PROPOSED 7 LOT SUBDIVISION
ELLERDALE DRIVE, GLENDALE

Monteath & Powys Pty Ltd

GEOTWARA20644AA-AB
2 April 2008

Coffey Geotechnics Pty Ltd ABN 93 056 929 483
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coffey geotechnics
SPECIALISTS MANAGING THE EARTH

2 April 2008

Monteath & Powys Pty Ltd
PO Box 726
NEWCASTLE NSW 2300

Attention: Stuart Greville

Dear Stuart

RE: PROPOSED 7 LOT SUBDIVISION

LOT 17 ELLERDALE DRIVE, GLENDALE

GEOTECHNICAL INVESTIGATION

Please find enclosed our report on the above project.

If you have any questions regarding this matter, please do not hesitate to contact Robert Pearce or the undersigned.

For and on behalf of Coffey Geotechnics Pty Ltd

Jason Lee

Manager – Newcastle Office

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CONTENTS

Figures

Appendices

1 INTRODUCTION

This report presents the results of a geotechnical assessment carried out by Coffey Geotechnics Pty Ltd (Coffey) on behalf of Monteath & Powys Pty Ltd for the proposed residential subdivision to be located at Lot 17 Ellerdale Drive, Glendale.

The work was commissioned by Angelo Augostis, Director of Krigus Pty Ltd, by way of a signed Authorisation to Proceed form, dated 17 January 2008.

The proposed development is understood to involve the subdivision of the site into 7 residential allotments and construction of approximately 90m of new road.

The scope of work for the geotechnical assessment included providing recommendations on:

- Site preparation;
- Excavation conditions and depth to rock;
- The suitability of the site soils for use as fill an on fill construction procedures;
- Pavement design and construction;
- Site classification to AS2870 – 1996;
- Special requirements for construction procedures and or site drainage.

The following report presents the results of field investigations and laboratory testing and provides discussion and recommendations relevant to the above scope of work.

2 FIELD WORK

Field work was carried out on 24 January 2008 and consisted of:

- Excavation of five boreholes (BH1 to BH5) by hand auger methods to practical refusal on weathered rock at depths varying from 0.50m to 1.50m. Bulk disturbed samples and thin wall undisturbed samples (U50 tubes) of representative materials were taken for subsequent laboratory testing;
- Site observations and mapping of relevant site features.

All field work was carried out in the full time presence of an Engineering Geologist from Coffey who located the boreholes, carried out the sampling and testing and produced engineering logs of the boreholes. Engineering logs of the boreholes are presented in Appendix A, together with explanation sheets defining the terms and symbols used in their preparation.

The boreholes were located by measurements relative to existing site boundaries inferred from plans provided by Monteath & Powys Pty Ltd, (Ref: CAD File 06133k.dwg. Rev. A). Approximate borehole locations are shown on Figure 1.

3 SITE CONDITIONS

3.1 Surface Conditions

The site is located at Lot 17 Ellerdale Drive, Glendale, in an area of gently to undulating topography, on the lower to mid slopes of north-west trending spur.

The site is bounded to the west by a natural watercourse, to the south and east by existing bushland, and to the north by existing residential developments. Surface slopes are typically in the order of about 5° to 10°, with some localised steeper slopes up to about 15° in the vicinity of the existing watercourse to the west of the site. The aspect of the proposed development is west, north-west.

Access to the site is via Paddock Close from the north. There are some localised areas of fill at the end of the existing Paddock Close, associated with the construction of that pavement.

Surface drainage across the site is assessed to be in a west-north-westerly direction, towards the existing watercourse, which discharges towards Ironbark Creek. No areas of seepage or ponded water were observed at the time of the investigation.

Vegetation across the site is comprised of mature *Eucalyptus* trees with maximum heights in the order of 15-20 metres, with an undergrowth of native shrubs and grasses.

3.2 Subsurface Conditions

Reference to the 1:100,000 scale Newcastle Coalfield Regional Geology Sheet indicates the site to be underlain by the Lambton Subgroup of the Newcastle Coal Measures comprising of sandstone, siltstone, claystone, coal and tuff, and soils derived from these rock types.

The typical soil types encountered at the borehole locations have been divided into geotechnical units as summarised in Table 1.

TABLE 1 – SUMMARY OF GEOTECHNICAL UNITS AT BOREHOLES LOCATIONS

GEOTECHNICAL UNIT	MATERIAL TYPE	MATERIAL DESCRIPTION
UNIT 1A	TOPSOIL / FILL	Gravelly Sandy CLAY, low plasticity, fine to coarse sand, fine to medium gravels, trace of sandstone angular cobbles.
UNIT 1B	TOPSOIL	Gravelly Sandy SILT, Clayey SILT and Sandy SILT, of low liquid limit, some fine to medium angular gravels, light brown, with some rootlets.
UNIT 2	COLLUVIUM	Sandy Silty CLAY and Sandy CLAY, medium plasticity, stiff to very stiff consistency, light brown mottled orange. Gravels are fine to medium and angular.
UNIT 3	RESIDUAL	Sandy CLAY, medium to high plasticity, fine to coarse sand, very stiff consistency, light brown to light grey mottled light orange and red.
UNIT 4	WEATHERED ROCK	SANDSTONE (tuffaceous), fine to medium grained, light orange and light grey, extremely to highly weathered.

Table 2 provides a summary of the distribution of the above geotechnical units at each borehole location.

TABLE 2 –DISTRIBUTION OF GEOTECHNICAL UNITS AT BOREHOLE LOCATIONS

BOREHOLE	DEPTH (m)			
	UNIT 1A / 1B Topsoil / Fill	UNIT 2 Colluvium	UNIT 3 Residual	UNIT 4 Weathered Rock
BH 1	0.00 – 0.15	0.15 – 0.35	0.35 – 0.50	> 0.50 (R)
BH 2	0.00 – 0.10	0.10 – 0.50	0.50 – 0.70	0.70 – 0.75 (R)
BH 3	0.00 – 0.20	0.20– 0.30	0.30 – 0.50	0.50 – 0.55 (R)
BH 4	0.00 – 0.20	0.20 – 0.60	0.60 – 1.35	1.35 – 1.50
BH 5	0.00 – 0.15	0.15 – 0.60	0.50 – 0.75	> 0.75 (R)
Note: (R) = Practical hand auger refusal met on weathered rock.				

No groundwater inflows or water levels were encountered in the boreholes during the limited time they remained open on the day of the field investigations.

4 LABORATORY TESTING

Samples obtained during the field investigations were returned to Coffey's NATA registered Newcastle Laboratory for testing. The testing comprised of:

- (2 no) Shrink/Swell index tests;
- (1 no) Laboratory compaction;
- (1 no) Four day soaked California Bearing Ratio (CBR) test.

The results of the laboratory tests are presented in Appendix B and are discussed in the following sections of this report.

5 DISCUSSION AND RECOMMENDATIONS

5.1 Site Preparation

Site preparation and earthworks suitable for pavement and structure support should consist of:

- Prior to construction of the new access road or placement of any fill, the proposed areas should be stripped to remove all vegetation, topsoil, root affected or other potentially deleterious material;
- Following stripping, the exposed subgrade materials should be proof rolled to identify any wet or excessively deflecting material. Any such areas should be over excavated and backfilled with an approved select material;

- Approved fill beneath roads should be placed in layers not exceeding 300mm loose thickness and be compacted to a minimum density ratio of 95% Standard Compaction in accordance with AS1289 5.1.1 or equivalent. Clay subgrade fill should be placed and maintained at 60% to 90% of standard Optimum Moisture Content (OMC);
- The top 300mm of natural subgrade below the pavement or the final 300mm of road subgrade replaced should be compacted to a minimum density ratio of 100% Standard Compaction or equivalent within the above stated moisture range;
- Site fill beneath structures should be compacted to a minimum density ratio of 95% Standard Compaction within ±2% of OMC;
- All fill should be supported by properly designed and constructed retaining walls or else battered at 1V:2H or flatter and protected against erosion;
- Earthworks should be carried out in accordance with the recommendations outlined in AS3798-2007 'Guidelines for Earthworks for Commercial and Residential Developments'.

5.2 Excavation Conditions

Where excavation is required, it is anticipated that all site materials could be excavated by conventional backhoe or excavator bucket at least to the depths indicated on the appended borehole logs. The depth of topsoil and depth to rock (hand auger refusal) where encountered during field work are summarised in Table 2.

It is expected that rock below the depth of hand auger refusal could be excavatable to some greater depth although this has not been assessed as part of the current investigation. The use of hydraulic rock hammers may be required should hard bands of rock be encountered, particularly in deeper or confined excavations such as for service trenches.

5.3 Reuse of Materials

The following comments are made regarding the suitability of the site materials for reuse in filled areas:

- Where site regrade is proposed, UNIT 1A & 1B (Topsoil / Fill), vegetation or other potentially deleterious material should be removed to spoil or stockpiled for reuse as landscaping materials only. Stripping is generally expected to be required to depths of about 0.2m;
- The requirement for stripping UNIT 2 (Colluvial) will be dependent on moisture condition at the time of exposure. Stripping may be required to depths of up to 0.5m locally if unsuitable materials are exposed at the time of construction;
- The underlying UNIT 3 (Residual) and UNIT 4 (Weathered Rock) should be carefully stripped as necessary and stockpiled for reuse as general site fill;
- The clayey soils on-site are moderately to highly reactive, as indicated by the laboratory testing (susceptible to volume changes with variation in moisture content), and will need to be placed and compacted close to the specifications outlined to minimise reactive soil movements.

5.4 Pavement Design

5.4.1 Design Parameters

A design traffic loading of 7×10^4 ESAs (Urban Residential, Access Place or Cul-de-Sac) for a 30 year design life has been adopted for the proposed new access road in accordance with Lake Macquarie City Council (LMCC) Design Guidelines.

Based on the results of the fieldwork and laboratory testing, a design subgrade California Bearing Ratio (CBR) of 5.0% has been adopted for a clay subgrade that can be prepared to specification.

5.4.2 Flexible Pavement Design

A flexible pavement thickness design has been prepared in accordance with LMCC Design Guidelines, with reference to ARRB Special Report No 41 and APRG Report No 21.

The recommended material, construction specification and pavement make-up is presented on the attached Pavement Thickness Design Summary (PTDS).

At the time of the field investigation, the moisture content of the clay subgrade tested was assessed to be within 1% of standard Optimum Moisture Content (OMC). Moisture conditioning and drying back of the subgrade may be necessary prior to compaction and placement of pavement materials. The required time period to prepare the subgrade is likely to be dependant on the prevailing weather conditions at the time of construction.

If over wet subgrades exist at the time of construction or deleterious fill materials are encountered at subgrade level, these materials should be over-excavated and be replaced with a minimum depth of 250mm of well graded granular select material with CBR of 15% or greater.

The requirement for, and extent of subgrade replacement should be confirmed by the geotechnical authority at the time of construction.

If rock subgrade materials are encountered, the rock should be ripped and re-compacted for a minimum depth of 250mm to break-up preferential drainage paths and provide a dense homogenous surface on which to construct the pavement.

It is recommended that each construction length be boxed out to the minimum subgrade level required by the relevant pavement thickness design. Prior to pavement construction, the exposed subgrade should be assessed by the geotechnical authority to confirm the pavement thickness requirement for that section.

5.4.3 Drainage

The enclosed pavement designs assume the provision of adequate surface and subsurface drainage of the pavement and adjacent areas. It is recommended that subsoil drains by installed:

- Along the high side of roads aligned across site slopes;
- Along both sides of roads aligned down slope.

5.5 Site Classification

On the basis of the soil profiles encountered during the field investigations, laboratory testing and preliminary calculations, lots within the proposed subdivision are currently classified in accordance with AS2870-1996 *'Residential Slabs and Footings'*, as follows:

- Lots 1 to 4: Highly Reactive (Class 'H');
- Lots 5 to 7: Moderately Reactive (Class 'M').

It may be possible to reduce the classification of Lots 1 to 4 to Class 'M' if it can be shown that depth to weathered rock in the proposed building footprint area is less than 1.0m.

The effects of changes to the soil profile by additional cutting and filling and the effects of past and future trees should be considered in selection of the design value for differential movement. Footings for the proposed development should be designed and constructed in accordance with the requirements of AS2870.

The classification presented above assumes that:

- All footings are founded in controlled fill (if applicable) or in the natural soils below all non-controlled fill, topsoil material and root zones and fill under slab panels meets the requirements of AS2870, in particular, the root zone must be removed prior to the placement of fill materials beneath slab floors;
- The performance expectations set out in AS2870 are acceptable;
- Site maintenance complies with the provisions of CSIRO Sheet BTF 18, Foundation Maintenance and Footing Performance: A Homeowner's Guide, a copy of which is attached;
- Service trenches backfilled with uncontrolled fill do not extend below a line extending out and down at 45° from the ground surface at the edge of the building;
- The constructional and architectural requirements for reactive clay sites set out in AS2870 are followed.

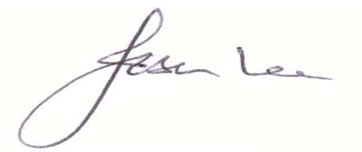
Where fill is to be placed to raise site levels, the affected allotments will require reclassification once the depth and type of placed fill are known and the level of earthworks control has been established. Final classification of the site will be made under cover of a separate report upon completion of filling and site earthworks.

6 CONSTRUCTION RISK

The extent of testing associated with this assessment is limited to discrete borehole locations and variations in ground conditions can occur between and away from such locations. If subsurface conditions encountered during construction differ from those given in this report further advice should be sought without delay.

Further advice on the uses and limitations of this report is presented in the attached document, *Important Information About Your Coffey Report*.

For and on behalf of Coffey Geotechnics Pty Ltd



Jason Lee

Manager – Newcastle Office

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SPECIALISTS MANAGING THE EARTH

19 Warabrook Boulevard, Warabrook, NSW, 2304
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pavement thickness design summary

client :	MONTEATH & POWYS PTY LTD PO BOX 726 NEWCASTLE NSW 2300	job no :	GEOTWARA020644AA
principal :		laboratory :	NEWCASTLE
project :	PROPOSED 7 LOT SUBDIVISION	report date :	April 02, 2008
location :	LOT 17 ELLERDALE DRIVE, GLENDALE	test report no.:	APR02-01
council :	LAKE MACQUARIE CITY COUNCIL	designed by :	JEL checked by :

road name or type :		ACCESS ROAD			
chainage interval :	(m)	FULL LENGTH			
design traffic loading:	(ESA)	7×10^4			
wearing course thickness :	(mm)	30			
basecourse thickness:	(mm)	120			
sub-base thickness:	(mm)	200			
select thickness:	(mm)	-			
total thickness :	(mm)	350			
CBR used for design :	(%)	5			

design traffic loading : Design traffic loading is the number of equivalent standard axles (E.S.A.) in the design lane during the design period. For definitions, refer Appendix 1.1 "Pavement Design" AUSTROADS. Refer covering letter/report.

Material Quality

wearing course : *To Lake Macquarie City Council requirements*

basecourse : *Conforming to ARRB Special Report No 41*

sub-base: *Conforming to ARRB Special Report No 41*

select : *Well graded material, CBR> 15%*

Note : Recommended material types may vary from those of job specification or statutory authority. Refer covering letter/report.

Compaction Requirements

wearing course :	To Lake Macquarie City Council requirements	
basecourse :	98% MODIFIED	**Modified**: Minimum required dry density ratio, AS1289 5.4.1-1993, calculated using field dry density determined by AS1289 5.3.1-2004 or equivalent, and the maximum dry density obtained using AS1289 5.2.1-2003 or equivalent.
sub-base :	95% MODIFIED	**Standard:** As above, but maximum dry density obtained using AS1289 5.1.1-2003 or equivalent.
select :	100% STANDARD	**Density Index:** Minimum required Density Index AS1289 5.6.1-1998, calculated using field dry density determined by AS1289 5.3.1-2004 or equivalent, and laboratory values of maximum and minimum density obtained by AS1289 5.5.1-1998 or equivalent.
subgrade :	100% STANDARD	
fill below :	95% STANDARD	

Note: Recommendations for compaction may vary from those of job specification or statutory authority. Refer covering letter/report.

Drainage: The design assumes the provision of adequate surface and subsurface drainage of the pavement and adjacent areas. Refer covering letter/report.

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SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

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

Your report is based on project specific criteria

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

Subsurface conditions can change

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

Interpretation of factual data

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

Your report will only give preliminary recommendations

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

Your report is prepared for specific purposes and persons

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

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Important information about your **Coffey** Report

Interpretation by other design professionals

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

Data should not be separated from the report*

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

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

Geoenvironmental concerns are not at issue

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

Rely on Coffey for additional assistance

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

Responsibility

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

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

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).

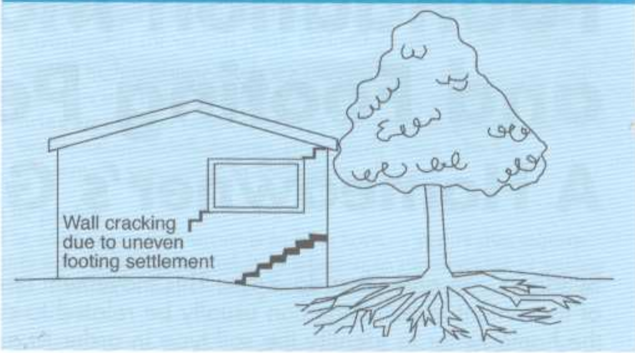
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

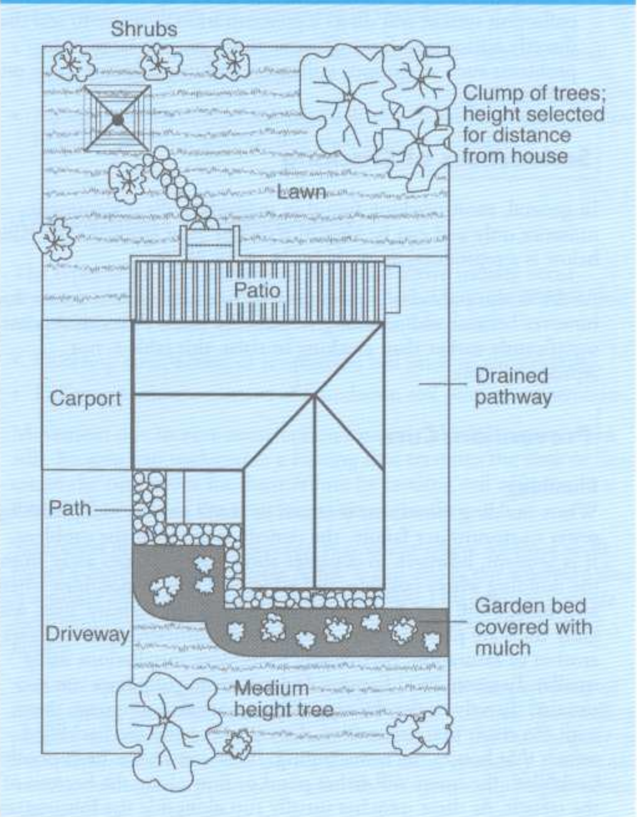
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

Gardens for a reactive site



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.

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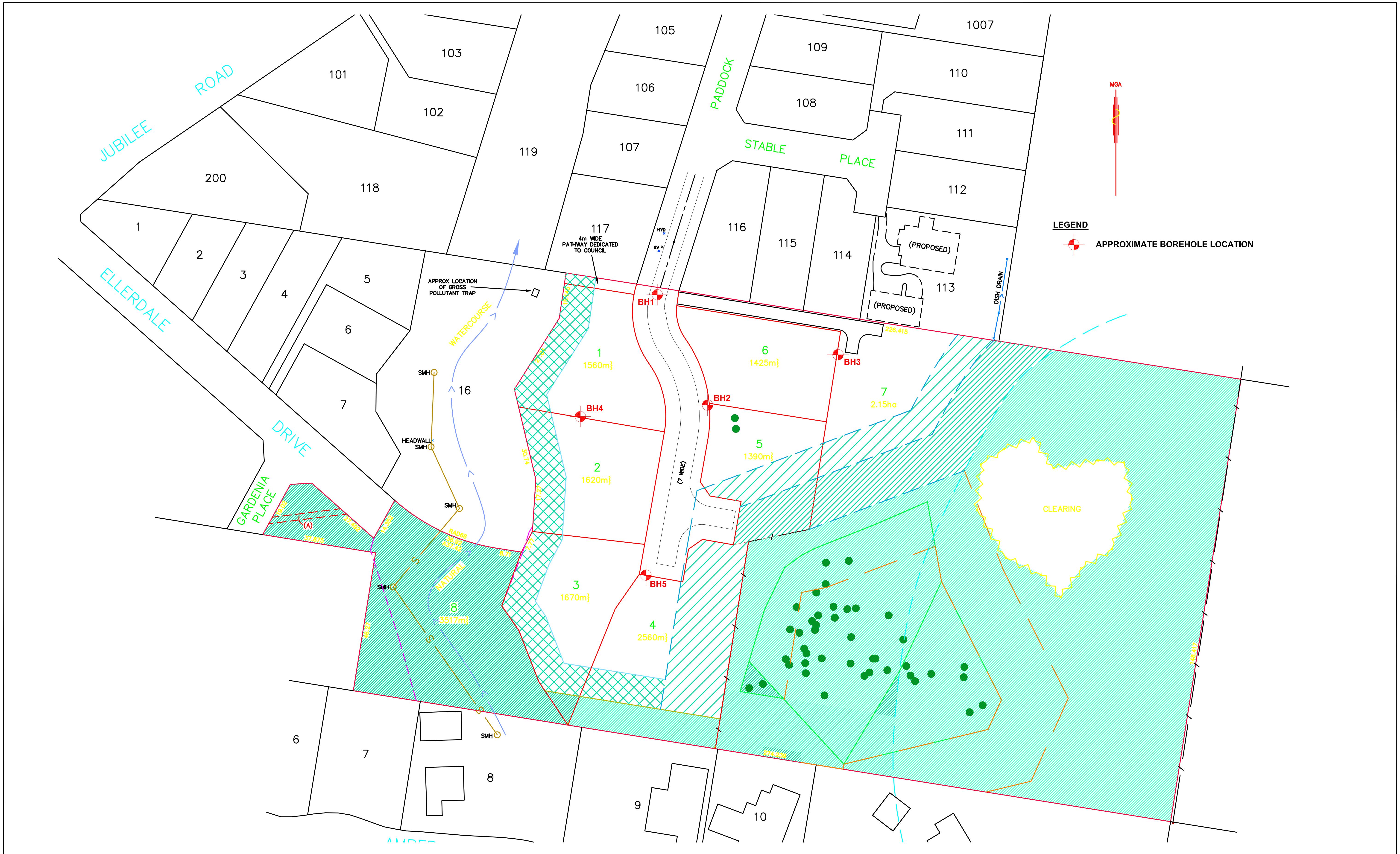
Figures



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coffey geotechnics
SPECIALISTS MANAGING THE EARTH

client:	MONTEATH & POWYS PTY LTD
project:	PROPOSED SUBDIVISION ELLERDALE DRIVE, GLENDALE GEOTECHCIAL ASSESSMENT
title:	BOREHOLE LOCATION AND SITE PLAN
project no:	GEOTWARA20644AA
figure no:	FIGURE 1

Appendix A

Results of Field Investigation

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Soil Description Explanation Sheet (1 of 2)

DEFINITION:

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

CLASSIFICATION SYMBOL & SOIL NAME

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

PARTICLE SIZE DESCRIPTIVE TERMS

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

MOISTURE CONDITION

Dry Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through hands.

Moist Soil feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.

Wet As for moist but with free water forming on hands when handled.

CONSISTENCY OF COHESIVE SOILS

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

DENSITY OF GRANULAR SOILS

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

MINOR COMPONENTS

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

SOIL STRUCTURE

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

GEOLOGICAL ORIGIN

WEATHERED IN PLACE SOILS

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

TRANSPORTED SOILS

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

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Soil Description Explanation Sheet (2 of 2)

SOIL CLASSIFICATION INCLUDING IDENTIFICATION AND DESCRIPTION

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

• Low plasticity – Liquid Limit W_L less than 35%. • Modium plasticity – W_L between 35% and 50%.

COMMON DEFECTS IN SOIL

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

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

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Rock Description Explanation Sheet (1 of 2)

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

DEFINITIONS: Rock substance, defect and mass are defined as follows:

Rock Substance In engineering terms roch substance is any naturally occurring aggregate of minerals and organic material which cannot be disintegrated or remoulded by hand in air or water. Other material is described using soil descriptive terms. Effectively homogenous material, may be isotropic or anisotropic.

Defect Discontinuity or break in the continuity of a substance or substances.

Mass Any body of material which is not effectively homogeneous. It can consist of two or more substances without defects, or one or more substances with one or more defects.

SUBSTANCE DESCRIPTIVE TERMS:

ROCK NAME Simple rock names are used rather than precise geological classification.

PARTICLE SIZE Grain size terms for sandstone are:

Coarse grained	Mainly 0.6mm to 2mm
Medium grained	Mainly 0.2mm to 0.6mm
Fine grained	Mainly 0.06mm (just visible) to 0.2mm

FABRIC Terms for layering of penetrative fabric (eg. bedding, cleavage etc.) are:

Massive	No layering or penetrative fabric.
Indistinct	Layering or fabric just visible. Little effect on properties.
Distinct	Layering or fabric is easily visible. Rock breaks more easily parallel to layering of fabric.

CLASSIFICATION OF WEATHERING PRODUCTS

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

Notes on Weathering:

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

ROCK SUBSTANCE STRENGTH TERMS

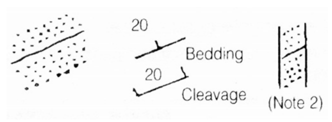
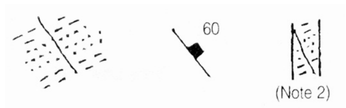
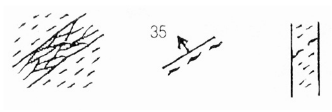
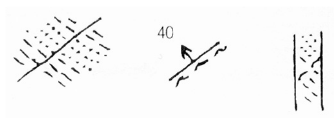
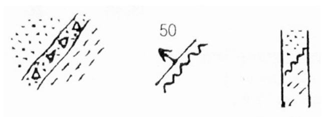
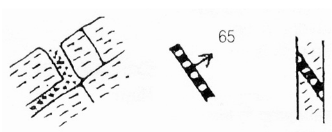
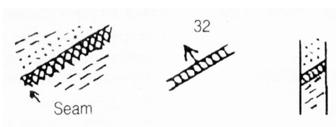
Term	Abbreviation	Point Load Index, I_S50 (MPa)	Field Guide
Very Low	**VL**	Less than 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with a knife; pieces up to 30mm thick can be broken by finger pressure.
Low	**L**	0.1 to 0.3	Easily scored with a knife; indentations 1mm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

Notes on Rock Substance Strength:

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

Rock Description Explanation Sheet (2 of 2)

COMMON DEFECTS IN ROCK MASSES

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

DEFECT SHAPE TERMS

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

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

ROUGHNESS TERMS

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

COATING TERMS

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

BLOCK SHAPE TERMS

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

Notes on Defects:

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

coffey geotechnics

Engineering Log - Borehole

Borehole No.	*BH 1*
Sheet	1 of 1
Project No:	*GEOTWARA20644AA*
Client:	*MONTEATH & POWYS PTY LTD*
Principal:	*STUART GREVILLE*
Project:	*PROPOSED SEVEN LOT SUBDIVISION, GLENDALE*
Borehole Location:	*REFER TO FIGURE 1*
Date started:	*24.1.2008*
Date completed:	*24.1.2008*
Logged by:	*GLV*
Checked by:	

drill model and mounting:	Hand Auger	Easting:		slope:	-90°	R.L. Surface:	
hole diameter:	100 mm	Northing		bearing:		datum:	

drilling information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa (100 200 300 400)	structure and additional observations
HA		N	None Observed					CL	FILL: Gravelly Sandy CLAY, low plasticity, light brown, fine to coarse grained sand, fine to medium grained angular gravel, trace sandstone cobbles.	M>Wp	VSt	×	TOPSOIL / FILL
								ML	**Sandy Gravelly SILT:** light brown-light grey, fine to medium grained sand, fine grained angular gravel, with some medium plasticity clay.	D	H	×	COLLUVIUM
						0.5		CI	**Sandy CLAY:** medium plasticity, light brown mottled red orange and red, fine to coarse grained sand.	M>Wp			RESIDUAL
						1.0			Terminated on Extremely Weathered Sandstone, hand auger refusal. Borehole BH 1 terminated at 0.5m				
						1.5							
						2.0							

BOREHOLE 20644AA LOGS.GPJ COFFEY.GDT 2.4.08

method

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

support

M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

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

notes, samples, tests

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

classification symbols and soil description
based on unified classification system

moisture

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

consistency/density index

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

Form GEO 5.3 Issue 3 Rev.2

coffey geotechnics

Borehole No.	BH 2
Sheet	1 of 1
Project No:	GEOTWARA20644AA

Engineering Log - Borehole

Client:	MONTEATH & POWYS PTY LTD	Date started:	24.1.2008
Principal:	STUART GREVILLE	Date completed:	24.1.2008
Project:	PROPOSED SEVEN LOT SUBDIVISION, GLENDALE	Logged by:	GLV
Borehole Location:	REFER TO FIGURE 1	Checked by:	

drill model and mounting:	Hand Auger	Easting:		slope:	-90°	R.L. Surface:	
hole diameter:	100 mm	Northing		bearing:		datum:	

drilling information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa (100 200 300 400)	structure and additional observations
HA		N	None Observed					MH	**Gravelly Sandy SILT:** light brown, fine to coarse grained, subrounded to angular gravels, fine grained sand.	M			TOPSOIL COLLUVIUM
								CI	**Sandy Silty CLAY:** medium plasticity, light brown mottled light orange, fine grained sand, trace of fine to medium grained angular gravels, trace of charcoal fine to medium grained sand.	M=Wp	St-VSt		COLLUVIUM
				Bs		0.5		CI-CH	**Sandy CLAY:** medium to high plasticity, orange mottled light brown, fine to medium grained sand.		VSt		RESIDUAL
									SANDSTONE: fine to medium grained, extremely weathered, light orange and light grey.				WEATHERED ROCK
									Terminated at Hand Auger Refusal. Borehole BH 2 terminated at 0.75m				
						1.0							
						1.5							
						2.0							

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

support
M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

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

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

classification symbols and soil description
based on unified classification system

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

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

coffey geotechnics

Engineering Log - Borehole

Borehole No. **BH 3**
Sheet 1 of 1
Project No: GEOTWARA20644AA

Client: MONTEATH & POWYS PTY LTD
Principal: STUART GREVILLE
Project: PROPOSED SEVEN LOT SUBDIVISION, GLENDALE
Borehole Location: REFER TO FIGURE 1

Date started: 24.1.2008
Date completed: 24.1.2008
Logged by: GLV
Checked by:

drill model and mounting: Hand Auger | Easting: | slope: -90° | R.L. Surface:
hole diameter: 100 mm | Northing | bearing: | datum:

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetrometer kPa (100 200 300 400)	structure and additional observations
HA		N	None Observed					SP	**Sandy SILT:** fine grained, light brown, some fine to medium grained angular to rounded gravel, trace of charcoal.	M			TOPSOIL
								CI	**Sandy CLAY:** medium plasticity, light brown mottled orange, fine to medium grained sand.	M=Wp	St		COLLUVIUM
				U_{50}				CI-CH	**CLAY:** medium to high plasticity, orange mottled light brown and red, trace of fine grained sand.		St/VSt		RESIDUAL
						0.5			**SANDSTONE:** (tuffaceous), fine grained, light grey and light brown.		H		EXTREMELY WEATHERED ROCK
									Hand auger refusal. Borehole BH 3 terminated at 0.55m				
						1.0							
						1.5							
						2.0							

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

support
M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

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

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

classification symbols and soil description
based on unified classification system

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

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

BOREHOLE 20644AA LOGS.GPJ COFFEY.GDT 2.4.08

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Engineering Log - Borehole

Borehole No. *BH 4*

Sheet 1 of 1

Project No: *GEOTWARA20644AA*

Client:	*MONTEATH & POWYS PTY LTD*	Date started:	*24.1.2008*
Principal:	*STUART GREVILLE*	Date completed:	*24.1.2008*
Project:	*PROPOSED SEVEN LOT SUBDIVISION, GLENDALE*	Logged by:	*GLV*
Borehole Location:	*REFER TO FIGURE 1*	Checked by:	

drill model and mounting:	Hand Auger	Easting:		slope:	-90°	R.L. Surface:	
hole diameter:	100 mm	Northing		bearing:		datum:	

drilling information | **material substance**

method	support	water	notes samples, tests, etc	RL	depth metres	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	structure and additional observations
HA	N	None Observed				ML	**Sandy SILT:** brown, fine to medium grained sand, some fine to medium grained angular to subrounded gravels.	M		TOPSOIL
						CL	**Silty Sandy CLAY:** low plasticity, light brown to light grey, fine to medium grained sand, trace of fine to medium grained angular gravels.	M=Wp	St	COLLUVIUM
			U50		0.5	CI-CH	**CLAY:** medium to high plasticity, light brown mottled orange, with some fine to medium grained angular gravel.			
						CI-CH	**CLAY:** medium to high plasticity, light brown-light grey mottled red, trace of fine grained sand, trace of angular gravel.		VSt	RESIDUAL
					1.0	CH	**CLAY:** high plasticity, light grey mottled red, orange.	M<Wp	VSt/H	
						CI	**Sandy CLAY:** light grey mottled red, medium plasticity, fine to medium grained sand.			
					1.5		**SANDSTONE:** (tuffaceous), fine grained, light grey.	D/M	H	EXTREMELY WEATHERED SANDSTONE
							Borehole BH 4 terminated at 1.5m			
					2.0					

pocket penetrometer kPa: 100 200 300 400

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

support
M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

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

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

classification symbols and soil description
based on unified classification system

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

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

Form GEO 5.3 Issue 3 Rev.2

BOREHOLE 20644AA LOGS.GPJ COFFEY.GDT 2.4.08

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Engineering Log - Borehole

Borehole No.	BH 5
Sheet	1 of 1
Project No:	GEOTWARA20644AA

Client:	MONTEATH & POWYS PTY LTD	Date started:	24.1.2008
Principal:	STUART GREVILLE	Date completed:	24.1.2008
Project:	PROPOSED SEVEN LOT SUBDIVISION, GLENDALE	Logged by:	GLV
Borehole Location:	REFER TO FIGURE 1	Checked by:	

drill model and mounting:	Hand Auger	Easting:		slope:	-90°	R.L. Surface:	
hole diameter:	100 mm	Northing		bearing:		datum:	

drilling information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
HA		N	None Observed					MH	Clayey SILT: brown, some fine to medium grained sand, trace of fine grained angular gravel.	M			TOPSOIL
								CI-CH	CLAY: medium to high plasticity, light brown mottled light orange, trace of fine to coarse grained sand, trace of fine grained angular gravel.	M=Wp	St	x	COLLUVIUM
				U50		0.5							
								CI	Sandy CLAY: medium plasticity, light brown-light grey, fine to coarse grained sand, trace of fine to medium grained angular gravel.	M<Wp	VSt	x	RESIDUAL
									Terminated at Hand Auger refusal on Extremely Weathered Sandstone. Borehole BH 5 terminated at 0.75m				
						1.0							
						1.5							
						2.0							

method		support		notes, samples, tests		classification symbols and soil description		consistency/density index	
AS	auger screwing*	M mud	N nil	U50	undisturbed sample 50mm diameter	based on unified classification system		VS	very soft
AD	auger drilling*	C casing		U63	undisturbed sample 63mm diameter			S	soft
RR	roller/tricone	penetration 1 2 3 4		D	disturbed sample			F	firm
W	washbore	no resistance ranging to refusal		N	standard penetration test (SPT)			St	stiff
CT	cable tool			N*	SPT - sample recovered	moisture		VSt	very stiff
HA	hand auger	water		Nc	SPT with solid cone	D	dry	H	hard
DT	diatube	10/1/98 water level on date shown		V	vane shear (kPa)	M	moist	Fb	friable
B	blank bit			P	pressuremeter	W	wet	VL	very loose
V	V bit			Bs	bulk sample	Wp	plastic limit	L	loose
T	TC bit	water inflow		E	environmental sample	W_L	liquid limit	MD	medium dense
*bit shown by suffix		water outflow		R	refusal			D	dense
e.g.	ADT							VD	very dense

BOREHOLE 20644AA LOGS.GPJ COFFEY.GDT 2.4.08

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Appendix B

Results of Laboratory Testing

FEB08-02

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

19 Warabrook Boulevard, Warabrook, NSW, 2304
Ph: (02) 4016 2300 Fax (02) 4016 2380

shrink swell index test

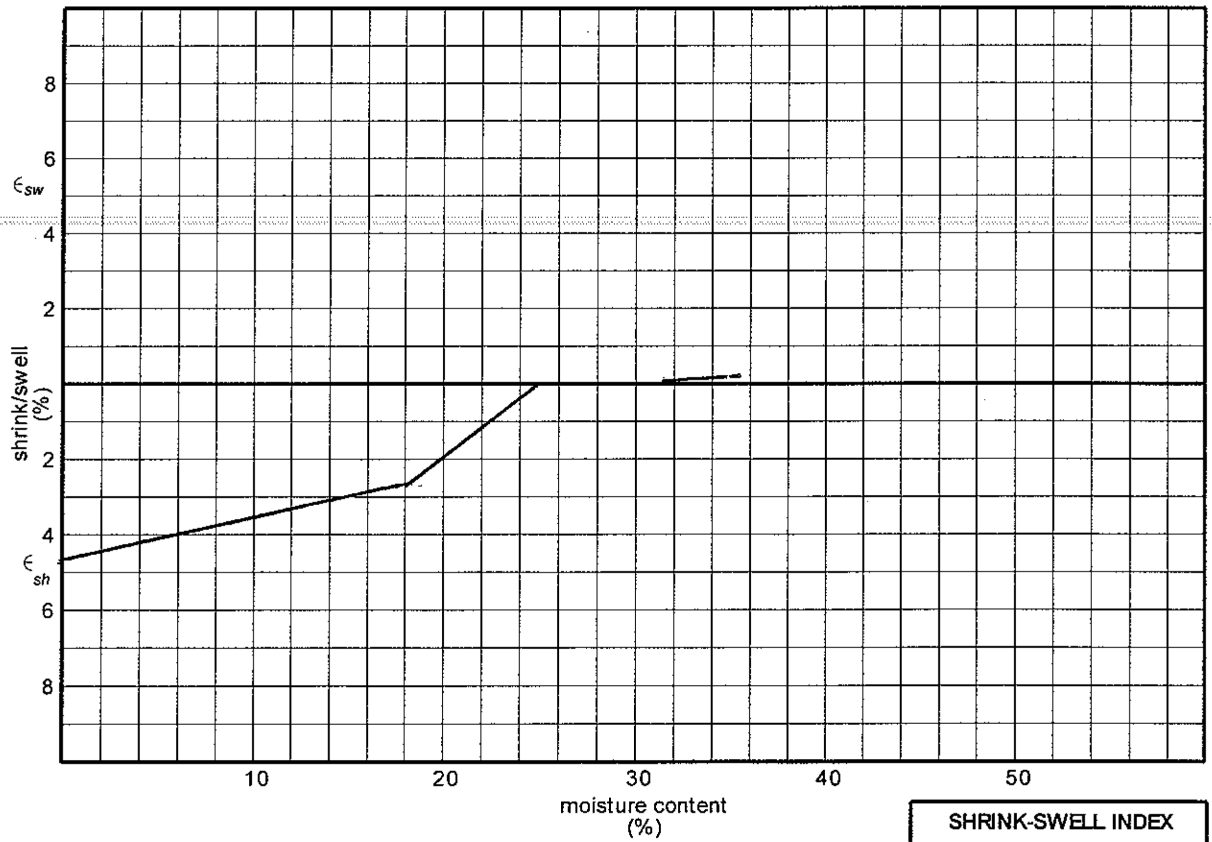
client :	*COFFEY GEOTECHNICS PTY LTD* *19 WARABROOK BOULEVARD NSW 2304*	job no :	*LABTWARA00506AA*
principal :	*MONTEATH & POWYS PTY LTD*	laboratory :	*NEWCASTLE*
project :	*GEOTWARA20644AA*	report date :	*February 08, 2008*
location :	*GLENDALE*	test report no. :	*FEB08-02*

test procedure : *AS1289 7.1.1 - 1998*

borehole : *BH 3* depth : *0.2-0.43* date tested : *30/01/08*

material classification :
(CH) CLAY, high plasticity, M> Wp, mottled brown / orange.

SWELL TEST					SHRINK TEST			
swell on saturation (%)	moisture content (%)		estimated unconfined compressive strength (kPa)		shrink on drying %	estimated inert material present %	extent of crumbling during shrinkage	extent of cracking during shrinkage
	before test	after test	before test	after test				
0.3	*30.8*	*35.6*	*300*	*180*	*4.7*	-	-	-



SHRINK-SWELL INDEX
I_{ss} = 2.7 %

remarks:

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NATA WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory No. 431

Date : *8 February 2008*

Approved Signatory: *Alan Cullen*

Form Number L4.6R1 Version 6.1

FEB08-02

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

19 Warabrook Boulevard, Warabrook, NSW, 2304
Ph: (02) 4016 2300 Fax (02) 4016 2380

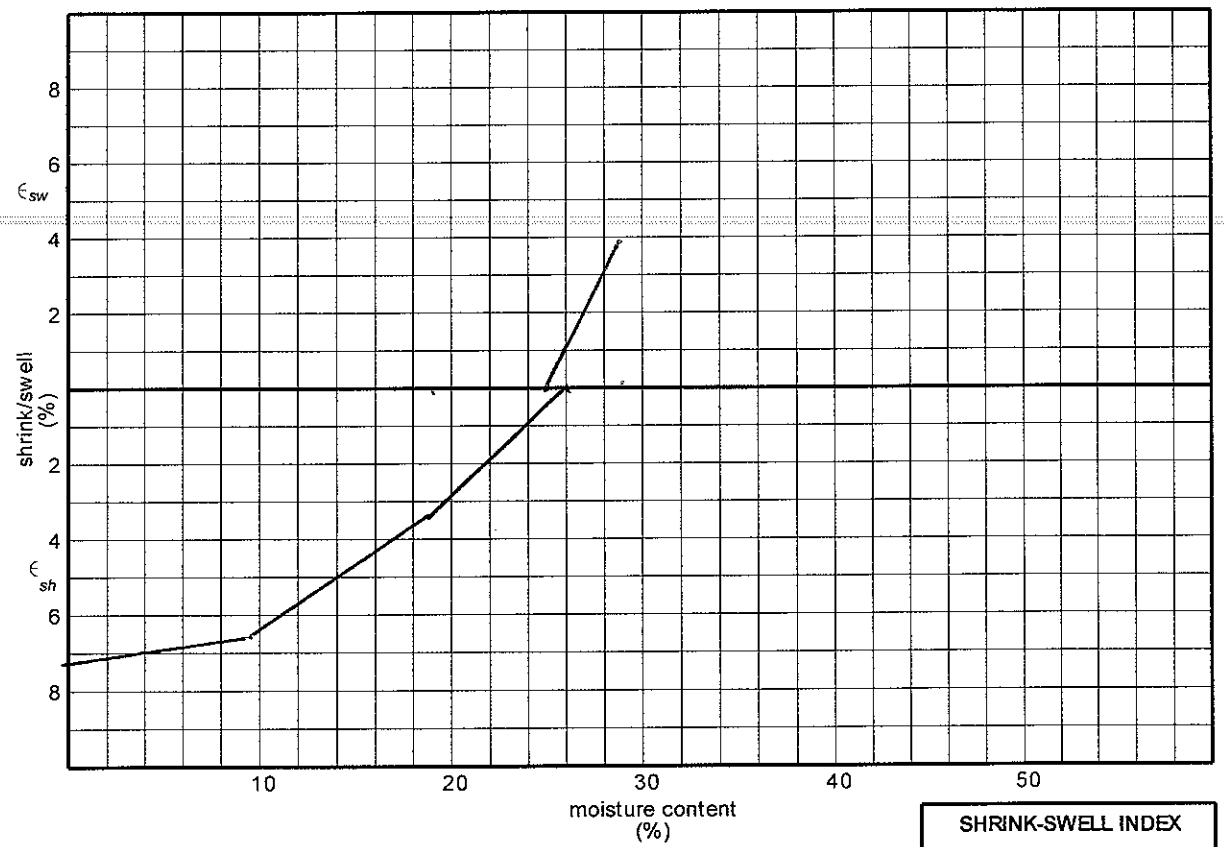
shrink swell index test

client :	COFFEY GEOTECHNICS PTY LTD 19 WARABROOK BOULEVARD NSW 2304	job no :	LABTWARA00506AA
principal :	MONTEATH & POWYS PTY LTD	laboratory :	NEWCASTLE
project :	GEOTWARA20644AA	report date :	February 08, 2008
location :	GLENDALE	test report no. :	FEB08-02

test procedure : AS1289 7.1.1 - 1998

borehole : BH 5 depth : 0.35-0.70 date tested : 30/01/08
material classification :
(CL-CH) CLAY, medium to high plasticity, M> Wp, brown.

SWELL TEST					SHRINK TEST			
swell on saturation (%)	moisture content (%)		estimated unconfined compressive strength (kPa)		shrink on drying %	estimated inert material present %	extent of crumbling during shrinkage	extent of cracking during shrinkage
	before test	after test	before test	after test				
3.9	25.0	28.9	280	180	7.2	-	-	-



SHRINK-SWELL INDEX
I_{ss} = 5.1 %

remarks:

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NATA
WORLD RECOGNISED ACCREDITATION

NATA Accredited Laboratory No. 431 Date : 8 February 2008
Approved Signatory:
Alan Cullen

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Warabrook, Newcastle Laboratory

Coffey Geotechnics Pty Ltd
ABN 93 056 929 483
Lot 101, 19 Warabrook Boulevard
Warabrook NSW 2304

Telephone: +61 2 4016 2300
Facsimile: +61 2 4016 2380

California Bearing Ratio

Report No: CBR:WARA08S-00486
Issue No: 1
This report replaces all previous issues of report no 'CBR:WARA08S-00486'.

Client:	Coffey Geotechnics (Warabrook) 19 Warabrook Boulevard Warabrook NSW 2304
Principal:	Monteath & powys Pty. Ltd.
Job No:	LABTWARA00506AA
Project:	GEOTWARA20644AA - Ellerdale Drive
Lot No:	**TRN:**

NATA
WORLD RECOGNISED ACCREDITATION

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Approved Signatory: Alan Cullen (Laboratory Manager)
NATA Accredited Laboratory Number: 431
Date of Issue: 6/02/2008

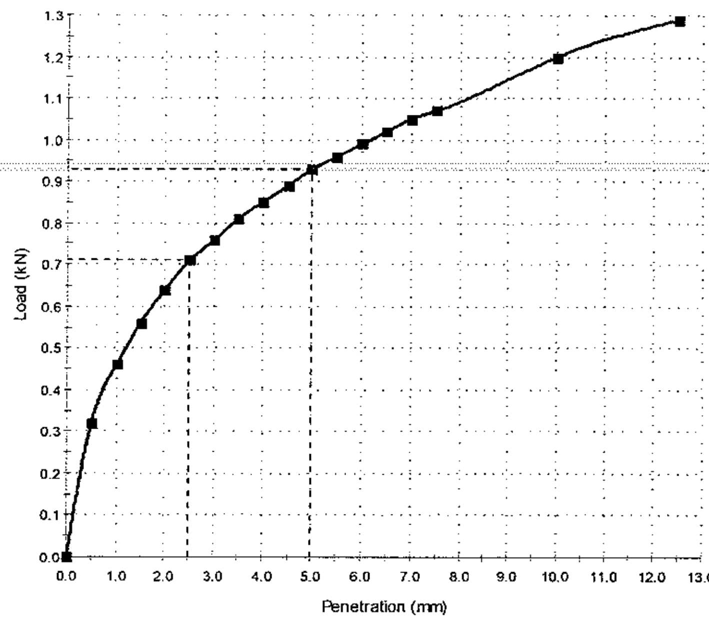
Sample Details

Product:	0.35 - 0.70m	**Date Sampled:**	25/01/2008
Source:	BH2	**Sampling Method:**	AS1289.1.2.1 Clause 6.4b
Location:	Glendale	**Sample ID:**	WARA08S-00486
Client Ref:	0001		

Test Results

Description	Result
Test Method	AS 1289.6.1.1
Maximum Dry Density (t/m³)	1.480
Optimum Moisture Content (%)	27.9
CBR 2.5mm (%)	**5.0**
CBR 5.0mm (%)	4.5
Preparation	Soaked
Initial Moisture Content (%)	29.4
Achieved Dry Density (t/m³)	1.451
Achieved Moisture Content (%)	29.4
Swell (%)	0.0
Moisture After Penetration (%)	31.3
Period of Soaking (days)	4
Moisture Content of Top 30mm (%)	31.4
Moisture of Penetrated End (%)	
Compaction Type	Standard
Surcharge Mass (kg)	4.50
Laboratory Moisture Ratio After Compaction (%)	105
Laboratory Density Ratio After Compaction (%)	98
Oversize Material Excluded	YES
Percent Oversize Excluded	0.0
Rate of Penetration	1.0

Chart



CBR (%): 5.0

Comments

(CH) Sandy CLAY - High Plasticity, Brown, Fine Sand
FMC = 28.3%