GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for ______________________________

Name of Applicant

Address of site 2 Bruce Street Mona Vale

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, **LACHLAN TAYLOR** *on behalf of* **TAYLOR GEOTECHNICAL ENGINEERING PTY LIMITED**
(Insert Name) (Trading or Company Name)

on this the **1 June 2020** certify that I am a geotechnical engineer ~~or engineering geologist or coastal engineer~~ as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

- ■ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ☐ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- ☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.
- ☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: **TGE22026 Report on Geotechnical Investigation 2 Bruce Street Mona Vale**

Report Date: **1 June 2020**
:
Author: **Lachlan Taylor**

Author's Company/Organisation: **Taylor Geotechnical Engineering Pty Limited**

Documentation which relate to or are relied upon in report preparation:

Robert Jones Architects construction certificate plans, Drawing No. CC01 to CC05 dated December 2019
SDG Land Development Solutions Survey Plan Ref. 8115 Issue A dated 12 March 2020

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ....

Name ...**LACHLAN TAYLOR**..

Chartered Professional Status **CPEng MIEAust NER**.........

Membership No. **2145895**...

Company...**Taylor Geotechnical Engineering Pty Limited**

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for____
Name of Applicant

Address of site **2 Bruce Street Mona Vale**

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: **TGE22026 Report on Geotechnical Investigation 2 Bruce Street Mona Vale**
Report Date: **1 June 2020**
Author: **Lachlan Taylor**
Author's Company/Organisation: Taylor Geotechnical Engineering Pty Limited

Please mark appropriate box

- ☐ Comprehensive site mapping conducted ______________ (date)
- ☐ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ■ Subsurface investigation required
  - ☐ No Justification ……………………………………………………..
  - ■ Yes Date conducted **1 June 2020**

Geotechnical model developed and reported as an inferred subsurface type-section
Geotechnical hazards identified

  - ■ Above the site
  - ■ On the site
  - ■ Below the site
  - ■ Beside the site
- ■ Geotechnical hazards described and reported
- ■ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  - ■ Consequence analysis
  - ■ Frequency analysis
- ■ Risk calculation
- ■ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
- ■ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
- ■ Design Life Adopted:
  - ■ 100 years
  - ☐ Other ……………………………………………… specify
- ■ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
- ■ Additional action to remove risk where reasonable and practical have been identified and included in the report.
- ☐ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ……………………………………………………………

Name … **LACHLAN TAYLOR** ………………………………….

Chartered Professional Status…**CPEng MIEAust NER** …

Membership No. …**2145895**………………………………

Company… **Taylor Geotechnical Engineering Pty Limited**

REPORT ON GEOTECHNICAL INVESTIGATION

PROPOSED RESIDENTIAL DEVELOPMENT

2 BRUCE STREET MONA VALE

CLIENT: ADAM KIBBLE & ROSIE BURTON

PROJECT: TGE22026

DATE: 1 JUNE 2020

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Taylor Geotechnical Engineering
Geotechnical Civil Engineers & Project Managers
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taylorgeotech@bigpond.com *Mobile: 0407 984 128*

LRT
Report TGE22026
1 June 2020

REPORT ON GEOTECHNICAL INVESTIGATION
PROPOSED RESIDENTIAL DEVELOPMENT
2 BRUCE STREET MONA VALE

1. INTRODUCTION

This report details the results of a geotechnical investigation undertaken on the site of proposed residential development at 2 Bruce Street Mona Vale. Robert Jones Architects, requested the investigation on behalf of Adam Kibble & Rosie Burton, property owners. The investigation was carried out by Taylor Geotechnical Engineering Pty Limited on 1st June 2020 in accordance with Proposal tgeP2011 dated 18th May 2020.

The proposed development comprises alterations and additions to the existing residence including converting the existing garage into a games room and storage room, construction of a new carport and an inground swimming pool. The aim of the investigation was to provide information on subsurface and site conditions for assessment of geotechnical risk and to assist with planning and design.

The investigation comprised visual and photographic survey and inspection of exposed strata, drilling of test bores, in-situ testing of the subsurface strata and engineering assessment and analysis. Details of the fieldwork are given in the report, together with comments relating to design and construction practice.

2. SITE DESCRIPTION

The site is located on the western side of Bruce Street in Mona Vale and consists of a single block with an area of approximately 547.7 m^2 and the shape and dimensions as shown on Drawing 1 in Appendix 1. It is located atop a cliff line overlooking Warriewood Beach. Ground slopes fall to the south and east, with average ground slopes of approximately 3 degrees across the site. The site viewed from Bruce Street is shown in Photo 1 in Appendix 3. A concrete driveway is located in the north eastern section of the site leading to a double garage that constitutes the north eastern section of the residence (see Photo 2).

Bruce Street bounds the site to the east, Narrabeen Park Parade to the west, south west and south and neighbouring properties to the north. An existing two storey weatherboard residence is located centrally on the site with a grassed level yard located across the southern section of the site and a grassed yard located in the north western section of the site where the pool is to be located, (shown in Photos 3 & 4).

Reference to the Sydney 1:100,000 Geological Sheet indicates that the site is underlain by the Newport Formation from the Narrabeen Group, of the Triassic Period. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic-quartz sandstone. The rocks of this formation typically weather to form moderately reactive sandy and silty clay soils but highly reactive clay soils are possible.

The geological mapping was confirmed with weathered siltstone encountered at relatively shallow depth in the test bores.

3. FIELD WORK METHODS

The field work for this investigation comprised drilling of two test bores, insitu testing of the sub-surface strata and a geotechnical inspection and photographic survey of the site, detailing the location of any geological features or hazards that may affect site stability and pose an unacceptable risk of landslide or instability.

Dynamic penetrometer tests (DPT's) were conducted at each bore location, testing from the surface to a maximum depth of 2.4 m or prior refusal. The penetrometers were conducted in order to determine the depth to bedrock (if within 2.4 m) and provide an estimate of the strength of the near surface strata. The DPT's were conducted in accordance with test method AS1289.6.3.2.

4. FIELD WORK RESULTS

Details of the conditions encountered in the test bores are given in the test bore report sheets in Appendix 2 and are summarised below. The bores were drilled with a 100 mm diameter hand auger to depths of 0.6 m to 1.15 m. The location of the test bores and DPT's are shown on Drawing 1 – Site Plan, in Appendix 1 with Bore 1 located in the approximate position of the proposed carport and Bore 2 located in the location of the proposed inground swimming pool.

The sub-surface conditions encountered in the bores was relatively similar with each bore summarised as follows:

Bore 1 encountered topsoil consisting of silty sand to a depth of 0.1 m underlain by stiff silty clay to 0.3 m then extremely low strength siltstone. The test bore was terminated at a depth of 0.6 m due to auger refusal on the siltstone.

Bore 2 encountered topsoil consisting of silty sand to a depth of 0.15 m underlain by firm silty clay to 0.4 m then stiff silty clay to 1.0 m where extremely low strength siltstone was encountered. The test bore was terminated at a depth of 1.15 m due to auger refusal on the siltstone.

The results of the DPT's indicate that the natural clay soils underlying the front section of the site are generally in a dry stiff condition above the upper horizon of the weathered rock profile while the clays in the rear sections of the site are firm becoming stiff above the upper horizon of the weathered rock profile which underlies the site at a depth of approximately 1.0 m over the building footprint area for the swimming pool and less than 0.5 m in the area for the proposed carport.

Groundwater was not observed in the bores at the time of the investigation but allowance should be made for runoff and groundwater seepage during construction due to local topographic conditions, should rain events be experienced during the construction period.

No rock outcrops were observed on the site or on the adjacent sites to the north.

5. PROPOSED DEVELOPMENT

It is understood that the proposed development comprises alterations and additions to the existing residence including converting the existing garage into a games room and storage room, construction of a new carport and an inground swimming pool. Reference to Robert Jones Architects construction certificate plans, Drawing No. CC01 to CC05 dated December 2019 indicates that the new carport floor level will be at RL 33.2 and the in-ground swimming pool will be 1.5 m deep.

6. COMMENTS

6.1 Inferred Geological Profile

The results of the field work and knowledge gained from previous work in the area indicates that the geological profile underlying the site consists of sandy topsoils and clays over a shallow bedrock profile consisting of fine grained sandstone, siltstone and shale from the Newport Formation within the Narrabeen Group. The results of the field work indicate that the upper horizon of the weathered bedrock profile is approximately 1.0 m below the existing ground surface levels across the proposed building platform area for the pool and less than 0.5 m for the carport area.

6.2 Stability Risk Assessment

The results of the geotechnical investigation indicated that there is no evidence of recent instability (over the design life of the current development) and that currently there are no landslide hazards that would pose an unacceptable risk to property or life. It is expected that the proposed development will be constructed in a manner that will not increase the risk of instability to this or any adjoining sites. This will involve the control of stormwater and provision of adequate shoring measures (if required) for proposed excavations.

Assessment of the site has been made in accordance with the methods and requirements as outlined by the Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group paper titled 'Practice Note Guidelines for Landslide Risk Management 2007', and Northern Beaches Council's Geotechnical Risk Management Policy.

6.3 Excavation

Excavation of approximately 1.2 m will be required for construction of the carport and approximately 1.7 m for construction of the inground swimming pool. Based on the results of the field work, it is expected that the materials encountered within this depth range will consist of natural silty clay soils and weathered extremely low and very low strength siltstone and possibly sandstone bedrock that are usually readily excavated using conventional earthmoving equipment such as an excavator fitted with a digging bucket. It is possible that some low strength bands or medium strength ironstone bands may be encountered that may require the use of small rock breaker equipment.

If excavation faces are not to be retained they should be trimmed to a gradient that will ensure stability in both the short term during construction and the long term over the design life. The following table lists suggested batter slopes for materials likely to be encountered during excavation.

Table 1 - Batter Slopes

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	Long Term/ Permanent
Compacted filling	1.5:1	2.5:1
Sandy and clayey soils	1.5:1	2:1
Clayey Sandstone (extremely low strength)	1:1	1.5:1
Sandstone / Siltstone (very low & low strength)	0.5:1	0.75:1 *
Sandstone / Siltstone (medium or higher strength)**	Vertical *	0.25:1 *

* Dependent upon jointing and the absence of unfavourably oriented joints
** Unlikely to be encountered within the depth of excavation.

6.4 Foundations

The results of the field work indicate that weathered bedrock is at relatively shallow depth below the existing ground surface levels and will be exposed at the excavation level for the carport and pool and as such any new foundations for the development should be founded within the bedrock. It is recommended that shallow bored piers, founding in the weathered siltstone or sandstone bedrock, be used to support the inground swimming pool and conventional strip footings be used for the carport with the foundations dimensioned based on founding in at least very low strength sandstone / siltstone, with an allowable bearing pressure (for serviceability) of 600 kPa, increasing to 1000 kPa if founded in low strength sandstone / siltstone. Settlement is expected to be less than 1% of the footing width for footings founded in sandstone bedrock.

A geotechnical engineer should inspect and verify the founding strata for any new footings at the time of construction.

Some additional information on performance and maintenance of footings for residential developments is given in CSIRO BTF 18 which is enclosed in Appendix 4.

6.5 Retaining Walls

Where space limitations preclude the battering of either cut or filled slopes, it will be necessary to provide support to the cut or filled embankments using an appropriate "engineer designed" retaining wall system. Retaining walls will be required either side of the carport and the following design parameters are provided for design of the retaining walls.

Pressures acting on retaining walls can be calculated based on the parameters listed in Table 2 for the materials likely to be retained.

Table 2 - Retaining Structures Design Parameters

Material	Unit Weight (kN/m^3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (K_a)	At Rest (K_o)	
Residual clayey soils and filling	20	$\phi' = 25°$	0.35	0.5	2.0
Very low and low strength rock (jointed)	22	$\phi' = 20°$	0.25	0.4	400 kPa
Low strength rock	22	$\phi' = 20°$	0.20		2000 kPa
Medium or better strength rock	22	$\phi' = 30°$	0.1		6000 kPa

* Ultimate design values

Retaining walls should be designed for free draining granular backfill and appropriate surface and subsoil drains to either divert or intercept groundwater flow which otherwise could provide surcharging on the walls and additional pressures which may cause damage or failure of the walls.

6.6 Site Drainage

In order to maintain an acceptable level of risk of landslide it is crucial to control site drainage from both upslope areas and on the site itself. It is recommended that the existing stormwater drainage system be assessed for adequacy including all existing drainage infrastructure such as stormwater pipes and pits, roof gutters and down pipes. If the strata overlying bedrock is allowed to become saturated due to inadequate drainage or a broken service pipe, then the risk of slip or erosion would be significantly increased.

6.7 Geotechnical Verification

In order to verify design bearing capacities and founding strata for footings and retaining walls, a certification schedule will be required. In order for any footings to be certified, and thus comply with Northern Beaches Council development policy conditions (completion of Form 3), a geotechnical engineer or engineering geologist must inspect and verify the founding strata for any new footings and retaining walls at the time of construction to ensure that they comply with the certification schedule.

7.0 CONDITIONS RELATING TO MONITORING OF DESIGN AND CONSTRUCTION

In order to comply with Northern Beaches Council conditions and to allow the completion of Forms 2 and 3 required as part of the construction and post construction certification requirements of the Geotechnical Risk Management Policy, it will be necessary for Taylor Geotechnical Engineering Pty Limited to carry out the following:

1. Review the structural design drawings for compliance with the geotechnical recommendations in this report (for Form 2 Part B sign off).

2. Inspect any excavations for every 1.5 m depth interval to assess the need for specific stabilisation requirements.

3. Inspect retaining wall construction to ensure compliance with recommendations made in this report (for Form 3 sign off).

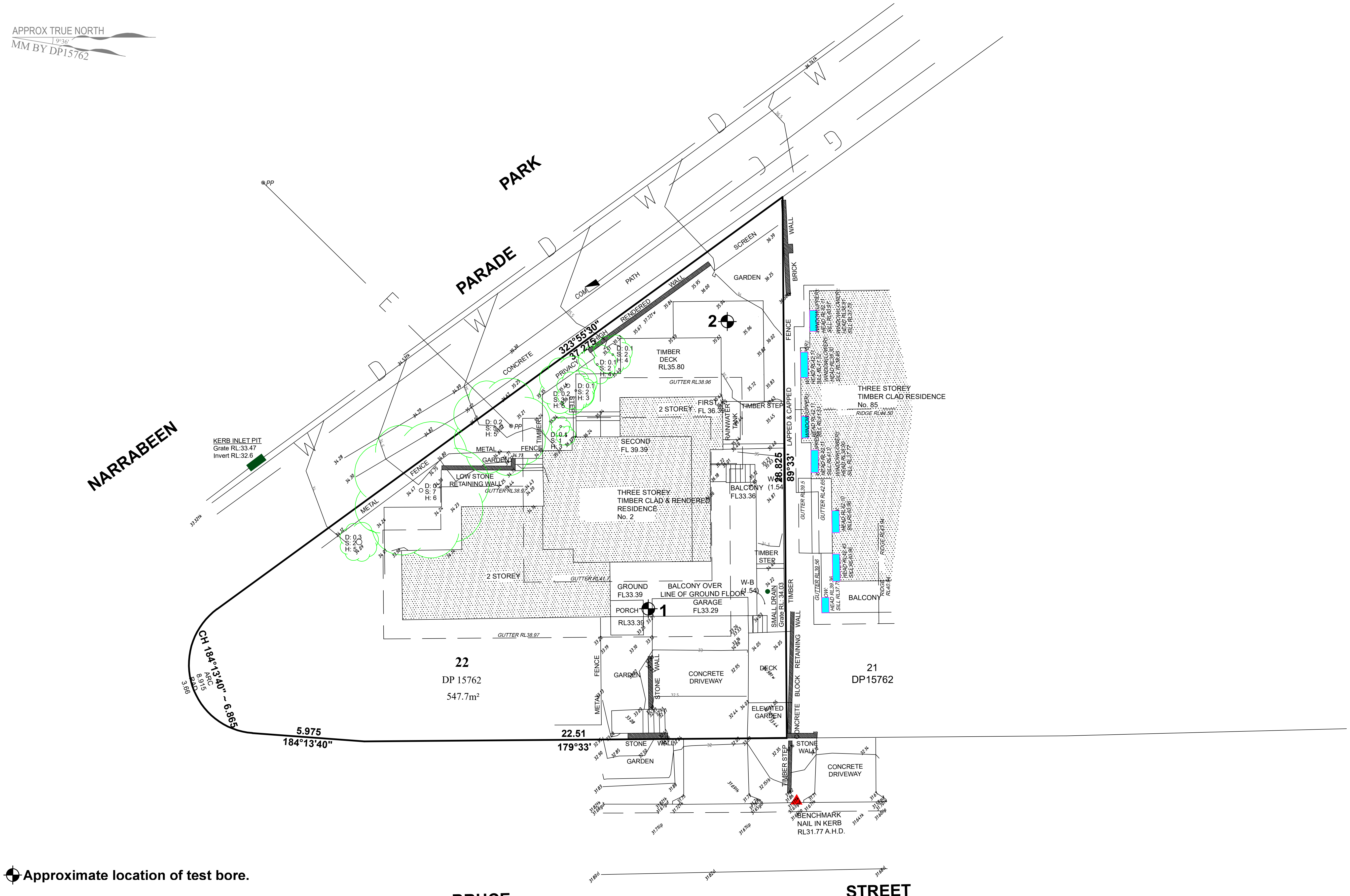
4. Inspect all footings prior to the placement of steel and concrete (for Form 3 sign off).

TAYLOR GEOTECHNICAL ENGINEERING PTY LIMITED,

LKTaylor

Lachlan Taylor
MIEAust. CPEng. NER
Principal Geotechnical Engineer

Appendix 1



Approximate location of test bore.

Note: Survey carried out by others.

BRUCE STREET

TGE *Taylor Geotechnical Engineering* *Geotechnical Civil Engineers & Project Managers*	*Taylor Geotechnical Engineering Pty Ltd* *PO Box 1906* *Dee Why NSW 2099* *taylorgeotech@bigpond.com*	*ABN: 22 120 426 155* *Phone: (02) 9999 6625* *Fax: (02) 9999 6650* *Mobile: 0407 984 128*	Drawing 1 - Site Plan Proposed Residential Development 2 Bruce Street Mona Vale
			Project: TGE22026 Date: 1 June 2020 Scale: As Shown

Appendix 2

TEST BORE REPORT

CLIENT: Adam Kibble & Rosie Burton | DATE: 1-Jun-2020 | Bore No: **1**

PROJECT: Proposed Residential Development | PROJECT No.: TGE22026 | 1 of 1

LOCATION: 2 Bruce Street Mona Vale | SURFACE LEVEL: RL = 33.2*

Depth (m)	Description of Strata	Sampling & In Situ Testing			
		Type	Depth (m)	Blows/150mm N Value	Core Recovery%
0.00	TOPSOIL - Dark brown silty sand.				
0.10	SILTY CLAY - Stiff, orange brown & grey silty clay.				
0.30	SILTSTONE - Extremely low strength, orange brown, yellow brown and grey siltstone.				
0.60	TEST BORE DISCONTINUED AT 0.6 METRES. Auger Refusal on siltstone.				

RIG: Hand Auger

TYPE OF BORING: 100mm diameter auger

GROUND WATER OBSERVATIONS: No Free Groundwater Observed.

REMARKS: *RL interpolated from survey plan.

DRILLER: Taylor

LOGGED: Taylor

CHECKED: [signature]

SAMPLING & IN SITU TESTING LEGEND

D = Disturbed auger sample

B = Bulk sample

Ux = x mm dia. Tube Sample

Taylor Geotechnical Engineering

TEST BORE REPORT

CLIENT: Adam Kibble & Rosie Burton   DATE: 1-Jun-2020   Bore No: **2**

PROJECT: Proposed Residential Development   PROJECT No.: TGE22026   1 of 1

LOCATION: 2 Bruce Street Mona Vale   SURFACE LEVEL: RL = 35.9*

Depth (m)	Description of Strata	Sampling & In Situ Testing			
		Type	Depth (m)	Blows/150mm N Value	Core Recovery%
0.00	TOPSOIL - Dark brown silty sand with a trace of clay.				
0.15	SILTY CLAY - Firm, dark grey brown & yellow brown silty clay.				
0.40	SILTY CLAY - Stiff, yellow brown & orange brown silty clay.				
0.70	SILTY CLAY - Stiff, grey & orange brown silty clay.				
1.00	SILTSTONE - Extremely low strength, grey & orange brown siltstone.				
1.15	TEST BORE DISCONTINUED AT 1.15 METRES. Auger Refusal on Siltstone.				

RIG: Hand Auger   DRILLER: Taylor

TYPE OF BORING: 100mm diameter auger   LOGGED: Taylor

GROUND WATER OBSERVATIONS: No Free Groundwater Observed.   CHECKED:

REMARKS: *RL interpolated from survey plan.

SAMPLING & IN SITU TESTING LEGEND

D = Disturbed auger sample

B = Bulk sample

Ux = x mm dia. Tube Sample

Taylor Geotechnical Engineering

RESULTS OF DYNAMIC PENETROMETER TESTS

CLIENT: Adam Kibble & Rosie Burton

DATE: 1 June 2020

PROJECT: Proposed Residential Development

PROJECT No: TGE22026

LOCATION: 2 Bruce Street Mona Vale

SHEET: 1 of 1

	PENETRATION RESISTANCE BLOWS / 150mm									
TEST LOCATION	**1**	**2**								
DEPTH (m)										
0.00 - 0.15	5	2								
0.15 - 0.30	4	3								
0.30 - 0.45	24	3								
0.45 - 0.60	25	4								
0.60 - 0.75	Refusal	5								
0.75 - 0.90		5								
0.90 – 1.05		7								
1.05 – 1.20		10/100mm								
1.20 – 1.35										
1.35 – 1.50										
1.50 – 1.65										
1.65 – 1.80										
1.80 – 1.95										
1.95 – 2.10										
2.10 – 2.25										
2.25 – 2.40										
2.40 – 2.55										
2.55 – 2.70										
2.70 – 2.85										
2.85 – 3.00										

TEST METHOD: AS 1289.6.3.2, CONE PENETROMETER YES

AS 1289.6.3.3, FLAT END PENETROMETER

TESTED BY: Taylor

REMARKS:

Taylor Geotechnical Engineering

Appendix 3

Photo 1 – View of site from Bruce Street, looking west.

Photo 2 – View of north eastern section of site where carport is to be located, looking west.

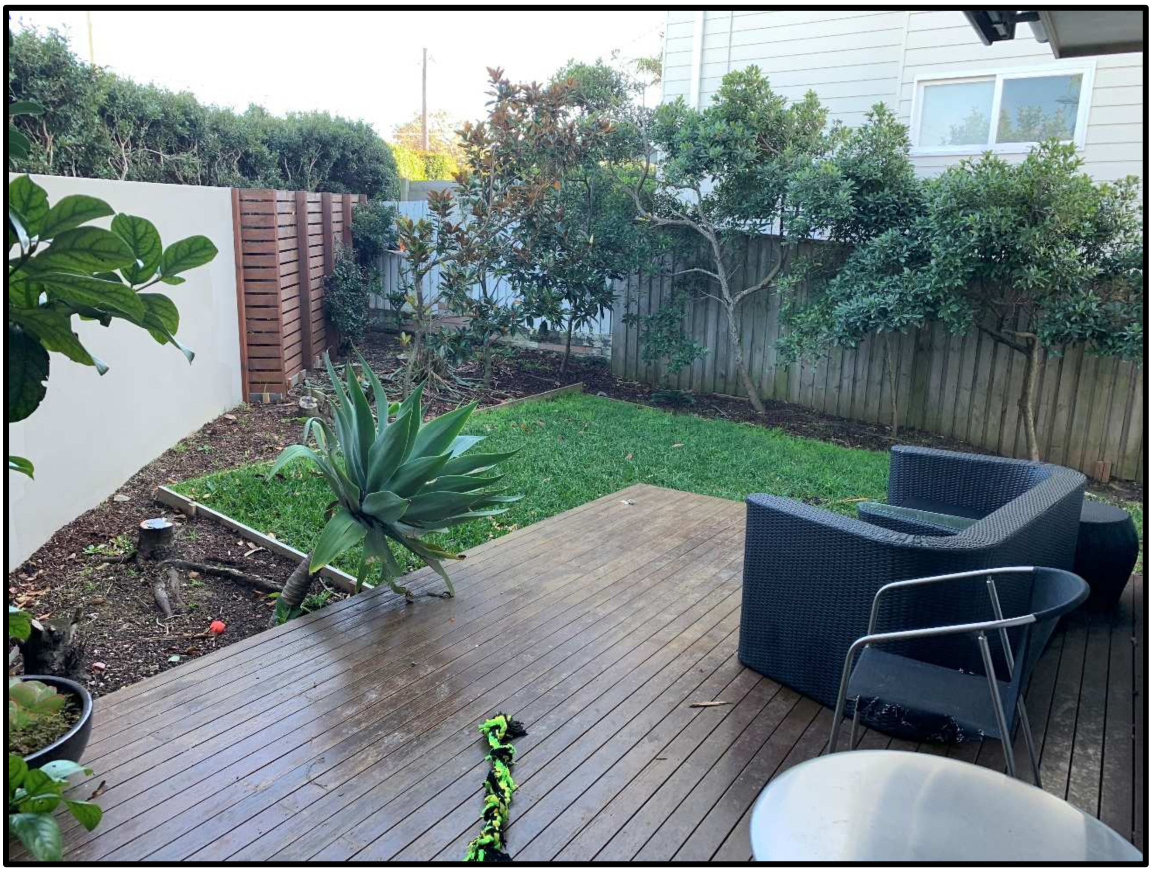


Photo 3 – View of north western section of site where pool is to be located, looking north west.

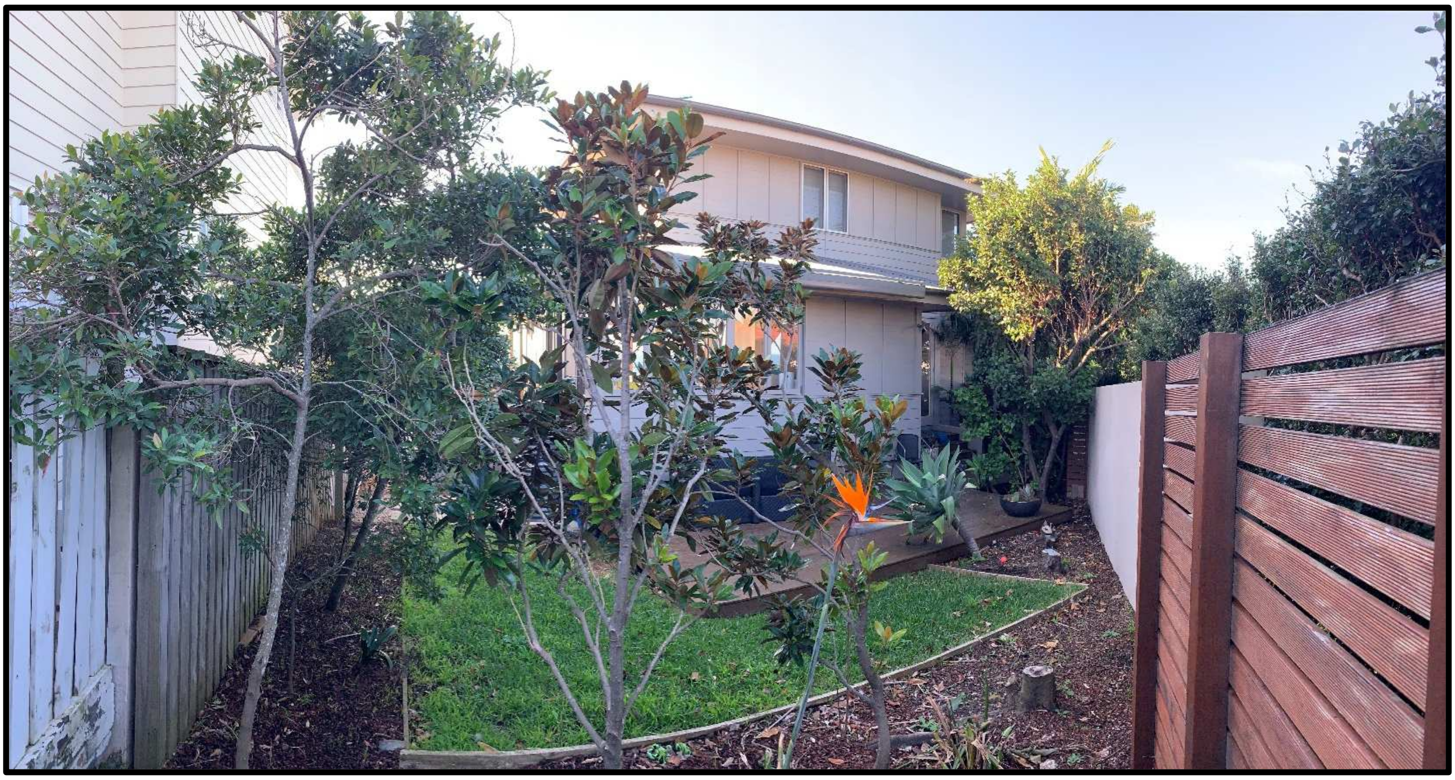


Photo 4 – View of north western section of site where pool is to be located, looking south east.

Appendix 4

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.

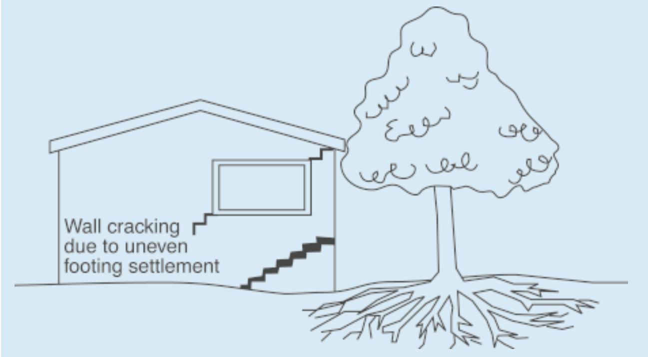
Seasonal swelling/shrinkage in clay

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.

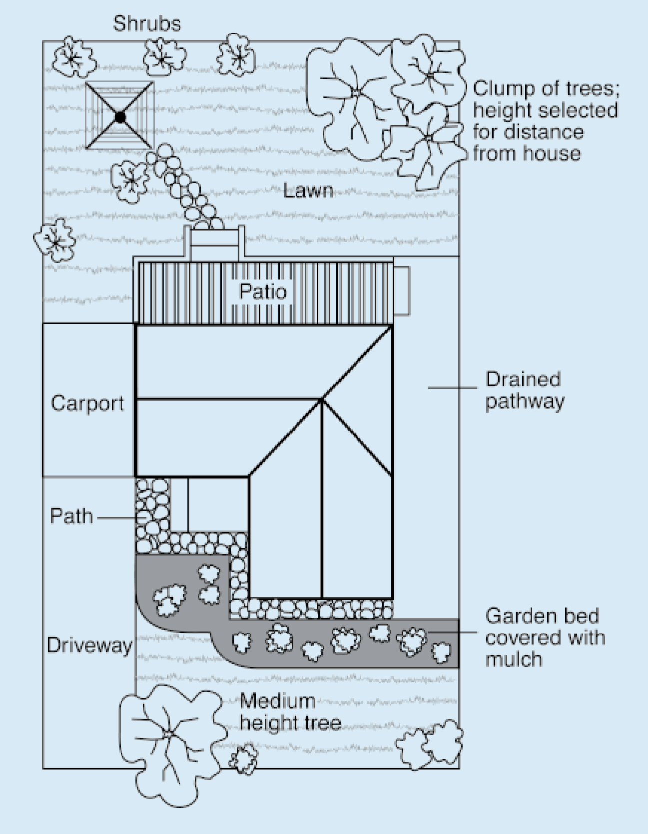
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

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