturbed Site:	Class S (slightly reactive) – maximum allowable bearing pressure of 100kPa for high level footings on slopewash or residual soils.
. Site modified by cut or controlled fill earthworks (refer Note 1 and Section 5.4):	Class M (moderately reactive) – maximum allowable bearing pressure of 100kPa for high level footings on slopewash, residual soils or controlled fill.
. Site modified by non-controlled fill:	Class P (problem) – requires not less than Class M footing piered to suitable natural ground beneath the fill.

Note 1

Substantial cut/fill earthworks (>0.4m depth) will alter the classification from Class S to Class M due to removal of an existing surficial cracked zone which currently mitigates surficial shrink-swell movements.

The above classifications are provided on the basis that the performance expectations set out in Appendix B of AS2870 – 1996 are acceptable and that future site maintenance is in accordance with the recommendations and advice contained in CSIRO Sheet BTF 18, a copy of which is attached.

Further advice should be sought if imported fill is used within the building areas in order to verify that the above classifications remain valid. A more reactive material when placed as controlled fill may raise the classification to Class H (highly reactive).

5.4 Earthworks

Prior to any controlled fill earthworks, vegetation, root affected soil and other deleterious materials should be removed to spoil or stockpiled for future landscaping. Stripped depths of typically 100 to 200mm should be considered, however localised deeper stripping should be anticipated.

The exposed surfaces should be proof rolled and any areas of localised softening should be excavated and replaced with an approved preferably granular fill. An initial select fill bridging layer about 0.5m thickness may be required if extensive wet ground is exposed at the time of construction. The bridging depth should be verified by the Geotechnical Testing Consultant after conducting trials.

Approved fill should be placed in layers of generally 200 to 300mm loose thickness and thoroughly and uniformly rolled. Fill should be compacted to a minimum Dry Density Ratio (AS1289 5.4.1 – 1993) of 98% Standard. Within pavement areas, compaction within the upper 300mm to subgrade level should be increased to not less than 100% Standard. All fill should be compacted within a moisture content range of about ± 2% from Standard Optimum. Fill required to support buildings or pavements should be

tested in accordance with AS3798 – 1996 "Guidelines on Earthworks for Commercial and Residential Developments".

Unsupported cuts and fills should be limited to a height of 1m, battered no steeper than 3H:1V within sandy topsoil, slopewash and similar fill soils, 2H:1V within residual clay/clayey sand or similar fill soils and 1H:1V within sandstone. Trimmed batters should be vegetated or otherwise protected against erosion. Unsupported temporary batters during construction should not be steeper than 1.5H:1V (sands) 1H:1V (clays) and 0.5H:1V (sandstone). Cuts and fills exceeding 1m height should be supported by engineered retaining walls constructed with generous provision for subsoil drainage and designed for surcharge loads from sloping ground and/or adjacent structures or loads.

Retaining walls may be designed using the following parameters:

	Soil Layer	Unit Weight (kN/m^3)	Coefficient of active earth pressure (Ka)	Coefficient of passive earth pressure (Kp)
Slopewash:	SAND or Clayey SAND	20	0.33	3
Residual:	Clayey SAND	19	0.4	2.5
	Sandy CLAY or Silty CLAY	18	0.4	2.5

Collected surface and runoff water should be discharged in a controlled manner as required by Council.

For and on behalf of
Network Geotechnics Pty Ltd

Gary Peake *BE (Civil), GCE*
Senior Geotechnical Engineer

Reviewed by

for: R J King *BE (Civil)*
Principal Geotechnical Engineer

Network Geotechnics Pty Ltd

GENERAL NOTES

GENERAL

Geotechnical reports present the results of investigations carried out for a specific project and usually for a specific phase of the project (e.g. preliminary design). The report may not be relevant for other phases of the project (e.g. construction), or where project details change.

SOIL AND ROCK DESCRIPTIONS

Soil and rock descriptions are based on AS 1726 – 1993, using visual and tactile assessment except at discrete locations where field and / or laboratory tests have been carried out. Refer to the terms and symbols sheet for definitions.

GROUNDWATER

The water levels indicated on the logs are taken at the time of measurement and depending on material permeability may not reflect the actual groundwater level at those specific locations. Also, groundwater levels can vary with time due to seasonal or tidal fluctuations and construction activities.

INTERPRETATION OF RESULTS

The discussion and recommendations in the accompanying report are based on extrapolation / interpolation from data obtained at discrete locations. The actual interface between the materials may be far more gradual or abrupt than indicated. Also, actual conditions in areas not sampled may differ from those predicted.

CHANGE IN CONDITIONS

Subsurface conditions can change with time and can vary between test locations. Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations can also affect subsurface conditions.

REPRODUCTION OF REPORTS

 Where information from the accompanying report is to be included in contract documents or engineering specification for the project, the entire report should be included in order to minimise the likelihood of misinterpretation from logs.

FURTHER ADVICE

Network Geotechnics would be pleased to further discuss how any of the above issues could affect your specific project. We would also be pleased to provide further advice or assistance including:

- assessment of suitability of designs and construction techniques;
- contract documentation and specification;
- construction control testing (earthworks, pavement materials, concrete);
- construction advice (foundation assessments, excavation support).

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

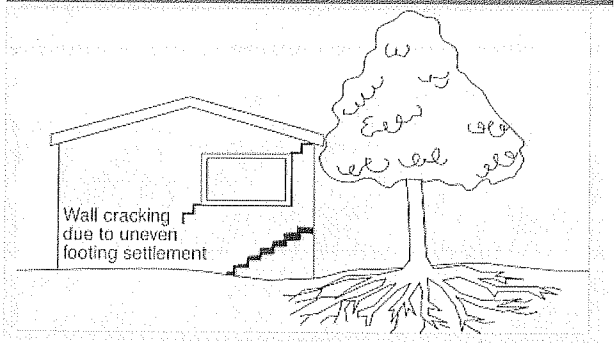
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

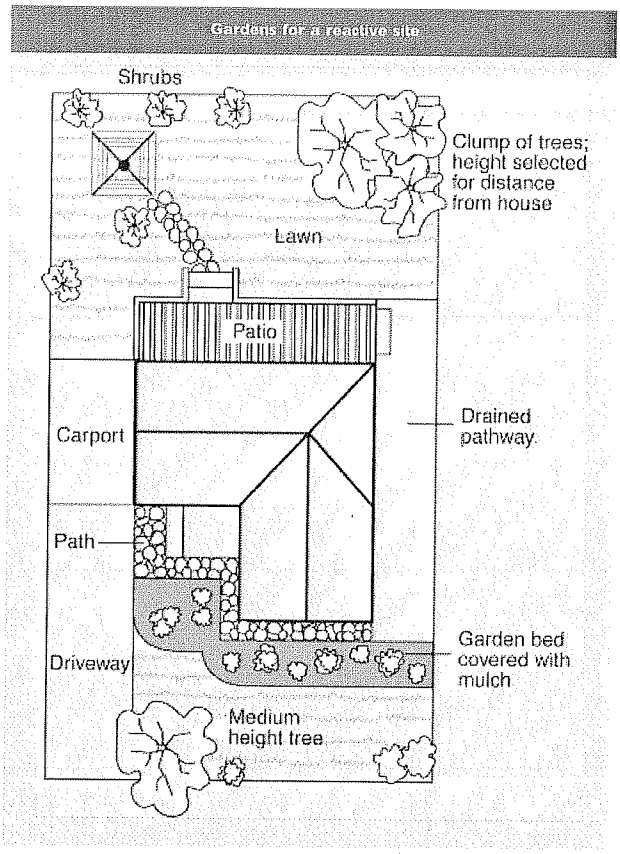
It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

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

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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ATTACHMENT A

Indicative Pavement Thickness

Proposed Alternative Shopping Centre & Commercial Precinct
Naval College Road, Vincentia

-- Indicative Pavement Thickness (mm) --

Location	Assumed Design Traffic (ESA's)	Assumed Design Traffic (CVAG's)	Design Subgrade (CBR %)	Select	Sub-base	Base-course	Wearing Course	TOTAL
HEAVY TRAFFIC								
Flexible Construction	(say) $5x10^6$	-	10 (lime stab or select)	(Note 3)	100 (U)	160 (U)	40 (AC)	300
			6 (natural)		220 (U)	160 (U)	40 (AC)	420
Rigid Construction	-	(say) $3x10^7$	10 (lime stab or select)	(Note 3)	125 (B)	-	200 (C)	325
			6 (natural)	-	125 (B)	-	210 (C)	335
MODERATE TRAFFIC								
Flexible Construction	(say) $3x10^5$	-	10 (lime stab or select)	(Note 3)	100 (U)	120 (U)	30 (AC)	250
			6 (natural)	-	190 (U)	120 (U)	30 (AC)	340
Rigid Construction	-	(say) $2x10^6$	10 (lime stab)	-	125 (B)	-	180 (C)	305
			6 (natural)	-	125 (B)	-	190 (C)	315
LIGHT TRAFFIC								
Flexible Construction	(say) $6x10^4$	-	10 (lime stab or select)	(Note 3)	100 (U)	120 (U)	30 (AC)	250
			6 (natural)		150 (U)	120 (U)	30 (AC)	300
Rigid Construction	-	(say) $4x10^5$	10 (lime stab or select)	-	100 (B)	-	170 (C)	270
			6 (natural)	-	100 (B)	-	180 (C)	280

Notes:

1. (AC) denotes asphaltic concrete on one-coat flush seal; (C) denotes 32 MPa concrete with joint and reinforcement details by a Civil Design Consultant, (U) denotes unbound pavements in accordance with RTA 3051 or similar; (B) denotes bound pavement materials in accordance with RTA 3052 or similar.

2. The indicative pavement thickness designs have been prepared in accordance with Austroads (1992) and APRG Report No 21 based on the design CBR values and assumed traffic loadings noted above. Please contact this office if other design conditions are anticipated.

3. The CBR value of 6% refers to natural soils. The CBR value of 10% refers to natural subgrade stabilised to about 300 to 350mm depth by the insitu addition of 3% lime by dry mass, subject to confirmatory testing; or select subgrade (CBR >10%) placed as a similar to slightly increased thickness.

4. There may be the need for further investigation and CBR testing once final road/carparking layout and long section plans are available. Notwithstanding the above, subgrade conditions, the depth of possible select subgrade replacement and the recommended pavement thickness designs should be verified after proof roll inspection of preliminary boxing.

5. The following minimum dry density ratios (AS1289 5.4.1 – 1993) should be achieved during construction:

Basecourse	98%	Modified
Sub-base	95%	Modified
Subgrade (natural or select)	100%	Standard
Subgrade Fill (below 300mm)	98%	Standard

6. Subsoil drainage lines should be installed to a depth preferable not less than 600mm below design subgrade level beneath/behind all kerblines and garden perimeters. Consideration should be given to the installation of upslope subsoil lines prior to subgrade boxing to facilitate pavement construction.

ATTACHMENT B

Soil Test Results Summary

	Location	Depth (m)	Layer	Abbrev. Description	Atterberg		CBR Data					S/S (Iss%)	Aggression to Steel or Concrete
					LL (%)	PI (%)	MDD (t/m^3)	OMC (%)	FMC (%)	MV (%)	CBR 2.5mm reading		
CURRENT STUDY	BH1	0.3-0.6	Slopewash	(CL) Sandy CLAY	26	12	1.85	13.5	14.5	+1.0	11	-	-
	BH1	0.7-1.0	Residual	(CL) CLAY	-	-	1.65	20.0	22.0	+2.0	6	-	-
	BH2	0.4-0.8	Alluvium/Slopewash	(SC) Clayey SAND	-	-	-	-	-	-	-	1.1	None
	BH4	0.5-0.9	Residual	(CL) Sandy CLAY	32	20	1.84	15.0	14.0	-1.0	10	1.2	None
	BH7	0.5-0.9	Residual	(CL) Sandy CLAY	-	-	-	-	-	-	-	1.2	-
PREVIOUS STUDY	TP10	0.5-0.8	Slopewash	(SP/SC) SAND/Clayey SAND	-	-	1.97	9.5	16.5	+7.0	25	-	-
	TP10	0.9-1.2	Residual	(CL) Gravelly Sandy CLAY	43	30	1.83	15.5	20.0	+4.5	7	-	None
	TH13	1.0-3.0	Residual	(CL) Sandy CLAY	-	-	1.74	18.0	21.5	+3.5	8	-	-

ATTACHMENT C

Summary Groundwater Readings

Piezometer Location		Surface to Groundwater Depth (m)					
		After Installation		30/4/04		2/6/04	
		Deep	Shallow	Deep	Shallow	Deep	Shallow
Earlier Site	BHF9	1.4	dry	1.24	1.24	1.25	1.16
	BHI1	1.5	dry	1.08	1.11	1.61	1.11
	BH3	dry	dry	4.79	dry	5.08	dry
	BH5	dry	dry	3.96	dry	4.76	dry
Alternative Site	BH2	2.4	dry	2.12	dry	2.35	dry
	BH3	1.7	dry	1.33	dry	1.38	dry
	BH4	2.8	dry	2.61	dry	2.76	dry
	BH5	2.2	dry	4.79	dry	5.25	dry
	BH7	0.8	dry	2.10	dry	2.40	dry
	BH10	4.0	-	0.80	-	1.08	-
Residential Site	BH8	2.0	-	0.97	-	1.38	-
	BH9	1.9	-	1.87	-	2.17	-

Note:

- ***Deep** piezometers were installed to the depth of the borehole with the upper 3 to 4m backfilled with bentonite and the lower screened portion backfilled with sand.*
- ***Shallow** piezometers were installed to 1.5m depth with the upper 0.5 to 0.75m backfilled with bentonite and the lower screened portion backfilled with sand.*

APPENDIX A

Field Investigation Results

Network Geotechnics Pty Ltd

TERMS AND SYMBOLS

SOIL DESCRIPTIONS

Moisture Condition

D	Dry
M	Moist
W	Wet
Wp	Plastic Limit
Wl	Liquid Limit
MC	Moisture Content

Consistency		Qu (kPa)
VS	Very Soft	<25
S	Soft	25 – 50
F	Firm	50 – 100
St	Stiff	100 – 200
VSt	Very Stiff	200 – 400
H	Hard	>400
Fb	Friable	

Density Index		I_D (%)
VL	Very Loose	< 15
L	Loose	15 – 35
MD	Medium Dense	35 – 65
D	Dense	65 – 85
VD	Very Dense	> 85

ROCK DESCRIPTIONS

Weathering

Rs	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
DW	Distinctly Weathered
SW	Slightly Weathered
FR	Fresh

(DW covers both HW & MW)

Strength		Is (50) MPa
EL	Extremely Low	< 0.03
VL	Very Low	0.03 – 0.1
L	Low	0.1 – 0.3
M	Medium	0.3 – 1
H	High	1 – 3
VH	Very High	3 – 10
EH	Extremely High	> 10

Structure	Spacing
Thinly Laminated	< 6mm
Laminated	6 – 20mm
Very thinly bedded	20 – 60mm
Thinly bedded	60 – 200mm
Medium bedded	0.2 – 0.6m
Thickly bedded	0.6 – 2.0m
Very thickly bedded	> 2.0m

NOTE: Soil And rock descriptions are based on AS 1726 - 1993

Natural Fractures

Type		Shape	
JT	Joint	pl	Planar
BP	Bedding plane	cu	Curved
SM	Seam	un	Undulose
FZ	Fractured zone	st	Stepped
SZ	Shear zone	ir	Irregular
VN	Vein		

Infill or Coating		Roughness	
Cn	Clean	pol	Polished
Cl	Clay	slk	Slickensided
Ca	Calcite	smo	Smooth
Fe	Iron oxide	rou	Rough
Mi	Micaceous	vro	Very rough
Qz	Quartz		

EXCAVATION/DRILLING METHOD AND CASING

BH	Backhoe/excavator bucket
NE	Natural exposure
HE	Hand excavation
AS	Auger Screwing *
AD	Auger Drilling *
R	Roller/Tricone
W	Washbore

** denotes bit shown by suffix*

B	Blank Bit
V	"V" Shaped Bit
T	Tungsten Carbide Bit

NMLC	NMLC Core Drilling
NQ/HQ	Wireline Core Drilling

C	Casing
M	Mud

SAMPLES/TESTS

B	Bulk sample
D	Disturbed sample
U50	Thin-walled tube sample (50mm diameter)
PP	Pocket penetrometer (kPa)
N*	SPT (blows per 300mm)

** denotes sample taken*

Nc	SPT with solid cone
R	SPT refusal

VANE SHEAR TESTS

s_U	Vane shear strength Peak/residual (kPa) and Vane size (mm)

WATER MEASUREMENTS

▼	Water level
▲–	Water inflow
–▲	Water outflow

BOREHOLE LOG

Network Geotechnics Pty Ltd
ACN 069 211 561
6/6 Morton Close
TUGGERAH NSW 2259
TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G24048/1
Hole No.	BH1
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	20/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	20/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286189E, 6116036N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT	3 3 B 4 4 4 B 4 7 8 20 8,13,25 N* = 38 Dynamic Cone Penetrometer (Blows/150mm)	1.0 2.0		SM	Silty SAND, fine to medium grained, grey, organics	M	L	TOPSOIL
				CL	Sandy CLAY, low plasticity, brown, fine to medium sand	M > Wp	St	SLOPEWASH
					CLAY, medium plasticity, pale brown to yellow mottled grey, some fine grained sand	≤ Wp ↓ ≈ Wp	St/ VSt H	RESIDUAL
▼ after drilling		3.0 4.0 5.0 6.0 7.0 8.0			Coring started at 2.45m depth Continued on BH1 sheet 2/3			

CORED BOREHOLE LOG

Network Geotechnics Pty Ltd
ACN 069 211 561
6/6 Morton Close
TUGGERAH NSW 2259
TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G24048/1
Hole No.	BH1
Sheet:	2/3
Started:	20/4/04
Finished:	20/4/04
Logged:	DS
Checked:	GP
RL surface:	—
Datum:	—

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286189E, 6116036N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, DW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
				Continued from BH1 sheet 1/3				
		1.0						
		2.0		Coring started at 2.45m depth				
NMLC		3.0	NO CORE	CLAYSTONE, brown - grey - orange, trace of fine grained sand, thickly bedded				CLAY seam, 40mm, 0° Is(50) = 0.16A Is(50) = 0.18D JT, 20mm, 90° CLAY seam, 10mm, 0° FZ, 50mm, 0° FZ, 20mm, 0° FZ, 150mm, 0° Is(50) = 0.32A Is(50) = 0.10D JT, 10° IRONSTONE band, 20mm, 0° GRAVEL and IRONSTONE band, 50mm, 0° CLAY seam, 20mm, 0°
		4.0						
		5.0						
		6.0		SILTSTONE, pale grey mottled orange becoming grey below 7.0m depth, thickly bedded				JT, 1mm, 90° Is(50) = 0.24A Is(50) = 0.24D IRONSTONE band, FZ, 100mm, 0° SILT seam, 20mm, 0° FZ, 50mm, 0° IRONSTONE band, 70mm, 0° SILT seam, 20mm, 0° JT, 45° FZ, 100mm, 0° Is(50) = 0.46A
		7.0						
		8.0		Continued from BH1 sheet 3/3				

CORED BOREHOLE LOG

Network Geotechnics Pty Ltd
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Job No.	G24048/1
Hole No.	BH1
Sheet:	3/3
Client:	FORBES RIGBY PTY LTD
Started:	20/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	20/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286189E, 6116036N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC				Continued from BH1 Sheet 2/3				
				SILTSTONE, grey				SILT seam, 5mm, 0° FZ, 40mm, 90° Is(50)=0.35A Is(50)=0.13D SILT seam, 15mm, 0° JT, 45°
		9.0						JT, 45° JT, 300mm, 90°
		10.0						JT, 45° Is(50)=0.13D
				BH1 terminated at 10.12m depth No Piezometer Installed				
		11.0						
		12.0						
		13.0						
		14.0						

BOREHOLE LOG

Network Geotechnics Pty Ltd
ACN 069 211 561
6/6 Morton Close
TUGGERAH NSW 2259
TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G24048/1
Hole No.	BH2
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	20/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	20/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286364E, 6115905N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm
Datum	——

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT	1 3 4 B 4 5 8 5	1.0		SM	Silty SAND, fine to medium grained, dark grey, low plasticity	D-M	L	TOPSOIL
				SC	Clayey SAND, fine to medium grained, brown, low to medium plasticity fines	M	MD	ALLUVIUM/ SLOPEWASH
after drilling	6 8 12	2.0		CL	CLAY, lowplasticity, white mottled pale red from 1.0 - 2.5m, pale red from 2.5 - 3.0m, grey below 3.0 m, trace of fine sand	< Wp ≈ Wp > Wp	St/ VSt	RESIDUAL
22/4	4,7,9 N* = 16	3.0						
	4,7,9 N* = 16	4.0			Coring started at 3.80m depth Continued on BH2 sheet 2/3			
		5.0						
		6.0						
		7.0						
		8.0						

Dynamic Cone Penetrometer (Blows/150mm)

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH2
Sheet:	2/3
Client:	FORBES RIGBY PTY LTD
Started:	20/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	20/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286364E, 6115905N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (VL 0.03, L 0.1, M 0.3, H 1.0, VH 3.0, EH 10.0)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
				Continued from BH2 sheet 1/3				
		1.0						
		2.0						
		3.0		Coring started at 3.8m depth				
NMLC		4.0	NO CORE	CLAY, low to medium plasticity, pale red with grey bedding, trace of fine grained sand, medium bedded				RESIDUAL
		5.0						
				CLAYSTONE, orange - grey - red, medium bedded				IRONSTONE band, 150mm, 0° FZ, 50mm, 0° IRONSTONE band, 50mm, 0° Is(50) = 0.64A
				IRONSTONE, pale to dark red, thinly bedded				
		6.0		SILTSTONE, dark grey, thickly bedded				FZ, 700mm, 90° Is(50) = 0.08D FZ, 20mm, 0° FZ, 50mm, 0° Is(50) = 0.10D Is(50) = 0.27A SILT seam, 100mm, 0° IRONSTONE band, 150mm, 0° Is(50) = 0.85A FZ, 50mm, 40° Is(50) = 0.68D IRONSTONE band, 5mm, 0°
		7.0						
		8.0		Continued from BH2 sheet 3/3				

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Job No.	G24048/1
Hole No.	BH2
Sheet:	3/3
Client:	FORBES RIGBY PTY LTD
Started:	20/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	20/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286364E, 6115905N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects: spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC				Continued from BH2 Sheet 2/3				SILT and GRAVEL band, 1mm, 0°
				SILTSTONE, dark grey				JT, 0°
								Is(50)=0.47A
		9.0						JT, 10°
								FZ, 20mm, 0°
		10.0						Is(50)=0.25D
								Is(50)=1.04A
				BH2 terminated at 10.2m depth				
		11.0		Piezometer Installed to 10.0m depth Bentonite 0.0 - 4.0m Sand 4.0 - 10.0m Screen 5.0 - 10.0m				
		12.0		Adjacent Piezometer Installed to 1.5m depth Bentonite 0.0 - 0.65m Sand 0.65 - 1.5m Screen 0.75 - 1.5m				
		13.0						
		14.0						

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Job No.	G24048/1
Hole No.	BH3
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286445E, 6115972N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT	2 3 3 4 5 4 7 13 14 Dynamic Cone Penetrometer (blows/150mm)	1.0		SM	Silty SAND, fine to medium grained, dark grey, low plasticity fines	D-M	L	TOPSOIL
				CL	Sandy CLAY, medium plasticity, grey becoming grey mottled orange below 0.7m depth becoming grey below 1.5m depth, fine to medium sand	> Wp	F/ St	ALLUVIUM
22/04/04 ▼	2,4,6 N* = 10	2.0					St/ VSt	
after drilling ▼					CLAY, medium plasticity, grey - white, some fine to medium sand	≃ Wp		PROBABLE RESIDUAL
	4,8,9 N* = 17	3.0						
		4.0						
		5.0			CLAY, low plasticity, dark grey becoming dark grey with white interbedding below 6.0m depth	< Wp		RESIDUAL
		6.0						
		7.0			Coring started at 7.0m depth Continued on BH3 sheet 2/3			
		8.0						

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH3
Sheet:	2/3
Started:	21/4/04
Finished:	21/4/04
Logged:	DS
Checked:	GP
RL surface:	—
Datum:	—

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286445E, 6115972N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description: rock type, grain characteristics, colour structure and minor components	degree of weathering: RS, XW, HW, MW, SW, FR	strength Is(50) Mpa: EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH	Natural fractures and Defects: spacing (mm): 30, 100, 300, 1000, 3000	Description: type, inclination, thickness, planarity, roughness, coating
				Continued from BH1 sheet 1/3				
		1.0						
		2.0						
		3.0						
		4.0						
		5.0						
		6.0						
		7.0		Coring started at 7.0m depth				
NMLC				CLAY, low to medium plasticity, grey mottled brown, trace of fine sand, thinly bedded				SILT seam, 100mm, 0°
				SILT, low to medium plasticity, dark grey, thinly bedded				Is(50)=0.33A; JT, 150mm, 90°; Is(50)=0.04D; SILT seam, 100mm, 0°; SILT seam, 100mm, 0°
		8.0		SILTSTONE, dark grey, some fine to medium sand, thickly bedded				JT, 0°

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH3
Sheet:	3/3
Started:	21/4/04
Finished:	21/4/04
Logged:	DS
Checked:	GP
RL surface:	——
Datum:	——

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286445E, 6115972N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects: spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC		9.0		Continued from BH3 Sheet 2/3 SILTSTONE, dark grey, some fine to medium sand				Is(50) = 0.15A GRAVEL cobble 30mm Is(50) = 0.25A SILT seam, 20mm, 0° FZ, 100mm, 0° Is(50) = 0.17D JT, 0° JT, 0° Is(50) = 0.03D Is(50) = 0.11A
		10.0						
		11.0		BH3 terminated at 10.0m depth Piezometer Installed to 10.0m depth Bentonite 0.0 - 3.0m Sand 3.0 - 10.0m Screen 5.0 - 10.0m Adjacent Piezometer Installed to 1.5m depth Bentonite 0.0 - 0.7m Sand 0.7 - 1.5m Screen 0.75 - 1.5m				
		12.0						
		13.0						
		14.0						
		15.0						

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Job No.	G24048/1
Hole No.	BH4
Sheet	1/3

Client:	FORBES RIGBY PTY LTD	Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE	Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286406E, 6116180N	Logged	DS
		Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG	RL surface:	——
Borehole Diameter:	100mm	Datum	——

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT after drilling	B	5 10 12 11 9 6 6 7 14		SM	Silty SAND, fine to medium grained, dark grey, low plasticity fines	D-M		TOPSOIL
		1.0		CL	Sandy CLAY, low plasticity, grey to dark grey, fine to medium sand	≤ Wp	St/ VSt	ALLUVIUM
	5,9,6 N* = 15 Dynamic Cone Penetrometer (Blows/150mm)	2.0		CL	CLAY, low to medium plasticity, grey mottled red, trace of fine to medium sand	> Wp		
22/04	4,5,6 N* = 11	3.0			Sandy CLAY, medium plasticity, grey, fine to medium sand	≃Wp		
		4.0			Sandy CLAY, medium plasticity, orange becoming pale brown below 4.9m becoming red below 6.0m	> Wp		
		5.0						
		6.0						
During Drilling		7.0						
		8.0			CLAY, medium plasticity, brown, some fine to medium sand			RESIDUAL

Continued on BH4 Sheet 2/3

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH4
Sheet	2/3
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286406E, 6116180N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm
Datum	——

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT					CLAY, medium plasticity, brown, some fine to medium sand	> Wp	St/ VSt	RESIDUAL
		9			Coring started at 8.5m depth Continued on BH4 sheet 3/3			
		10						
		11						
		12						

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH4
Sheet:	3/3
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286406E, 6116108N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS XW HW MW SW FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000) Description type, inclination, thickness planarity, roughness coating
				Continued from BH4 sheet 2/3 Coring started at 8.5m depth			
NMLC		9.0		SILTSTONE, dark grey, trace of fine grained sand thickly bedded			CLAY seam, 20mm, 0° Is(50) = 0.20A Is(50) = 0.05D SILT seam, 10mm, 0° Is(50) = 0.58A Is(50) = 0.20D JT, 0°
		10.0					JT, 0° JT, 0° Is(50) = 0.60A Is(50) = 0.14D
		11.0		BH4 terminated at 10.0m depth Piezometer Installed to 10.0m depth Bentonite 0.0 - 3.0m Sand 3.0 - 10.0m Screen 5.0 - 10.0m Adjacent Piezometer Installed to 1.5m depth Bentonite 0.0 - 0.7m Sand 0.7 - 1.5m Screen 0.75 - 1.5m			
		12.0					
		13.0					
		14.0					

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH5
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286306E, 6116179N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT	3, 8, 5, 6, 7, 9 Dynamic Cone Penetrometer (Blows/150mm)			SM	Silty SAND, fine to medium grained, dark grey, low plasticity fines	D-M	L	TOPSOIL
				CL	CLAY, medium plasticity, pale brown, trace of fine to medium sand	<Wp	St/ VSt	RESIDUAL
		1.0			CLAY, low to medium plasticity, pale grey to white, trace of fine to medium sand			
	7R N* = 7+	2.0			CLAY, low to medium plasticity, pale brown, trace of fine to medium sand	~Wp	VSt/ H	
after drilling		3.0						
22/4	5R N* = 5+							
		4.0			Coring started at 3.6m depth Continued on BH5 sheet 2/3			
		5.0						
		6.0						
		7.0						
		8.0						

CORED BOREHOLE LOG

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6/6 Morton Close
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FAX: (02) 43516300

Job No.	G24048/1
Hole No.	BH5
Sheet:	2/3
Started:	21/4/04
Finished:	21/4/04
Logged:	DS
Checked:	GP
RL surface:	——
Datum:	——

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286306E, 6116179N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, DW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000) Description type, inclination, thickness planarity, roughness coating
				Continued from BH5 Sheet 1/3			
		1.0					
		2.0					
		3.0		Coring started at 3.6m depth			
NMLC		4.0	NO CORE	CLAYSTONE, brown mottled orange, trace of fine to medium sand, medium bedded			FZ, 40mm, 0°
				SANDSTONE, fine to medium grained, grey mottled orange, some low to medium plasticity fines, medium bedded			Is(50) = 0.10A Is(50) = 0.02A JT, 0°
		5.0		CLAYSTONE, pale brown mottled orange, some fine to medium grained sand, medium bedded			Clayey SAND seam, 100mm, 0° FZ, 30mm, 0°
		6.0		SILTSTONE, dark grey, medium bedded			JT, 45° Is(50) = 0.10D FZ, 250mm, 0° Is(50) = 0.14A GRAVEL cobble 50mmd Band of EW SANDSTONE, 50mm, 0° JT, 0° BP (SILT), 20mm, 0° JT, 60°
		7.0		Continued on BH5 Sheet 3/3			

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Job No.	G24048/1
Hole No.	BH5
Sheet:	3/3
Started:	21/4/04
Finished:	21/4/04
Logged:	DS
Checked:	GP
RL surface:	——
Datum:	——

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286306E, 6116179N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH 10.0)	Natural fractures and Defects: spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC				Continued from BH5 Sheet 2/3				
				SILTSTONE, dark grey				JT, 800mm, 90° Is(50) = 0.32D Is(50) = 0.41A
		9.0						JT, 45°
								Is(50) = 0.70D Is(50) = 1.5A
		10.0						JT, 0° Is(50) = 0.60A
				BH2 terminated at 10.0m depth				
		11.0		Piezometer Installed to 10.0m depth Bentonite 0.0 - 4.0m Sand 4.0 - 10.0m Screen 5.0 - 10.0m				
		12.0		Adjacent Piezometer Installed to 1.5m depth Bentonite 0.0 - 0.6m Sand 0.6 - 1.5m Screen 0.75 - 1.5m				
		13.0						
		14.0						
		15.0						

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH6
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	22/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	22/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286285E, 6116069N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT	6 13 18 9 8 8 Dynamic Cone Penetrometer (Blows/150mm)			SM	Silty SAND, fine to medium grained, dark grey, low plasticity fines	D-M	MD	TOPSOIL
				CL	Sandy CLAY, medium plasticity, brown, fine to medium sand	≃Wp	VSt	RESIDUAL
		1.0			CLAY, low to medium plasticity, grey mottled orange becoming becoming grey mottled red below 0.8m depth becoming red below 1.2m depth becoming red mottled grey below 1.6m depth	>Wp	VSt/ H	
▼ after drilling	5,11,21 N* = 32	2.0						
	10R N*>10	3.0						
		4.0			CLAY, low plasticity, grey	>>Wp		
		5.0						
		6.0			Coring started at 5.5m depth Continued on BH6 sheet 2/3			
		7.0						
		8.0						

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH6
Sheet:	2/3
Client:	FORBES RIGBY PTY LTD
Started:	22/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	22/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286285E, 6116069N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering RS XW HW MW SW FR	strength Is(50) Mpa EL 0.03 VL 0.1 L 0.3 M 1.0 H 3.0 VH 10.0 EH	Natural fractures and Defects spacing (mm) 30 100 300 1000 3000	Description type, inclination, thickness planarity, roughness coating
				Continued from BH6 Sheet 1/3				
		1.0						
		2.0						
		3.0						
		4.0						
		5.0		Coring started at 5.5m depth				
NMLC		6.0	NO CORE	SILTSTONE, dark grey, some fine to medium sand, thickly bedded				CLAY seam, 10mm, 0° Is(50) = 0.35A FZ, 40mm, 0° JT, 1mm, 0° JT, 0° Is(50) = 0.60DA JT, 0°
		7.0						FZ, 30mm, 0° Is(50) = 0.46D Is(50) = 0.90A JT, 0° JT, 45° JT, 45°
				Continued on BH6 Sheet 3/3				

CORED BOREHOLE LOG

Network Geotechnics Pty Ltd
ACN 069 211 561
6/6 Morton Close
TUGGERAH NSW 2259
TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G24048/1
Hole No.	BH6
Sheet:	3/3
Client:	FORBES RIGBY PTY LTD
Started:	22/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	22/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286285E, 6116069N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	——
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	——

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, DW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC		9.0		Continued from BH6 Sheet 2/3 SILTSTONE, dark grey, some fine to medium sand				Is(50) = 0.30A Is(50) = 0.04D Is(50) = 0.13A SILT seam, 50mm, 0° JT, 0° JT, 45° JT, 150mm, 90° JT, 45° Is(50) = 1.10D Is(50) = 4.00A JT, 0° JT, 0° JT, 0° Is(50) = 0.60A JT, 0°
		10.0		BH6 terminated at 10.0m depth No Piezometer Installed				
		11.0						
		12.0						
		13.0						
		14.0						
		15.0						

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH7
Sheet	1/3
Client:	FORBES RIGBY PTY LTD
Started:	22/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	22/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286296E, 6116037N
Logged	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT				SM	Silty SAND, fine to medium grained, dark grey, low plasticity fines	D-M	L	TOPSOIL
	2 3 4 6 4 4 8 6 8 8	1.0		CL	Sandy CLAY, medium plasticity, brown becoming orange-red below 0.5m depth, fine to medium sand	> Wp	St St/ VSt	RESIDUAL
After Drilling	B 5,8,12 N* = 20 6,20+ N* = 20+ (Dynamic Cone Penetrometer (Blows/150mm))	2.0 3.0		CH	CLAY, medium to high plasticity, grey becoming orange below 3.1m depth	≈ Wp < Wp	VSt/ H	
		4.0		CL	CLAY, medium plasticity, brown - dark grey	> Wp		
		5.0 6.0 7.0 8.0			Coring started at 4,9m depth Continued on BH7 sheet 2/3			

CORED BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH7
Sheet:	2/3
Client:	FORBES RIGBY PTY LTD
Started:	22/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	22/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286296E, 6116037N
Logged:	DS
Checked:	GP
Equipment type:	TRUCK MOUNTED DRILL RIG
RL surface:	—
Borehole Diameter:	100mm Inclination: 0 deg: Bearing: 0
Datum:	—

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (VL 0.03, L 0.1, M 0.3, H 1.0, VH 3.0, EH 10.0)	Natural fractures and Defects spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
				Continued from BH7 Sheet 1/3				
		1.0						
		2.0						
		3.0						
		4.0		Coring started at 4.9m depth				
NMLC		5.0		SILTSTONE, dark grey, medium bedded				Is(50) = 0.30D Is(50) = 0.40A BP, 1mm, 60°
		6.0	NO CORE					Silt SEAM, 150mm, 0° BP, 1mm, 0° JT, 400mm, 45° SILT seam, 40mm, 0°
		7.0						Is(50) = 0.35A BP, 10mm, 0° Is(50) = 0.60D JT, 5° JT, 150mm, 90° SILT seam, 10mm, 0° Is(50) = 0.21AD JT, 0°
				Continued on BH7 Sheet 3/3				

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

CORED BOREHOLE LOG

Network Geotechnics Pty Ltd
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6/6 Morton Close
TUGGERAH NSW 2259
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Job No.	G24048/1
Hole No.	BH7
Sheet:	3/3
Started:	22/4/04
Finished:	22/4/04
Logged:	DS
Checked:	GP
RL surface:	——
Datum:	——

Client: FORBES RIGBY PTY LTD

Project: ALTERNATIVE SHOPPING CENTRE SITE

Location: NAVAL COLLEGE ROAD, VINCENTIA
MGA: 56286296E, 6116037N

Equipment type: TRUCK MOUNTED DRILL RIG

Borehole Diameter: 100mm Inclination: 0 deg: Bearing: 0

method	water	depth (m)	graphic log	Rock substance description rock type, grain characteristics, colour structure and minor components	degree of weathering (RS, XW, HW, MW, SW, FR)	strength Is(50) Mpa (EL 0.03, VL 0.1, L 0.3, M 1.0, H 3.0, VH 10.0, EH)	Natural fractures and Defects: spacing (mm) (30, 100, 300, 1000, 3000)	Description type, inclination, thickness planarity, roughness coating
NMLC				Continued from BH7 Sheet 2/3				JT, 0° FZ, 150mm, 0°
				SILTSTONE, dark grey, medium bedded				GRAVEL cobble, 50mmd0
		9.0						JT, 0° JT, 0°
		10.0						JT, 0° Is(50)=0.92A Is(50)=0.31D
		11.0		BH7 terminated at 10.2m depth				
		12.0		Piezometer Installed to 10.0m depth Bentonite 0.0 - 3.5m Sand 3.5 - 10.0m Screen 5.0 - 10.0m				
		13.0		Adjacent Piezometer Installed to 1.5m depth Bentonite 0.0 - 0.7m Sand 0.7 - 1.5m Screen 0.75 - 1.5m				
		14.0						
		15.0						

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH8
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56285901E, 6116382N
Logged	GP
Checked:	RJK
Equipment type:	DINGO 950P DRILL
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT				ML	Clayey SILT, low plasticity, pale grey	< Wp		TOPSOIL
2.3m after drilling, 2.0m after piezo installation				SC	Clayey SAND, fine to medium grained, pale grey mottled yellow-brown, low to medium plasticity	D-M ↓ M-W	(MD)	SLOPEWASH
		1.0		CL	Sandy CLAY, medium plasticity, yellow-brown mottled pale grey, fine to medium sand	> Wp	(St)	RESIDUAL
				SC	Clayey SAND, fine to medium grained, pale grey, low plasticity, some fine to medium gravel	D	(MD/ D)	
ADB		2.0			SANDSTONE, moderately weathered, fine grained, brown becoming orange-brown, est low rock strength		—	ROCK TC bit refusal 2.2m
		3.0			BH8 terminated at 2.6m depth ~ Auger refusal on rock Piezometer Installed to 2.6m depth 0.0 - 1.6m Bentonite 1.6 - 2.6m Screen & Sand 0.5m Stick up			Central Gully Upstream Centreline No surface water
		4.0						
		5.0						
		6.0						
		7.0						
		8.0						

BOREHOLE LOG

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6/6 Morton Close
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Job No.	G24048/1
Hole No.	BH9
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 56286144E, 6116665N
Logged	GP
Checked:	RJK
Equipment type:	DINGO 950P DRILL
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT				SM	Silty SAND, fine grained, brown, roots	D-M		TOPSOIL
				SC	Clayey SAND, fine to medium grained, yellow-brown mottled pale grey, low plasticity	M	(L/ MD)	SLOPEWASH
	2.2m after drilling, 1.9m after piezo installation	1.0		SP	SAND, fine to coarse grained, pale grey-white	D-M ↓ M		ALLUVIUM
		2.0			SAND, fine to medium grained, orange-brown mottled grey, some low to medium plasticity clay fines, trace of fine gravel (ironstone)			
		3.0		CH	Sandy CLAY, high plasticity, pale grey, fine to medium sand increasing below about 2.5m depth	> Wp ↓ ≥ Wp	(St) ↓ (VSt)	
		4.0		SP	SAND, fine to medium grained, pale grey	W	(L/ MD)	
		5.0		SC	Clayey SAND, fine to medium grained, orange-brown mottled pale grey, low to medium plasticity	W	(MD/ D)	RESIDUAL
		6.0		CL	Sandy CLAY, medium plasticity, orange-brown mottled grey, trace fine gravel	≤ Wp	(VSt)	
					BH9 terminated at 6.0m depth Piezometer Installed to 6m depth 0.0 - 3.0m Bentonite 3.0 - 6.0m Screen & Sand 0.5m Stick			Central Gully Downstream Approx. CL (very broard)
		7.0						
		8.0						

BOREHOLE LOG

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Job No.	G24048/1
Hole No.	BH10
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	21/4/04
Project:	ALTERNATIVE SHOPPING CENTRE SITE
Finished:	21/4/04
Location:	NAVAL COLLEGE ROAD, VINCENTIA MGA: 286440E, 6116065N
Logged	GP
Checked:	RJK
Equipment type:	DINGO 950P DRILL
RL surface:	—
Borehole Diameter:	100mm
Datum	—

water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
ADT				SP	SAND, fine to medium grained, pale grey	D		RECENT SLOPEWASH
				ML	Clayey SILT, low to medium plasticity, dark brown, trace of roots	< Wp		TOPSOIL
		1.0		CL	Sandy CLAY, pale grey mottled orange, fine sand, some fine to medium sandstone gravel	> Wp	(St)	PROBABLE ALLUVIUM
		2.0		SC	Clayey SAND, fine to medium grained, pale grey mottled orange, fine to medium sand	M-W	(MD)	
4.0m after piezo installation		3.0		CL/ CH	Sandy CLAY, medium to high plasticity, pale grey mottled red-brown, fine sand, some medium gravel	> Wp	(St/ VSt)	PROBABLE RESIDUAL
5.5m after drilling		4.0						
		5.0		SC	Clayey SAND, fine to medium grained, pale grey mottled pale brown, low plasticity	M-W	(MD/ D)	
		6.0						
		7.0			BH10 terminated at 6m depth Piezometer Installed to 6m depth 0.0 - 3.0m Bentonite 3.0 - 6.0m Screen & Sand 0.5m Stick up			Commercial Centre Creek Line
		8.0						

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

TEST PIT LOG

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TUGGERAH NSW 2259
TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G23085/1
Pit No.	TPG1 (SLOPE)
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	29/7/03
Project:	FEASIBILITY FOR DEVELOPMENT
Finished:	29/7/03
Location:	NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66) AMG: 56286106E 6115931N
Logged	GP
Checked:	RJK
Equipment type:	EXCAVATOR 7 TONNE
RL surface:	
Bucket Size:	450mm
Datum	

method	water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
BH	None Encountered	D	0.0		SM	Silty SAND, fine to medium grained, grey-brown, some roots	M	MD	TOPSOIL
		D	0.5		CL	Sandy CLAY, medium plasticity, yellow-brown/pale grey, fine to medium sand, some tree roots	> Wp	St	RESIDUAL
		D	1.0		CL	Sandy Silty CLAY, low to medium plasticity, pale grey mottled yellow, fine to medium sand	< Wp	VSt	
		D	1.5			SANDSTONE, extremely weathered, fine grained, yellow-brown/pale grey, bands of interbedded SILTSTONE; brown, some fine gravel, est. very low rock strength	D	—	ROCK
			2.0						
			2.5			TPG1 terminated at 2.4m depth			
			3.0						
			3.5						
			4.0						

Dynamic Cone Penetrometer (blows/150mm): 3, 4, 5, 5, 8, 8

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

TEST PIT LOG

Network Geotechnics Pty Ltd
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6/6 Morton Close
TUGGERAH NSW 2259
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Job No.	G23085/1
Pit No.	TPG2 (SLOPE)
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	29/7/03
Project:	FEASIBILITY FOR DEVELOPMENT
Finished:	29/7/03
Location:	NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66) AMG: 56286231E 6116057N
Logged	GP/GV
Checked:	RJK
Equipment type:	EXCAVATOR 7 TONNE
RL surface:	
Bucket Size:	450mm
Datum	

method	water	samples, tests etc	Dynamic Cone Penetrometer (blows/150mm)	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
BH	None Encountered	D	4 9			SM	Silty SAND, fine to medium grained, grey-brown, some roots	M	MD/D	TOPSOIL
		D	6 7	0.5			Silty SAND, fine to medium grained, yellow-brown/ pale grey	M-W		PROBABLE SLOPEWASH
		B	4 4 5	1.0		CL/ CH	Sandy CLAY, medium to high plasticity, red-brown/ orange-brown/pale grey, fine to medium sand, trace fine gravel	≈Wp	St	RESIDUAL
			5 9 9 15	1.5		SC	Clayey SAND, fine to medium grained, pale grey/red-brown/orange-brown, low plasticity, trace fine to medium gravel	M	D	
		D		2.0		ML	Clayey SILT, lowplasticity, pale grey mottled red-brown some fine to coarse SILTSTONE gravel, trace fine roots	<Wp	(H)	
				2.5			SANDSTONE, extremely weathered, red-brown, inter-bedded pale grey Clayey SILT, est very low rock strength	D	—	ROCK
							TPG2 terminated at 2.6m depth			
				3.0						
				3.5						
				4.0						

TEST PIT LOG

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Job No.	G23085/1
Pit No.	TPF8 (VALLEY)
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	30/7/03
Project:	FEASIBILITY FOR DEVELOPMENT
Finished:	30/7/03
Location:	NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66) AMG: 56286305E 6115940N
Logged	GP/GV
Checked:	RJK
Equipment type:	EXCAVATOR 7 TONNE
RL surface:	
Bucket Size:	450mm
Datum	

method	water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
BH		Dynamic Cone Penetrometer (blows/150mm): 1, 2, 4, 7, 9, 12, 15, 20	0.0		SM	Silty SAND, fine grained, brown, grass and shrub roots	W	L	TOPSOIL
		D	0.5		SM-SC	Silty Clayey SAND, fine to mediumgrained, pale grey mottled yellow-brown, low plasticity		D	PROBABLE SLOPEWASH
		D	1.0		CL/CH	Sandy CLAY, medium to high plasticity, grey mottled red-brown, fine sand, some fine to medium gravel	> Wp	(VSt)	RESIDUAL
		D	1.5		SP	SAND, fine to medium grained, pale grey mottled yellow-brown/red-brown, some low plasticity clay fines	D	(D)	
			2.0			becoming			
			2.5		SC	Clayey SAND, fine to medium grained, pale grey mottled orange-brown/red-brown, some fine to coarse gravel	D-M ↓ M-W		
			3.0			TPF8 terminated at 3.0m depth			
			3.5						
			4.0						

TEST PIT LOG

Network Geotechnics Pty Ltd
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6/6 Morton Close
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TEL: (02) 43516200
FAX: (02) 43516300

Job No.	G23129/1
Pit No.	TP10
Sheet	1/1
Client:	THE RIVERVIEW GROUP
Started:	9/10/03
Project:	PROPOSED SHOPPING CENTRE & COMMERCIAL PRECINCT
Finished:	9/10/03
Location:	CNR NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA
	GPS (AUS 66): 56286332E 6115727N
Logged	GP
Checked:	GP
Equipment type:	JOHN DEERE 315C 4X4 EXTENDAHOE
RL surface:	
Bucket Width:	600mm
Datum	

method	water	samples, tests etc	Dynamic Cone Penetrometer (Blows/150mm)	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
BH	None Encountered		1			SM	Silty SAND, fine grained, grey, roots	M	MD	TOPSOIL
			3			SP	SAND, fine grained, yellow-brown			SLOPEWASH
			4	0.5						
		B	2			SP/ SC	SAND/Clayey SAND, fine to medium grained, mottled yellow-brown/pale grey, low plasticity		L	PROBABLE SLOPEWASH
			2							
			1			CL	Sandy CLAY, medium plasticity, white mottled red-brown, fine to medium sand, some fine to medium gravel, some silt	≥ Wp	S St/ VSt	RESIDUAL
		B	6	1.0						
			12							
			7							
			7	1.5						
			9							
				2.0		SC	Clayey SAND, fine to medium grained, white, low to medium plasticity	D	—	
				2.5						
							SANDSTONE, highly weathered, fine to medium grained, mottled red-brown/pale grey/orange-brown, est very low to low rock strength		—	ROCK
				3.0						
							TP10 terminated at 3.2m depth — machine refusal on rock			
				3.5						
				4.0						

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

BOREHOLE LOG

Network Geotechnics Pty Ltd
ACN 069 211 561
6/6 Morton Close
TUGGERAH NSW 2259
TEL: (02) 43516200
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Job No.	G23129/1
Pit No.	THole 11
Sheet	1/1
Client:	THE RIVERVIEW GROUP
Started:	10/10/03
Project:	PROPOSED SHOPPING CENTRE & COMMERCIAL PRECINCT
Finished:	10/10/03
Location:	CNR NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66): 56286376E 6115770N
Logged	GP
Checked:	GP
Equipment type:	SKID STEER – SOLID FLIGHT AUGERS
RL surface:	
Bucket Width:	100mm
Datum	

method	water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
AD	After drilling	1			SM	Silty SAND, fine grained, grey, some roots	M-W	MD	TOPSOIL
		2							
		3			SP	SAND, fine grained, mottled grey/pale brown, some low plasticity clay fines			SLOPEWASH
		6	0.5					D	
		9							
		11				SAND, fine to medium grained, white, some low plasticity fines, trace of roots			RESIDUAL
		13	1.0						
		13					W		
		15							
		14	1.5						
		Dynamic Cone Penetrometer (Blows/150mm)			CL	Sandy CLAY, low to medium plasticity, white becoming white mottled red-brown below about 2m depth, fine to medium sand	≈Wp	—	
			2.0						
			2.5		CL/ SC	Sandy CLAY/Clayey SAND, low to medium plasticity, mottled red-brown/pale grey/orange, fine to medium sand, trace fine to medium gravel			
			3.0						
			3.5						
			4.0			THole 11 terminated at 4m depth			

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

BOREHOLE LOG

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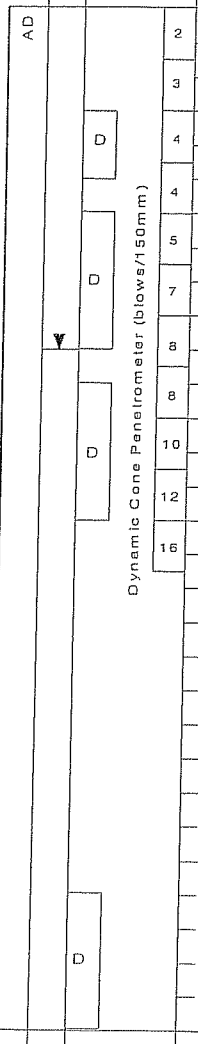
Job No.	G23085/1
Pit No.	BH13 (LOWER SLOPE)
Sheet	1/1
Client:	FORBES RIGBY PTY LTD
Started:	31/7/03
Project:	FEASIBILITY FOR DEVELOPMENT
Finished:	31/7/03
Location:	NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66) AMG: 56286364E 6115707N
Logged	GP/GV
Checked:	RJK
Equipment type:	SKID STEER DRILL 100mm DIA SOLID FLIGHT AUGERS
RL surface:	
Datum	



USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
SM	Silty SAND, fine grained, yellow-brown, roots to about 0.25m	M-W	L/MD	SLOPEWASH
SC	Clayey SAND, fine grained, pale grey mottled yellow-brown, low plasticity	W	D	RESIDUAL
SC/ CL	Sandy CLAY/Clayey SAND, fine to medium grained, red-brown/pale grey, low plasticity clay increasing with depth, some fine to medium gravel	M		
CL/ ML	Silty CLAY/Clayey SILT, low plasticity, pale grey	< Wp	(VSt)	
	BH13 terminated at 3.0m depth – Slotted piezometer (0.5 to 3m depth range) installed			

BOREHOLE LOG

Network Geotechnics Pty Ltd
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6/6 Morton Close
TUGGERAH NSW 2259
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FAX: (02) 43516300

Job No.	G23129/1
Pit No.	THole 12
Sheet	1/1
Client:	THE RIVERVIEW GROUP
Started:	10/10/03
Project:	PROPOSED SHOPPING CENTRE & COMMERCIAL PRECINCT
Finished:	10/10/03
Location:	CNR NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66): 56286428E 6115779N
Logged	GP
Checked:	GP
Equipment type:	SKID STEER ~ SOLID FLIGHT AUGERS
RL surface:	
Bucket Width:	100mm
Datum	

method	water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
AD	3.8m after drilling, 3.6m 5 mins after drilling	Dynamic Cone Penetrometer (Blows/150mm): 4, 3, 4, 6, 7, 8, 8, 10, 13, 15	0.0		SM	Silty SAND, fine grained, grey-brown, roots to 0.15m depth	M	MD	TOPSOIL
			0.5		SP	SAND, fine to medium grained, grey, some low plasticity fines	M-W	D	SLOPEWASH
			1.0		SC	Clayey SAND, fine to medium grained, white, low plasticity			RESIDUAL
			1.5		CL	Sandy CLAY, low to medium plasticity, white becoming mottled red-brown/pale grey/orange below 1.4m depth, fine to medium sand, trace fine gravel below 1.4m depth	≥ Wp	VSt/ H	
			2.0						
			2.5		SC	Clayey SAND, fine to medium grained, mottled red-brown/white, low plasticity	M	—	
			3.0						
			3.5			SANDSTONE, extremely weathered, augers as Sandy Silty CLAY, low to medium plasticity, mottled white/red-brown/orange, est very low rock strength	< Wp		ROCK Note: GW seepage probably ≤ 3.2m depth
			4.0			THole 12 terminated at 4m depth			

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

BOREHOLE LOG

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Job No.	G23129/1
Pit No.	THole 13
Sheet	1/1
Client:	THE RIVERVIEW GROUP
Started:	10/10/03
Project:	PROPOSED SHOPPING CENTRE & COMMERCIAL PRECINCT
Finished:	10/10/03
Location:	CNR NAVAL COLLEGE ROAD & THE WOOL ROAD, VINCENTIA GPS (AUS 66): 56286420E 6115844N
Logged	GP
Checked:	GP
Equipment type:	SKID STEER ~ SOLID FLIGHT AUGERS
RL surface:	
Bucket Width:	100mm
Datum	

method	water	samples, tests etc	depth (m)	graphic log	USCS symbol	Material description Soil type, particle characteristics or fines plasticity, colour, secondary and minor components	Moisture condition	Consistency/ relative density	comments notes, structure and additional observations
AD		1			SM	Silty SAND, fine grained, dark grey-brown, roots	W	MD	TOPSOIL
		3			SP	SAND, fine to medium grained, mottled pale brown/ grey, some low plasticity fines	M-W	MD	SLOPEWASH
		6						D	
		8	0.5						
		9			SC	Clayey SAND, fine grained, pale grey, low plasticity			RESIDUAL
		13							
		18	1.0		CL	Sandy CLAY, medium plasticity, pale grey becoming pale grey mottled red-brown/orange below 2m depth, fine sand	≥ Wp	VSt/ H	
		20							
		B	1.5						
			2.0				M		
		B	2.5						
			3.0						
	▼ After drilling		3.5			Gravelly Silty CLAY, medium plasticity, white mottled red-brown, fine to medium gravel	< Wp		
			4.0			THole 13 terminated at 4m depth			

Dynamic Cone Penetrometer (Blows/150mm)

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

APPENDIX B

Laboratory Test Results

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Facsimilie 4351 6300

PARTICLE SIZE DISTRIBUTION REPORT SHEET

(Document No R16.2)

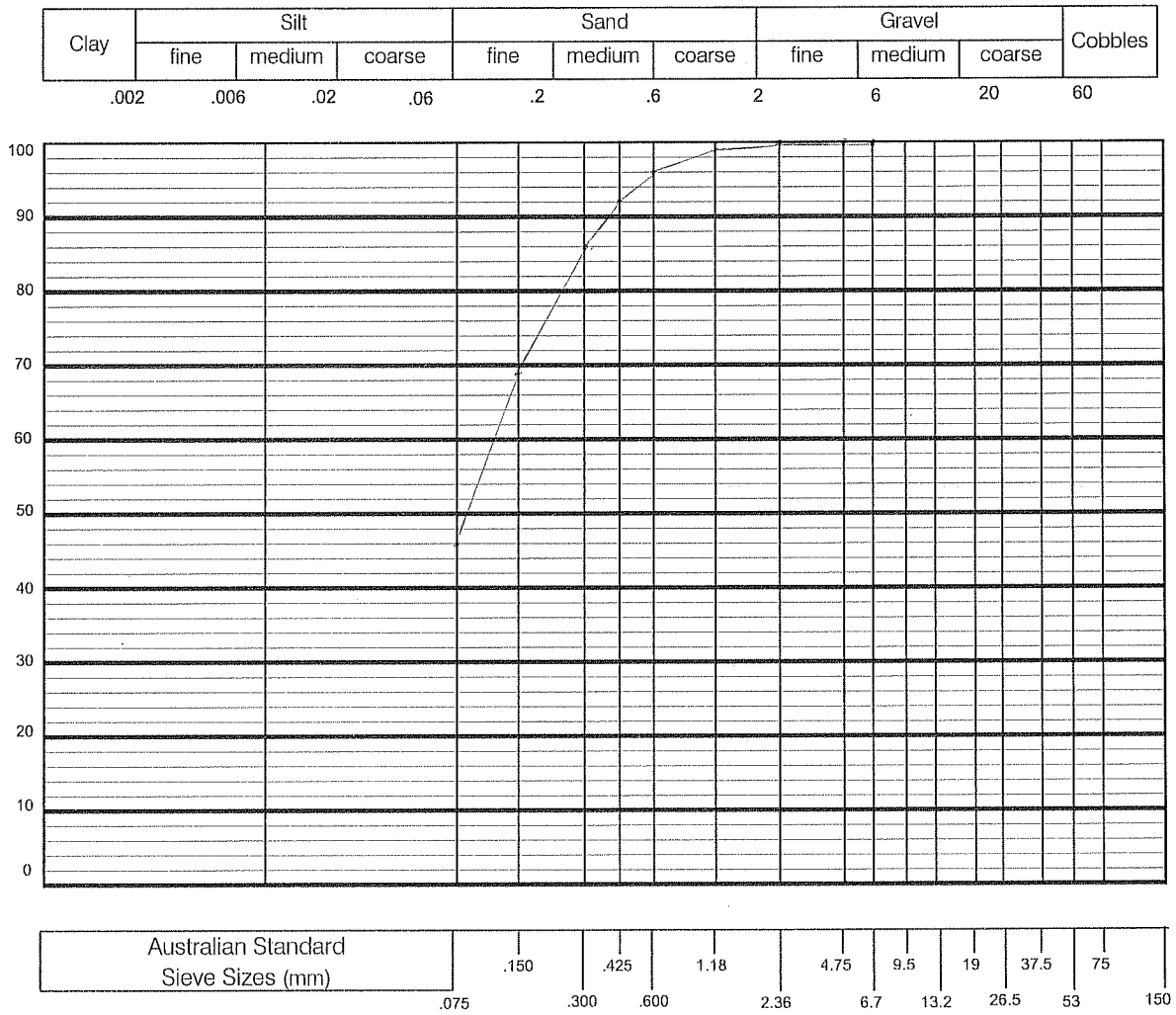
Client:	Forbes Rigby Pty Ltd	**Job No:**	G24048/1
Project:	Alternative Shopping Centre Site		
Location:	Naval College Road, Vincentia	**Date Tested:**	29/04/2004

Sample Identification
BH2 (0.4 to 0.8m)

Test Procedure
AS1289 3.6.1 (washed)

Material Description
(SC) Clayey SAND, fine to medium grained, brown, low to medium plasticity clay

Grading Results			
AS Sieve	**% Passing**	**AS Sieve**	**% Passing**
150mm		4.75mm	100
53mm		2.36mm	100
37.5mm		1.18mm	99
26.5mm		600um	96
19mm		425um	92
13.2mm		300um	86
9.5mm		150um	69
6.7mm	100	75um	46



Authorised Signature: 2/6/04

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Telephone 4351 6200
Facsimilie 4351 6300

PARTICLE SIZE DISTRIBUTION REPORT SHEET

(Document No R16.2)

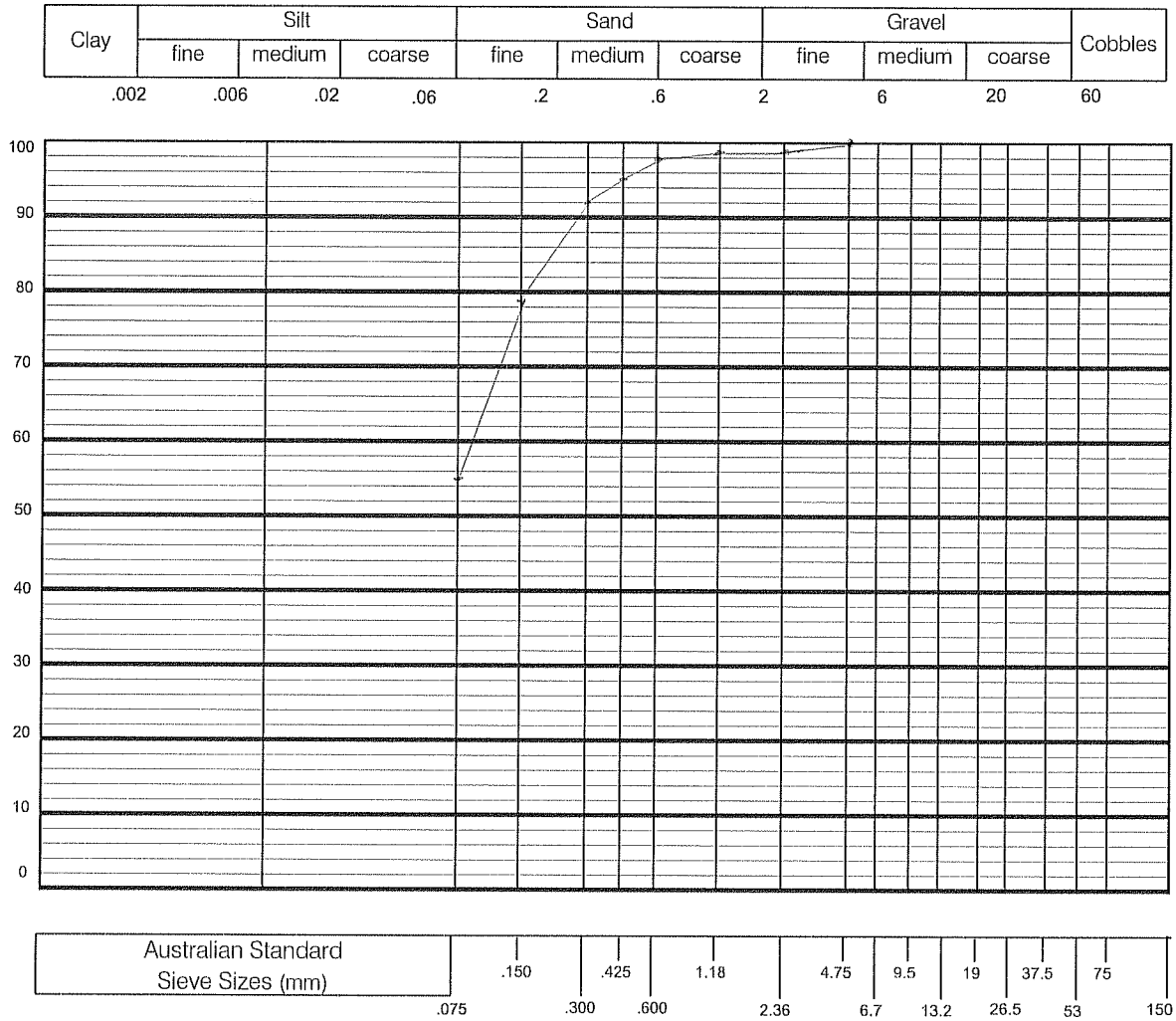
Client:	Forbes Rigby Pty Ltd	**Job No:**	G24048/1
Project:	Alternative Shopping Centre Site		
Location:	Naval College Road, Vincentia	**Date Tested:**	29/04/2004

Sample Identification
BH7 (0.5 to 0.9m)

Test Procedure
AS1289 3.6.1 (washed)

Material Description
(CL) Sandy CLAY, medium plasticity, orange-red, fine to medium sand

Grading Results			
AS Sieve	**% Passing**	**AS Sieve**	**% Passing**
150mm		4.75mm	100
53mm		2.36mm	99
37.5mm		1.18mm	99
26.5mm		600um	98
19mm		425um	95
13.2mm	100	300um	92
9.5mm	100	150um	79
6.7mm	100	75um	55



Authorised Signature:

2/6/04

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Email: gosnetgeo@bigpond.com

ATTERBERG LIMITS & LINEAR SHRINKAGE TEST REPORT SHEET

(Document No R12.1)

Client: Forbes Rigby Pty Ltd **Project:** Alternative Shopping Centre Site **Location:** Naval College Road, Vincentia	**Job No:** G24048/1 **Date Tested:** 4/5/04

SAMPLE DATA

Sample Number:	BH1 (0.3 to 0.6m)	BH4 (0.5 to 0.9m)	
Sample Location:	Refer to Drawing No. G24048/1-1		
Date Sampled:	21-4-04	21-4-04	
Sample Description:	(CL) Sandy CLAY, low plasticity, brown, fine to medium sand	(CL) Sandy CLAY, low plasticity, grey to dark grey, fine to medium sand	
Sample History:	Oven Dried	Oven Dried	
Preparation Method:	Dry Sieved	Dry Sieved	

TEST PROCEDURE		TEST RESULTS		
AS1289 3.1.2 - 1995 Liquid Limit (W_L)	%	26	32	
AS1289 3.2.1-1995 Plastic Limit (W_P)	%	14	12	
AS1289 3.3.1-1995 Plasticity Index (I_P)	%	12	20	

Comments:

Approved Signatory: S Waugh 2/6/04

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Facsimilie 4351 6300
gosnetgeo@bigpond.com

(Document No R11.5)

CALIFORNIA BEARING RATIO REPORT SHEET

Client: Forbes Rigby Pty Ltd
Project: Alternative Shopping Centre Site
Location: Naval College Road, Vincentia

Job No: G24048/1
Tested by: MK
Checked by: SW

SAMPLE DATA

Sample Number:	BH1 (0.03 to 0.6m)	BH1 (0.7 to 1.0m)	BH4 (0.5 to 0.9m)
Sample Location:	Refer to Drawing No. G24048/1-1		
Date Sampled:	21-4-04	21-4-04	21-4-04
Sample Description:	(CL) Sandy CLAY, low plasticity, brown, fine to medium sand	(CL) CLAY, medium plasticity, pale yellow brown mottled grey	(CL) Sandy CLAY, low plasticity, grey to dark grey, fine to medium sand
Field Moisture Content:	14.4	21.8	14.1

LABORATORY COMPACTION DATA [AS1289 5.1.1-1993]

Maximum Dry Density	t/m^3	1.85	1.65	1.84
Optimum Moisture Content	%	13.5	20.0	15.0

CALIFORNIA BEARING RATIO TEST RESULTS [AS1289 6.1.1-1998] (AS1289 2.1.1-1992)

Date Tested			3-5-04	3-5-04	3-5-04
Before Soakin	Dry Density	t/m^3	1.84	1.63	1.83
	Density Ratio	%	100	99	99
	Moisture Content	%	13.9	21.6	15.3
Number of days soaked			4	4	4
Surcharge		kg	9	9	9
Swell after soaking		%	0.0	1.0	0.0
After Soakin	Dry Density	t/m^3	1.84	1.62	1.82
	Density Ratio	%	100	98	99
	Moisture Content	%	16.0	23.4	16.3
After Tes	Moisture Content Top 30mm	%	15.5	24.0	16.6
	Moisture Content Whole sample	%	15.8	22.9	16.2
CBR value @ 2.5/5.0mm penetration		%	11/13	6/6	10/11

Comments:

Approved Signatory: S Waugh 2/6/04

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SHRINK/SWELL INDEX TEST REPORT SHEET

(Document No R19.1)

Client: Forbes Rigby Pty Ltd

Job No: G24048/1

Project: Alternative Shopping Centre Site

Location: Naval College Road, Vincentia

Date: 11-5-04

SAMPLE DATA

Sample Number:	BH2 (0.4 to 0.8m)	BH4 (0.5 to 0.9m)	BH7 (0.5 to 0.9m)
Sample Location:	Refer to Drawing No. G24048/1-1		
Date Sampled:	21-4-04	21-4-04	21-4-04
Sample Description:	(SC) Clayey SAND, fine to medium grained, brown, low to medium plasticity clay	(CL) Sandy CLAY, low plasticity, grey to dark grey, fine to medium sand	(CL) Sandy CLAY, medium plasticity, orange-red, fine to medium sand

TEST PROCEDURE		TEST RESULTS		
AS1289 2.1.1-1992 Moisture Content (Field)	%	12.8	12.3	15.9
AS1289 2.1.1-1992 Moisture Content (After Test)	%	14.1	17.0	18.6
AS1289 7.1.1-1998 Swelling Strain (Esw)	%	0.0	0.0	0.0
Shrinkage Strain (Esh)	%	2.0	2.1	2.1
Shrink/Swell Index (Iss)	%	1.1	1.2	1.2

Comment:

Approved Signatory: S Waugh 2/6/04

Corrosion & Scaling Assessment:
Soil Reporting Profile

Test Type I CSAS-CS
Order No Job No: G24048/1
Reference
Sample Name BH2 (0.4-0.8)
Sample No. 81010
Date Received 23/04/2004 Total No Pages: 2
Client: Network Geotechnics Pty Ltd
Brian Oberdorf
6/6 Morton Close
TUGGERAH NSW 2259

Quality System
Quality Endorsed Company
ISO9002 QEC1434S
Standards Australia

Sydney Environmental and Soil Laboratory
Specialists in Soil Chemistry and Agronomy
ABN 70 106 810 708

RECEIVED
7 MAY 2004
BY:

Sydney Environmental and Soil Laboratory Pty Ltd
(inc in NSW)
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~~ABN 23 002 825 569~~
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Thornleigh NSW 2120
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Pennant Hills NSW 1715
Telephone (02) 9980 6554
Facsimile (02) 9484 2427
http://www.sesl.com.au
Email: sesl@sesl.com.au

TEST	RESULT	COMMENTS
pH in water (1:2)	4.9	acidic - mild to moderately aggressive
EC mS/cm (1:2)	.07	low salinity level
Texture Class	loam fine sandy	
Soil Permeability Class	high	
SOLUBLE ANION ANALYSIS		
Sulphate (1:2) $mgSO_4/kg$	350	non-aggressive to concrete
Chloride (1:2) mgCl/kg	100	non-aggressive to steel
* Resistivity Ω.m	99.5	non-aggressive to steel

* Resistivity tested on a saturated sample/paste

(Note:- 10,000 mg/L = 1%)

Recommendations

These results suggest this material is not aggressive to either concrete or steel structures.

Explanation of the Methods:
pH, EC, Soluble SO_4: Bradley et al., (1983); **Cl,** (4500-Cl- E; APHA, 1998);
Texture Class, AS2159:1995;
Resistivity, AS1289.4.4.1:1997,

Checked by Principal.....
Simon Leake Date of Report 30/04/2004

Consultant.....
N.Burrows

Corrosion & Scaling Assessment: Soil Reporting Profile

Test Type I CSAS-CS
Order No Job No: G24048/1
Reference
Sample Name BH4 (0.5-0.9)
Sample No. 81011
Date Received 23/04/2004 Total No Pages: 2
Client: Network Geotechnics Pty Ltd
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Quality Endorsed Company ISO9002 QEC1435 Standards Australia

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http://www.sesl.com.au
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TEST	RESULT	COMMENTS
pH in water (1:2)	4.5	acidic - non-aggressive to mildly aggressive
EC mS/cm (1:2)	.19	low salinity level
Texture Class	silty loam	
Soil Permeability Class	low	
SOLUBLE ANION ANALYSIS		
Sulphate (1:2) $mgSO_4/kg$	40	non-aggressive to concrete
Chloride (1:2) mgCl/kg	70	non-aggressive to steel
* Resistivity Ω.m	34.7	non-aggressive to steel

* Resistivity tested on a saturated sample/paste

(Note:- 10,000 mg/L = 1%)

Recommendations

These results suggest this material is not aggressive to either concrete or steel structures.

Explanation of the Methods:
pH, EC, Soluble SO_4: Bradley et al., (1983); **Cl,** (4500-Cl- E; APHA, 1998);
Texture Class, AS2159:1995;
Resistivity, AS1289.4.4.1:1997,

Checked by Principal.....
Simon Leake Date of Report 30/04/2004

Consultant.....
N.Burrows

SCALE 1:5000 @ A3
0 50 100 150 200m

26 May 2004

Prepared for:
STOCKLAND TRUST GROUP

Prepared by:
ANNAND ALCOCK URBAN DESIGN
Retail Precinct prepared by B+N Group

LEGEND

Approximate borehole locations (This Study)
Approximate Borehole/Test Pits (Previous Study)

Network Geotechnics Pty Ltd
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6/6 Morton Close, Tuggerah
Tel: (02) 4351 6200 Fax: (02) 4351 6300

N

SCALE:
AS SHOWN

DRAWING NO.
G24048/1-1

FORBES RIGBY PTY LTD
PROPOSED VINCENTIA COASTAL VILLAGE & COMMERCIAL PRECINCT
NAVAL COLLEGE ROAD,
VINCENTIA

SITE PLAN