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AG-1756_1
23rd November 2024

RE: Site Classification at 43 Idaline Street, Collaroy Plateau, NSW, 2097

This letter presents a geotechnical report on the inspection and testing services associated with the geotechnical investigation undertaken at the above project.

Should you have any questions related to this report please do not hesitate to contact the undersigned.

For and on behalf of
Australian GeoEnviro Pty Ltd

N. Smith
Principal

Reviewed By

J. Lu
Geotechnical Engineer
M.Eng (Civil)

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APPENDICES

1. INTRODUCTION

Australian GeoEnviro Pty Ltd (AG) has prepared this report to discuss the results of the geotechnical investigation undertaken for the proposed new residential development at 43 Idaline Street, Collaroy Plateau, NSW, 2097 (herein referred to as the "site"). AG was engaged to provide a site classification in accordance with AS2870:2011, Residential Slabs and Footings, Standards Australia.

2. SITE DETAILS

The following information, presented in Table 1, describes the site.

Table 1: Summary of Site Details

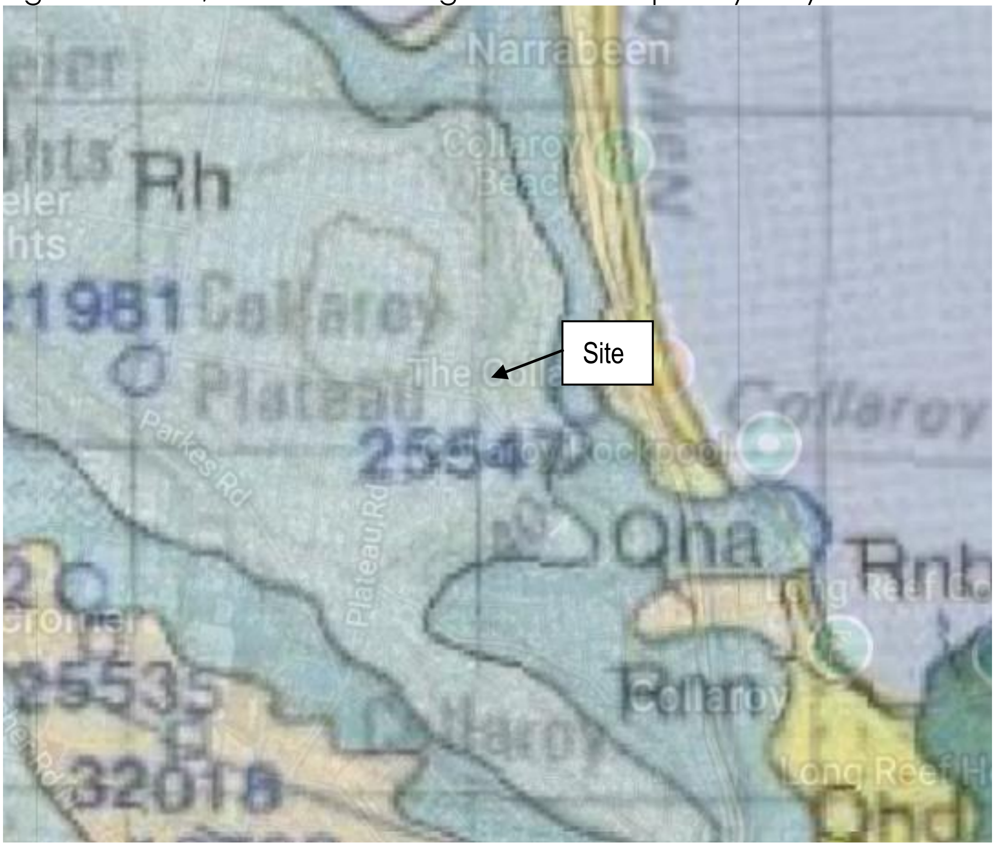
Site Address.	43 Idaline Street, Collaroy Plateau, NSW, 2097
Prepared For.	Vanguard Consulting Engineers
Council.	Northern Beaches

2.1 Geology

The Soil Landscape Series Sheet 9130lh, Scale 1:100,000, 2002, prepared by the Soil Conservation Service of NSW, indicates that the site is located within the Lucas Heights landscape which generally comprises: *Hawkesbury Sandstone, which is a medium to coarse-grained quartz sandstone with minor shale and laminite lenses.*

The 1:100,000 scale Geological Series Map of the Sydney region indicates that the subject site is underlain by Hawkesbury Sandstone (Rh), described as "*medium to coarse-grained quartz sandstone and very minor shale and laminate lenses*". Refer to figure 1 below;

Figure 1: 1:100,000 scale Geological Series Map of Sydney



3. GEOTECHNICAL INVESTIGATION

Fieldwork was undertaken on 18th November 2024 which included augering one (1) borehole using a trailer mounted solid flight auger with a TC-Bit attachment and one (1) borehole using a hand auger. Two (2) Dynamic Cone Penetrometers (DCP) were completed adjacent to the boreholes to aid in the assessment of in-situ soil conditions. Borehole log and field observations are presented in Appendix B.

3.1 Soil Profiles

The boreholes indicated that the soil profile generally comprised of the following;

- UNIT 1. Encountered between 0 – 500mm; FILL; Silty SAND, fine to medium grained, loose to medium dense, brown, dry.
- UNIT 2. Encountered between 400 – 1700mm; NATURAL, Clayey SAND, low plasticity, fine to medium grained sand, firm to stiff, yellow brown grey, moist.
- UNIT 2A. Encountered between 400 – 800mm (BH2 only); NATURAL, SAND, fine to medium grained sand, very loose, pale grey, trace silt, moist.
- UNIT 3. Encountered between 1300mm - 1700mm; SANDSTONE, distinctly weathered, low strength, fine to medium grained, grey. Bedrock inferred based on DCP penetration in borehole numbered BH2.

Groundwater seepage was not encountered during our investigation. However, it should be noted that no long-term ground water monitoring was conducted at the time of our investigation.

4. RECOMMENDATIONS

4.1 SITE CLASSIFICATION

Australian Standard AS 2870-2011 establishes performance requirements and specific designs for common foundation conditions as well as providing guidance on the design of footing systems using engineering principles. Site classifications as defined on Table 2.1 and 2.3 of AS2870 are presented on Table 2 below;

Table 2: Summary of Site Classifications AS2870

Site Classification	Foundation	**Characteristic Surface Movement**
A	Most sand and rock sites with little or no ground movement from moisture changes	
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes	0-20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	20-40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes	40-60mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes	60-75mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes	75mm+
A to P	Filled sites (refer to clause 2.4.6 of AS 2870)	
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.	

The lot in its existing condition and in the absence of abnormal moisture conditions would be classified as detailed in Table 3 below;

Table 3: Summary of Lot Classification

Site Location	Recommended Site Classification
43 Idaline Street, Collaroy Plateau, NSW, 2097	**Class P – Soft soils to approximately 1.0m below surface levels**

In accordance with the AS2870-2011, table D2. Footings and slabs founded on proven natural material should be designed in accordance with **Class "S"** as per AS2870:2011.

4.2 FOOTINGS – BEARING CAPACITY

Footings should be founded through any uncontrolled fill, silt, topsoil, slopewash, deleterious soils and founded into the natural sandstone bedrock. To minimise the effects of differential settlement under the building loads, this office recommends that all footings are founded into the bedrock of similar consistent. Recommended Pad Footing and Pile Design Parameters are outlined within Table 4 below;

Table 4 – Soil Parameters

Soil Type	Allowable Bearing Capacity (kPa)	Ultimate Vertical End Bearing Pressure (kPa)	Ultimate Shaft Adhesion in Compression (kPa)	Ultimate Shaft Adhesion in Tension (kPa)
Unit 1: FILL, Silty CLAY	N/A	N/A	0	0
Unit 2 and 2A: NATURAL, Silty SAND and SAND	N/A	N/A	0	0
Unit 3: SANDSTONE (low strength)	700	2,100	70	30

N/A – Not recommended for the proposed development

The quality of the founding stratum in all footing excavations is to be assessed by a geotechnical professional to confirm that the design parameters recommended in this report are appropriate. Footing excavations are to be cleaned out and inspected by a geotechnical professional prior to concrete placement. Concrete is to be placed within 24 hours of excavation, since the soils may deteriorate rapidly upon exposure.

It is also recommended that where piles penetrate expansive soils, which are susceptible to shrink and swell due to seasonal moisture, shaft adhesion be ignored due to the potential of shrinkage cracking.

4.3 FILLING

Where any filling is required, the following recommended compaction targets should be considered:

- Place horizontal loose layers not more than 300mm thickness over the prepared subgrade.
- Compact to a minimum dry density ratio not less than 98% of the maximum dry density for the building platforms.
- The moisture content during compaction should be maintained at ±2% of the Optimal Moisture Content (OMC).
- The upper 150mm of the subgrade should be compacted to a dry density ratio not less than 100% of the maximum dry density of 75% density index (DI).

Any soils which are imported onto the site for the purpose of filling and compaction of the excavated areas should be free of deleterious materials and contamination. The imported soils should also include appropriate validation documentation in accordance with current regulatory authority requirements. The design and construction of earthworks should be carried out in accordance with AS 3798-2007. Inspections of the prepared subgrade should be carried out by a geotechnical engineer, and should include proof rolling as a minimum. These inspections should be established as “Hold Points”.

4.4 SUBGRADE PREPARATION

The following are general recommendations on subgrade preparation for earthworks, slab on ground constructions and pavements:

- Remove existing fill and topsoil, including all materials which are unsuitable from the site.
- Excavate natural soils and rock.
- Excavated material may be used for engineered fill.
- Rock may be used for subgrade material underlying pavements.
- Any natural soils (predominately sandy soils) exposed at the bulk excavation level should be treated and have a moisture condition of 2% OMC. This should be followed by proof rolling and compaction of the upper 150mm layer.
- Any soft or loose areas should be removed and replaced with engineered or approved fill material.
- Any rock exposed at the bulk excavation level should be clear of any deleterious materials (and free of loose or softened materials). As a guideline, remove an additional 150mm from the bulk excavation level.
- Ensure the foundations and excavated areas are free of water prior to concrete pouring.
- Areas which show visible heaving under compaction or proof rolling should be excavated at least 300mm and replaced with engineered or approved fill, and compacted to a minimum dry density ratio not less than 98% of the maximum dry density or 75% density index (DI).

5.0 GENERAL RECOMMENDATIONS

5.1 Footing Design

- It is recommended that all footing excavations be inspected by a geotechnical engineer from AG to confirm that founding conditions are consistent with design recommendations. The footing size and the founding level may need to be adjusted, if required founding material is not encountered at the design founding level.

- To reduce soil moisture variations near the footings, the builder should compact clean soil (without rubble or organic matter) around the footings to minimize water ingress around the footings.

- To reduce, but not eliminate, the possibility of damage to the footing, tree planting should be restricted to a distance from the structures of 1 x mature height of the trees.

- Good drainage is an important part of any footing design. The builder should prevent water accumulation near the building footings (even during construction). It is recommended that sufficient ground clearance be created to accommodate paving which slopes a minimum of 1:20 away from the building. This slope should be achieved by excavation and not by building-up loose fill around the footings.

- The roof water should be diverted away from the footing as soon as the roof is constructed by using temporary pipes, if necessary. The surface water should also be provided by constructing surface gutters or grading the surface to divert the water away from the footing.

- Specific geotechnical advice should also be obtained for footing deigns and end bearing capacities, and design of the foundation system (shallow and pile foundations) should be carried out in accordance with AS 2870-2011 and AS 2159-2009.

- Any proposed footings which are close to an easement and/or other excavations, (including those in adjoining properties) should be founded below a line projected up at 30˚ to the horizontal (for Sand) and 40˚ to the horizontal (for firm/stiff Clay) and measured from the nearest base of the easement excavations.

- Avoid excavations close to footings since those founded on sandy soils can experience settlements while those founded in clayey soils can also move due to the shrinking and swelling of the clay. Plumbers and drainers should follow all the recommendations made in AS 2870 and other appropriate codes with respect to drainage works.

- All batter slopes within the site should remain stable providing all surcharge and construction loads are kept out of the "zone of influence" (obtained by drawing a line 45º above horizontal from the base of the proposed excavation walls) plus an additional 1.0m. A geotechnical engineer or engineering geologist should inspect the batter slopes within the site.

6.0 CONDITIONS OF THE RECOMMENDATIONS

The adopted investigation scope was limited by site access restrictions due to presence of structures at the site at the time of our investigation and by the investigation intent. Further geotechnical inspections should be carried out during construction to confirm both the geotechnical model and the design parameters provided in this report.

Your attention is drawn to the document "Important Information", which is included in Appendix D of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Australian GeoEnviro Pty Ltd, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

7.0 REFERENCES

- AS2870 (2011), Residential Slab and Footings – Construction
- AS1726:2017, Geotechnical Site Investigations, Standards Australia.
- AS2159:2009, Piling – Design and Installation, Standards Australia.
- AS2870:2011, Residential Slabs and Footings, Standards Australia.
- AS3798:2007, Guidelines on Earthworks for Commercial and Residential Developments, Standards Australia
- NSW Department of Finance and Service, Spatial Information Viewer, maps.six.nsw.gov.au.
- 1:100,000 scale Geological Series Map of the Sydney Region

APPENDIX A

FIGURES

Figure 1: BOREHOLE LOCATION PLAN

Approximate Test Locations

Source: Sketch plans prepared by Sixmaps

AUSTRALIAN GEOENVIRO	Client: Vanguard Consulting Engineers	Project Name: Proposed Development	Report No: AG-1756_1	N	Figure No: Figure 2	Figure Title: Borehole Locations
		Project Address: 43 Idaline Street, Collaroy Plateau, NSW, 2097	Figure Date: 25/11/24			

APPENDIX B

BOREHOLE LOGS

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Geotechnical Log - Borehole

BH1

UTM	: 31N	**Drill Rig**	: trailer mounted 100mm solid flight auger	**Job Number**	: AG1756
Easting (m)	: 166,021.44	**Driller Supplier**	: AP Smith	**Client**	: Vanguard Consulting Engineers
Northing (m)	: 0.00	**Logged By**	: NS	**Project**	: Proposed Development
Ground Elevation	: -3492.00 (m)	**Reviewed By**	: NS	**Location**	: 43 Idaline Street, Collaroy Plateau NSW
Total Depth	: 1.8 m BGL	**Date**	: 18/11/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Weathering	Moisture	Material Description	Consistency	Testing: New Child Column
			Fill		SM		D	Fill Silty SAND SM: loose to medium dense, brown, fine to medium grained, dry.	L-MD	0, 0, 0, 0, 1
		1	Natural		SC		M	Natural Clayey SAND SC: low to medium plasticity clay, yellow brown, fine to medium grained, moist.		1, 0, 2, 6, 3, 5
					SC			Natural Clayey SAND SC: medium plasticity clay, grey brown, fine to medium grained, moist.		9, 14, 14, 5, 4, Bouncing
			Rock		SST	DW	D	Rock SANDSTONE: distinctly weathered, low strength, grey, fine to medium grained, dry.	LS	
		2						**BH1 refusal at 1.8m**		
		3								

Water

- Water inflow
- Water outflow
- Ground water Level during drilling

Weathering

- **XW** : Extremely weathered
- **DW** : Distinctly weathered
- **HW** : Highly weathered
- **MW** : Moderately weathered
- **SW** : Slightly weathered
- **FR** : Fresh

Altering

- **XA** : Extremely altered
- **DA** : Distinctly altered
- **HA** : Highly altered
- **MA** : Moderately altered
- **SA** : Slightly altered

Consistency

- **VS** : Very soft
- **S** : Soft
- **F** : Firm
- **St** : Stiff
- **VSt** : Very stiff
- **H** : Hard
- **FR** : Friable

Moisture

- **D** : Dry
- **M** : Moist
- **W** : Wet

Density

- **VL** : Very loose
- **L** : Loose
- **MD** : Medium dense
- **D** : Dense
- **VD** : Very dense

Rock Strength

- **VLS** : Very low
- **LS** : Low
- **MS** : Medium
- **HS** : High
- **VH** : Very high
- **XH** : Extremely high

Tests&Results

- **U50** : Undisturbed 50mm diam tube.
- **D** : Disturbed sample.
- **SPT** : Standard Penetration Test, N = number of blows to drive 50mm sampler 300mm with a 63.6kg hammer falling 762mm.
- **PP** : Hand penetrometer estimate of unconfined compressive strength, kPa.
- **S** : Vane shear value kPa.
- **DCP** : Dynamic Cone Penetrometer test.

Australian Geoenviro
PO Box 4153, Denistone East, NSW, 2112
Phone: 0403904030

Geotechnical Log - Borehole

BH2

UTM	**: 31N**	**Drill Rig**	**: Hand Auger**	**Job Number**	**: AG1756**
Easting (m)	**: 166,021.44**	**Driller Supplier**	**: Example supplier**	**Client**	**: Vanguard Consulting Engineers**
Northing (m)	**: 0.00**	**Logged By**	**: NS**	**Project**	**: Proposed Development**
Ground Elevation	**: -3492.00 (m)**	**Reviewed By**	**: NS**	**Location**	**: 43 Idaline Street, Collaroy Plateau NSW**
Total Depth	**: 1 m BGL**	**Date**	**: 18/11/2024**	**Loc Comment**	**:**

Drilling Method	Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Weathering	Moisture	Material Description	Consistency	Testing: New Child Column
			Fill		SM		M	Fill Silty SAND SM: very loose, brown, fine to medium grained, moist.	VL	0, 0, 0, 0
			Natural		SW			Natural SAND SW: very loose, pale grey, fine to medium grained, trace low plasticity silt, moist.		0, 0, 0, 0
					SC			Natural Clayey SAND SC: loose to medium dense, low plasticity clay, pale grey, fine to medium grained, moist.	L-MD	2, 2
		2, 3						**BH2 Terminated at 1m**		3, 6, Bouncing

Water
- Water inflow
- Water outflow
- Ground water Level during drilling

Weathering
- **XW** : Extremely weathered
- **DW** : Distinctly weathered
- **HW** : Highly weathered
- **MW** : Moderately weathered
- **SW** : Slightly weathered
- **FR** : Fresh

Altering
- **XA** : Extremely alterated
- **DA** : Distinctly alterated
- **HA** : Highly alterated
- **MA** : Moderately alterated
- **SA** : Slightly alterated

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- **VS** : Very soft
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- **D** : Dry
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- **W** : Wet

Density
- **VL** : Very loose
- **L** : Loose
- **MD** : Medium dense
- **D** : Dense
- **VD** : Very dense

Rock Strength
- **VLS** : Very low
- **LS** : Low
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- **HS** : High
- **VH** : Very high
- **XH** : Extremely high

Tests&Results
- **U50** : Undisturbed 50mm diam tube.
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- **SPT** : Standard Penetration Test, N = number of blows to drive 50mm sampler 300mm with a 63.6kg hammer falling 762mm.
- **PP** : Hand penetrometer estimate of unconfined compressive strength, kPa.
- **S** : Vane shear value kPa.
- **DCP** : Dynamic Cone Penetrometer test.

APPENDIX C

CSIRO - FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

Foundation Maintenance and Footing Performance: A Homeowner's Guide

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).

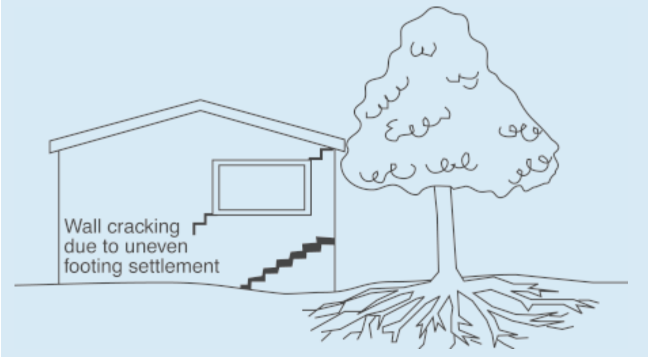
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

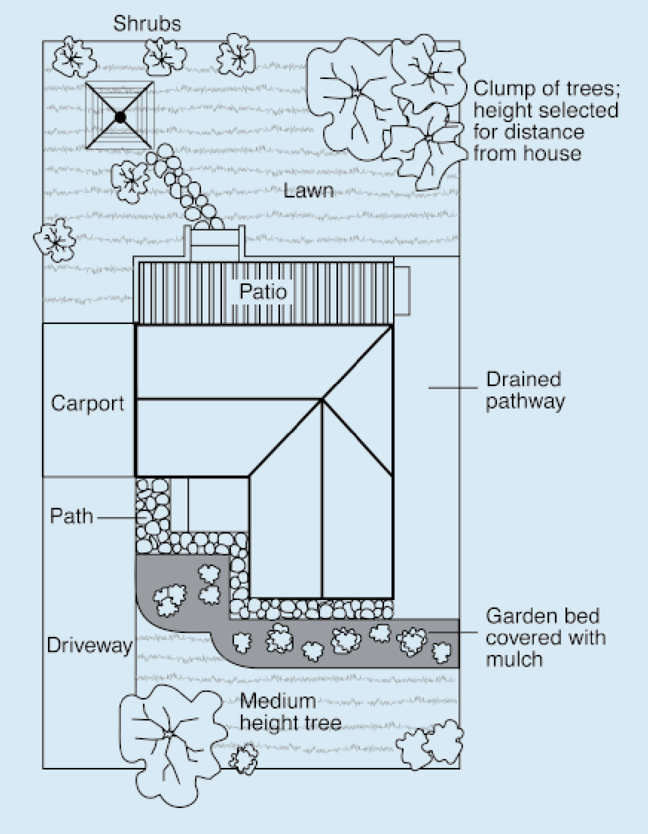
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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APPENDIX D

IMPORTANT INFORMATION

Important Information

SCOPE OF SERVICES

The geotechnical report ("the report") has been prepared in accordance with the scope of services as set out in the contract, or as otherwise agreed, between the Client and Australian GeoEnviro Pty Ltd (Aus Geo). The scope of work may have been limited by a range of factors such as time, budget and access.

RELIANCE ON DATA

Aus Geo has relied on data provided by the Client and other individuals and organizations, to prepare the report. Such data may include surveys, analyses, designs, maps and plans. Aus Geo has not verified the accuracy or completeness of the data except as stated in the report. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations ("conclusions") are based in whole or part on the data, Aus geo will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Aus Geo.

GEOTECHNICAL ENGINEERING

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared for a specific client, for a specific project and to meet specific needs, and may not be adequate for other clients or other purposes (e.g. a report prepared for a consulting civil engineer may not be adequate for a construction contractor). The report should not be used for other than its intended purpose without seeking additional geotechnical advice. Also, unless further geotechnical advice is obtained, the report cannot be used where the nature and/or details of the proposed development are changed.

LIMITATIONS OF SITE INVESTIGATION

The investigation programme undertaken is a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions. The data derived from the site investigation programme and subsequent laboratory testing are extrapolated across the site to form an inferred geological model, and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation, the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies. The engineering logs are the subjective interpretation of subsurface conditions at a particular location and time, made by trained personnel. The actual interface between materials may be more gradual or abrupt than a report indicates.

SUBSURFACE CONDITIONS ARE TIME DEPENDENT

Subsurface conditions can be modified by changing natural forces or man-made influences. The report is based on conditions that existed at the time of subsurface exploration. Construction operations adjacent to the site, and natural events such as floods, or ground water fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. Aus Geo should be kept appraised of any such events, and should be consulted to determine if any additional tests are necessary.

VERIFICATION OF SITE CONDITIONS

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that Aus Geo be notified of any variations and be provided with an opportunity to review the recommendations of this report. Recognition of change of soil and rock conditions requires experience and it is recommended that a suitably experienced geotechnical engineer be engaged to visit the site with sufficient frequency to detect if conditions have changed significantly.

REPRODUCTION OF REPORTS

This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of this Company. 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 minimize the likelihood of misinterpretation from logs.

REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the Client and no other party. Aus Geo assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Aus Geo or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

OTHER LIMITATIONS

Aus Geo will not be liable to update or revise the report to take into account any events or emergent circumstances or fact occurring or becoming apparent after the date of the report.

EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

GENERAL

Information obtained from site investigations is recorded on log sheets. The "Cored Drill Hole Log" presents data from an operation where a core barrel has been used to recover material - commonly rock. The "Non-Core Drill Hole - Geological Log" presents data from an operation where coring has not been used and information is based on a combination of regular sampling and insitu testing. The material penetrated in non-core drilling is commonly soil but may include rock. The "Excavation - Geological Log" presents data and drawings from exposures of soil and rock resulting from excavtion of pits, trenches, etc.

The heading of the log sheets contains information on Project Identification, Hole or Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material substance description and structure presented as a series of columns in relation to depth below the ground surface which is plotted on the left side of the log sheet. The common depth scale is 8m per drill log sheet and about 3-5m for excavation logs sheets.

As far as is practicable the data contained on the log sheets is factual. Some interpretation is inevitable in the identification of material boundaries in areas of partial sampling, the location of areas of core loss, description and classification of material, estimation of strength and identification of drilling induced fractures. Material description and classifications are based on SAA Site Investigation Code AS 1726 - 1993 with some modifications as defined below.

These notes contain an explanation of the terms and abbreviations commonly used on the log sheets.

DRILLING

Drilling & Casing

AS	Auger Screwing
AD/V	Auger Drilling with V-Bit
AD/T	Auger Drilling with TC Bit
WB	Wash-bore drilling
RR	Rock Roller
NMLC	NMLC core barrel
NQ	NQ core barrel
HMLC	HMLC core barrel
HQ	HQ core barrel

Drilling Fluid/Water

The drilling fluid used is identified and loss of return to the surface estimated as a percentage.

Drilling Penetration/Drill Depth

Core lifts are identified by a line and depth with core loss per run as a percentage. Ease of penetration in non-core drilling is abbreviated as follows:

VE	Very Easy
E	Easy
F	Firm
H	Hard
VH	Very Hard

Groundwater Levels

Date of measurement is shown.

▼ Standing water level measured in completed borehole

▽ Level taken during or immediately after drilling

Samples/Tests

D	Disturbed
U	Undisturbed
C	Core Sample
SPT	Standard Penetration Test
N	Result of SPT (*sample taken)
VS	Vane Shear Test
IMP	Borehole Impression Device
PBT	Plate Bearing Test
PZ	Piezometer Installation
HP	Hand Penetrometer Test

EXCAVATION LOGS

Explanatory notes are provided at the bottom of drill log sheets. Information about the origin, geology and pedology may be entered in the "Structure and other Observations" column. The depth of the base of excavation (for the logged section) at the appropriate depth in the "Material Description" column. Refusal of excavation plant is noted should it occur. A sketch of the exposure may be added.

MATERIAL DESCRIPTION - SOIL

Classification Symbol - In accordance with the Unified Classification System (AS 1726-1993, Appendix A, Table A1)

Material Description - In accordance with AS 1726-1993, Appendix A2.3

Moisture Condition

D	Dry, looks and feels dry
M	Moist, No free water on remoulding
W	Wet, free water on remoulding

Consistency - In accordance with AS 1726-1993, Appendix A2.5

VS	Very Soft	< 25kPa
S	Soft	25 - 50kPa
F	Firm	50 - 100kPa
St	Stiff	100 - 200kPa
VSt	Very Stiff	200 - 400kPa
H	Hard	≥ 400kPa

Strength figures quoted are the approximate range of Unconfined Compressive Strength for each class.

Density Index. (%) is estimated or is based on SPT results. Approximate N Value correlation is shown in right column.

VL	Very Loose	< 15%	0 - 4
L	Loose	15 - 35%	4 - 10
MD	Medium Dense	35 - 65%	10 - 30
D	Dense	65 - 85%	30 - 50
VD	Very Dense	> 85%	> 50

MATERIAL DESCRIPTION -ROCK

Material Description

Identification of rock type, composition and texture based on visual features in accordance with AS 1726-1993, Appendix A3.1-A3.3 and Tables A6a, A6b and A7.

Core Loss

Is shown at the bottom of the run unless otherwise indicated.

Bedding

Description	Spacing (mm)
Thinly Laminated	< 6
Laminated	6 - 20
Very Thinly Bedded	20 - 60
Thinly Bedded	60 - 200
Medium Bedded	200 - 600
Thickly Bedded	600 - 2000
Very Thickly Bedded	> 2000

Weathering - No distinction is made between weathering and alteration. Weathering classification assists in identification but does not imply engineering properties.

Fresh (F)	Rock substance unaffected by weathering
Slightly Weathered (SW)	Rock substance partly stained or discoloured. Colour and texture of fresh rock recognisable.
Moderately Weathered (MW)	Staining or discolouration extends throughout rock substance. Fresh rock colour not recognisable.
Highly Weathered (HW)	Stained or discoloured throughout. Signs of chemical or physical alteration. Rock texture retained.
Extremely Weathered (EW)	Rock texture evident but material has soil properties and can be remoulded.

Strength - The following terms are used to described rock strength:

Rock Strength Class	Abbreviation	Point Load Strength Index, Is(50) (MPa)
Extremely Low	EL	< 0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	≥ 10

Strengths are estimated and where possible supported by Point Load Index Testing of representative samples. Test results are plotted on the graphical estimated strength by using:

° Diametral Point Load Test

• Axial Point Load Test

Where the estimated strength log covers more than one range it indicates the rock strength varies between the limits shown.

MATERIALS STRUCTURE/FRACTURES

ROCK

Natural Fracture Spacing - A plot of average fracture spacing excluding defects known or suspected to be due to drilling, core boxing or testing. Closed or cemented joints, drilling breaks and handling breaks are not included in the Natural Fracture Spacing.

Visual Log - A diagrammatic plot of defects showing type, spacing and orientation in relation to core axis.

Defects	————	Defects open in-situ or clay sealed
	- - - - - - -	Defects closed in-situ
	....	Breaks through rock substance

Additional Data - Description of individual defects by type, orientation, in-filling, shape and roughness in accordance with AS 1726-1993, Appendix A Table A10, notes and Figure A2.

Type	BP	Bedding Parting
	JT	Joint
	SM	Seam
	FZ	Fracture Zone
	SZ	Shear Zone
	VN	Vein
	FL	Foliation
	CL	Cleavage
	DL	Drill Lift
	HB	Handling break
	DB	Drilling break

Orientation - angle relative to the plane normal to the core axis.

Infilling	CN	Clean
	X	Carbonaceous
	Clay	Clay
	KT	Chlorite
	CA	Calcite
	Fe	Iron Oxide
	Qz	Quartz
	MS	Secondary Mineral
	MU	Unidentified Mineral
Shape	PR	Planar
	CU	Curved
	UN	Undulose
	ST	Stepped
	IR	Irregular
	DIS	Discontinuous
Roughness	POL	Polished
	SL	Slickensided
	S	Smooth
	RF	Rough
	VR	Very Rough

SOIL

Structures - Fissuring and other defects are described in accordance with AS 1726-1993, Appendix A2.6, using the terminology for rock defects.

Origin - Where practicable an assessment is provided of the probable origin of the soil, eg fill, topsoil, alluvium, colluvium, residual soil.