

GCA Report No.  
Date:

G19397-1  
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**Geotechnical Letter Report at:**

1 Kareema Street Balgowlah NSW 2093

**Prepared for:**

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c/o – Lifestyle Home Designs  
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**Attachment 1:** Important Information About Your Geotechnical Report

**Attachment 2:** Foundation Maintenance and Footing Performance – CSIRO

## 1. INTRODUCTION

This geotechnical letter report has been prepared for a proposed development at No. 1 Kareema Street Balgowlah NSW 2093 (the site), in order to identify the potential for any Acid Sulphate Soils (ASS) which may be present within the site, as well as preliminary geotechnical commentary on the existing ground conditions within the site based on information provided by the client, and to provide necessary advice and recommendations from a geotechnical perspective for the proposed development.

This geotechnical letter report was commissioned by Peter and Meredith Downey (the client), and is assisted by documents provided to Geotechnical Consultants Australia Pty Ltd (GCA), referenced in Section 2 below.

For your review, **Attachment 1** contains a document prepared by GCA entitled "Important Information About Your Geotechnical Report", which summarises the general limitations, responsibilities, and use of geotechnical engineering reports.

## 2. PROVIDED INFORMATION

The following relevant information was provided to GCA during preparation of this letter report:

- Architectural drawings prepared by Lifestyle Home Designs, titled "Alterations & Additions 1 Kareema Street Lot 2, Sec. E, D.P. 2044 Balgowlah N.S.W. 2093", referenced project No. 1815, and included drawing nos. DA 01 to DA 05 inclusive.
- Site survey plan prepared by Richard & Loftus Surveying Services, titled "Plan of Detail Levels and Contours Lot 2 Section E D.P. 2044 Being No. 1 Kareema Street", referenced No. 2532, sheet 1 of 1, and dated 2<sup>nd</sup> April 2019.

### **3. PROPOSED DEVELOPMENT**

Information provided by the client indicates the proposed development comprises alterations and additions to the existing dwelling within the site.

Based on this information and existing site topography and level, cut and fill are expected to be required for construction of the proposed development, with locally deeper excavations for the proposed footings and services trenches.

### **4. TOPOGRAPHY**

The local topography surrounding the site generally falls towards the west to south-west, and towards the north to north-east. The site also generally falls towards the west to south-west, with levels within the site varying from approximately Reduced Level (RL) 87.4m to RL90.1m Australian Height Datum (AHD).

It should be noted that the site topography, levels and slopes are approximate and based off the site survey plan referenced in Section 2 of this letter report, along with reference to NSW Six Maps (<https://maps.six.nsw.gov.au/>). The actual local and site topography and levels are expected to vary from those outlined in this letter report.

### **5. REGIONAL GEOLOGY**

Information obtained on the local regional subsurface conditions, referenced from the Department of Mineral Resources, Sydney 1:100,000 Geological Series Sheet 9130 First Edition, dated 1983, by the Geological Survey of New South Wales, indicates the site is located within an area generally underlain by Triassic Aged Hawkesbury Sandstone (Rh). The Hawkesbury Sandstone typically comprises "medium to coarse grained quartz sandstone, very minor shale and laminite lenses".

A review of the regional maps by the NSW Government Environment and Heritage indicates the site is generally located within the Lambert (la) landscape group, which is recognised by undulating to rolling rises and low hills on Hawkesbury sandstone. Soils of the Lambert group typically have very high soil erosion hazard, rock outcrop, seasonally perched water tables, shallow, highly permeable soil, and very low soil fertility. Local reliefs are generally 20m to 120m, with slopes typically of approximately 20% in gradient and rock outcrops greater than 50%. Soils of the Lambert group are generally slightly (pH 6.0) to extremely (pH 3.5) acidic.

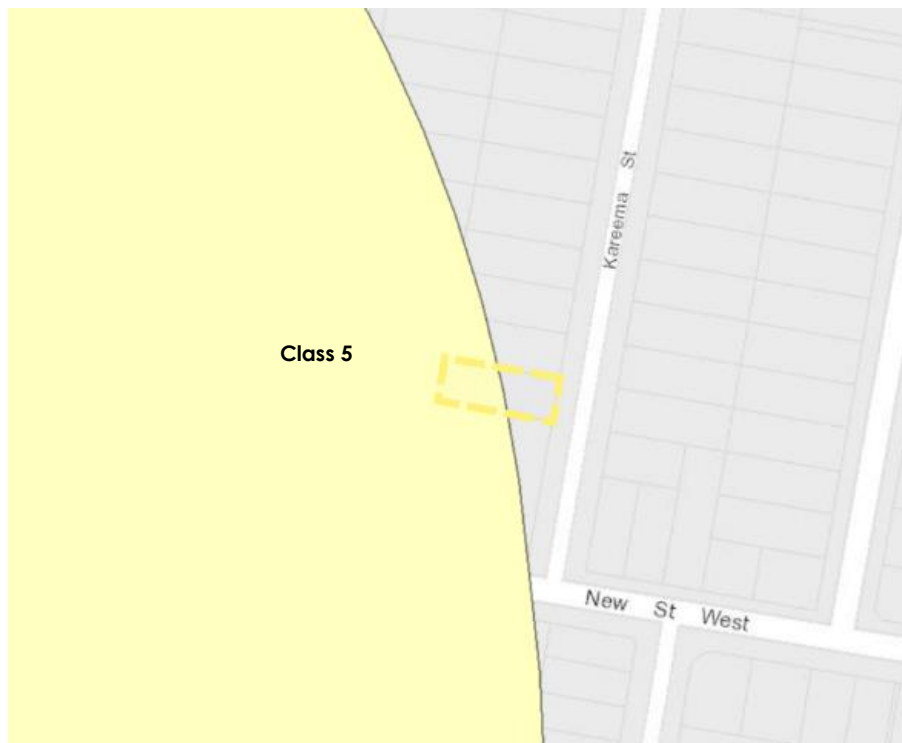
### **6. PRELIMINARY ACID SULPHATE SOILS**

#### **a. GENERAL**

Reference made to the NSW Planning Portal indicates the rear portion of the site is situated within an area of known ASS occurrences, identified as a Class 5 region, with the front portion of the site adjoining Kareema Street carriageway not affected by any known ASS occurrences, as shown in Figure 1 below.

It is noted that the NSW Planning Portal classifies ASS into 5 different classes based on the likelihood of the ASS being present in particular areas and at certain depths. ASS in Class 5 areas are not typically found within this region.

**Figure 1. ASS Site Location**



#### **b. PRELIMINARY ASSESSMENT AND RECOMMENDATIONS**

Based on our review of available information on the site, our experience with subsurface conditions within the local region and known ASS occurrences, as well as the proposed development which is not anticipated to require significant excavation works and mainly portioned within the Class 5 region for known ASS occurrences, it is in our opinion that the proposed development is not likely to be impacted by ASS.

This should be confirmed by a preliminary ASS assessment, carried out in accordance with in accordance with the Acid Sulphate Soils Management Advisory Committee (ASSMAC) guidelines, and the National Acid Sulphate Soils Guidance Manual, in order to investigate to the presence of Actual Acid Sulphate Soils (AASS) and Potential Acid Sulphate Soils (PASS) within the site.

Selected soil samples should be collected across the site and sent to a National Association of Testing Authorities, Australia (NATA) accredited laboratory, in order carry out a preliminary ASS screening on the presence of AASS or PASS within the site. Where laboratory testing results on the presence of AASS and PASS fall within the guideline criteria outlined in the ASSMAC and National Acid Sulphate Soils Guidance Manual, additional laboratory testing for determining the Suspended Peroxide Oxidation Combined Acidity and Sulphate (SPOCAS) of soil samples will be required. This should be carried out during the Construction Certificate (CC) stage, prior to any excavation works or construction activities within the site.

## **7. PRELIMINARY GEOTECHNICAL ASSESSMENT**

### **a. STRATIGRAPHY**

Any rock description has been based on Pells P.J.N, Mostyn G. & Walker B.F. Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, December 1998.

Based on site photographs provided by the client (Section 8), it is inferred that the majority of the site area, including areas underlying the proposed development footprint, will be underlain by sandstone bedrock, of generally highly weathered and low to medium estimated strength (or better). We infer fill material and some natural soils to overlie the bedrock within the site at varying depths throughout.

We note that the actual assessment of the defects and potential weathered zones within the underlying bedrock have not been carried out, and the estimated rock strength is approximate and solely based on a visual assessment of the provided photographs by the client.

Due to the variable ground conditions throughout the site, it is recommended that confirmation of the subsurface materials be carried out during construction, or by additional boreholes and rock strength testing. It should also be noted that ground conditions within the site are expected to differ from those encountered and inferred in this report, since no geotechnical or geological exploration program, no matter how comprehensive, can reveal and identify all subsurface conditions underlying the site.

### **b. GROUNDWATER**

Reference made to the site photographs provided by the client does not indicate the presence of any groundwater within the site, or throughout the exposed sandstone bedrock.

Groundwater which may be present within the site is expected to be in the form of seepage through the voids within the underlying fill material, and through the pore spaces between particles of unconsolidated natural soils, or through networks of fractures and solution openings in consolidated bedrock underlying the site. The presence of groundwater should not be precluded within the site and during construction.

It should be noted that groundwater levels have the potential to elevate during daily or seasonal influences such as tidal fluctuations, heavy rainfall, damaged services, flooding, etc., and moisture content within soils may be influenced by events within the site and adjoining properties. Groundwater monitoring should be carried out prior and during construction, to assess any groundwater inflows within the site.

### **c. EXCAVATION**

Cut and fill are expected to be required for construction of the proposed development, with locally deeper excavations also anticipated to be required for the proposed building footings and service trenches across the site.

Based on this information and existing ground conditions as encountered during the geotechnical investigation, it is anticipated that excavation will extend through fill, natural soils and then into sandstone bedrock, throughout the majority of the proposed development area (subject to confirmation).

The possibility for encountering higher strength bedrock (i.e. medium to high estimated strength, or better) should not be precluded during excavation/construction, predominately

where deeper excavations are required across the site. Estimated rock strength and depths should be confirmed by a geotechnical engineer.

Consultation should be made with subcontractors to discuss the feasibility and capability of machinery for the proposed development for the existing site conditions.

Excavation through softer soils and extremely low to low estimated strength bedrock should be feasible using conventional earth moving excavators, typically medium to large hydraulic excavators. Smaller sized excavators may encounter difficulty in high strength bands of soils and rocks which may be encountered. Where high strengths bands are encountered, rock breaking or ripping should be allowed for. Removal of the existing pavements and associated infrastructures within the site are also expected to require larger excavators and rock breaking and ripping.

Excavation of medium to higher estimated strength bedrock, which may be encountered across the site, would require higher capacity excavators, bulldozers or similar, for effective removal of the rock. This excavation will require the use of heavy ripping and rock breaking equipment or vibratory rock breaking equipment. Furthermore, excavation for the proposed building footings and service trenches may require the use of heavy ripping and rock breaking equipment or vibratory rock breaking equipment, with the possibility of rock saw cutting.

Should rock hammering be used for the excavation in the underlying bedrock, excavation should be carried out away from the adjoining structures, with vibrations transmitted being monitored to maintain vibrations within acceptable limits. Rock saw cutting should be carried out (where required), around the perimeter of excavations, prior to any rock breaking commencing.

Demolition, excavation and construction activities (or the like) will generate both vibration and noise, whilst being carried out within the site. Vibration control measures should be implemented as part of the construction process. All excavation works should be carried out in accordance with the NSW WorkCover code of practice for excavation work.

#### **d. FOUNDATIONS**

Based on the proposed development and assessment of the subsurface conditions from information provided by the client, a suitable foundation system comprising shallow foundations typically containing pad and/or strip footings, or a cast in-situ reinforced concrete raft slab constructed on appropriate strength, and consistent and competent sandstone bedrock underlying the site are likely to be adopted for the proposed development.

Shallow foundations should include local slab thickening to support internal walls and columns, where a raft foundation should include slab thickening to provide strip and pad footings for the support of the internal walls and columns, respectively. The use of settlement reduction piles with increased sock depths may also be considered, in order to increase the resistance against lateral loading induced by earthquake or winds, and to achieve higher bearing capacities than at the basement FFL.

Installation of piles (where adopted) should be complemented by inspections carried out by a geotechnical engineer during construction. The actual depth and embedment of the piles should be assessed by the project structural engineer, with all structural elements also inspected and approved by a suitably qualified structural engineer. Confirmation of the actual subsurface conditions underlying the proposed development area should be carried

out by a geotechnical engineer during construction. Consultation should be made with specialist subcontractors to discuss the feasibility of piles for the existing ground conditions. Consultation should be made with specialist subcontractors to discuss the feasibility of piles and machinery for the existing site conditions.

It should be noted that due to the potential variable bedrock conditions throughout the site following bulk excavation, precaution should be taken for the design of the building foundation system, taking into consideration the preliminary geotechnical design parameters in Table 1 below.

Higher allowable bearing capacities may be justified subject to confirmation by inspection during construction, or by additional borehole drilling and rock strength testing. Where higher estimated strength bedrock is encountered during construction, GCA should be contacted to re-assess the preliminary allowable bearing capacities provided in this report. Adoption of higher preliminary bearing capacities for the design of the proposed development outlined in Table 1 should be confirmed by a geotechnical engineer, as discussed in this report.

Given the potential for variable ground conditions and soil reactivity across the site, it is recommended that all foundations are constructed on consistent and competent bedrock throughout, in order to provide uniform support and reduce the potential for differential settlements. This could be attained by strip or pad footings where the suitable bearing capacity is achieved or exposed at bulk level excavation, and pile foundations elsewhere. Reference should be made to the estimated levels of the subsurface conditions outlined in this report, and compared to the final bulk excavation levels across the site.

Installation of piles may be required where the axial and working loads transmitted through the building walls and columns exceed the bearing pressure of the bedrock exposed at the proposed developments FFLs. These should be socketed into consistent and appropriate bedrock underlying the site. For cases where resistance against lateral loading induced by earthquakes or winds, and to achieve higher bearing capacities, piles may also be required. Piles sufficiently socketed into higher strength bedrock may achieve higher allowable bearing capacities, subject to confirmation by a geotechnical engineer by additional borehole drilling and rock strength testing, or by inspection during construction.

Where ground conditions vary from those outlined and inferred in this report, GCA should be contacted immediately for further advise. It is recommended that the preliminary findings and recommendations outlined in this report be confirmed by a geotechnical engineer, with appropriate fieldwork carried out in accordance with Australian Standards (AS) 1726-2017.

Table 1 provides preliminary recommended geotechnical design parameters.



**Table 1. Preliminary Recommended Geotechnical Design Parameters**

Maximum Allowable (Serviceability) Values (kPa)			
Unit Type/Material	End Bearing Pressure <sup>1</sup>	Shaft Adhesion (Compression)	Shaft Adhesion (Tension)
<b>Fill (Unit 1)</b>	N/A	N/A	N/A
<b>Natural Soils (Unit 2)</b>	N/A	N/A	N/A
<b>Bedrock (Unit 3)<sup>2</sup></b>	<b>EL – VL</b>	800	50
	<b>L<sup>3, 4</sup></b>	1,500	100
	<b>M<sup>3, 4</sup></b>	2,000	200

<sup>1</sup>Minimum embedment of 0.4m for shallow foundations and 0.5m for deep (pile) foundations.

<sup>2</sup>Confirmation of the underlying bedrock composition, continuity, strength and depth should be confirmed by additional borehole drilling and rock strength testing, or during construction by a geotechnical engineer.

<sup>3</sup>Preliminary only, and inferred to be present within the site at depth. Subject to confirmation by a geotechnical engineer during construction by inspection, or by additional borehole drilling and rock strength testing.

<sup>4</sup>At least Class IV Sandstone, or better. Subject to confirmation by a geotechnical engineer, as discussed in this report.

Notes:

- EL = Extremely Low estimated strength, VL = Very Low estimated strength, L = Low estimated strength, M = Medium estimated strength.
- N/A = Not Applicable. Not recommended for the proposed development.
- The composition, depth, strength and continuity of the underlying bedrock material should be confirmed either prior to construction by further borehole drilling and rock strength testing, or during construction by inspection.
- It is recommended that geotechnical inspections on the foundations are completed by a geotechnical engineer to determine the material and confirm the required bearing capacity has been achieved.

Bearing capacity and settlement behaviour varies according to foundation depth, shape and dimensions. Consultation should be made with specialist subcontractors to discuss the feasibility of piles for the existing site conditions. It should be noted that higher bearing capacities may be justified for the proposed foundations subject to confirmation by inspection during construction, or by additional borehole drilling and rock strength testing.

Foundations located within the “zone of influence” of any services or sensitive structures should be supported by a piled foundation. The depths of the piles should extend below the “zone of influence” and should ignore any shaft adhesion. Appropriate measures should be taken to ensure that any services or sensitive structures located within the “zone of influence” of the proposed development are not damaged during and following construction.

Specific geotechnical advice should also be obtained for footing designs 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. It is recommended that reference is made to the recommendations provided by CSIRO “Guide to Home Owners on Foundation Maintenance and Footing Performance”, attached as **Attachment 2**.

It is also recommended that suitable drainage and the use of impermeable surfaces be implemented as a precaution as part of the design and construction of the proposed development in order to divert surface water away from the building, and help eliminate or minimise surface water infiltration to minimise moisture within the soils. Although trees and vegetation are considered to contribute to the stability of the site, we recommend that planting of trees around the development area (i.e. in close proximity to the proposed building foundations) be limited as they can also affect moisture changes within the soil and cause significant displacement/damage within the building foundations by extensive tree root system movement.

The design and construction of the foundations should take into consideration the potential of flooding. All foundation excavations should be free of any loose debris and wet soils, and if groundwater seepage or runoff is encountered dewatering should be carried out prior to pouring concrete in the foundations. Due to the possibility of groundwater being encountered, or possible groundwater seepage during installation of bored piles within the site, it is recommended that consideration be given to other piling methods such as Continuous Flight Auger (CFA) piles.

Shaft adhesion may be applied to socketed piles adopted for foundations provided the socketed shaft lengths conform to appropriate classes of bedrock (subject to confirmation) in accordance with Pells et. al, and shaft sidewall cleanliness and roughness are to acceptable levels. Shaft adhesion should be ignored or reduced within socket lengths that are smeared or fail to satisfy cleanliness requirements (i.e. at least 80%). It is recommended that where piles penetrate expansive soils present within the site, which are susceptible to shrink and swell due to daily and seasonal moisture, shaft adhesion be ignored due to the potential of shrinkage cracking. Pile inspections should be complemented by downhole CCTV camera.

We recommend that geotechnical inspections of foundations be completed by an experienced geotechnical engineer to determine that the designed socket materials have been reached and the required bearing capacity has been achieved. The geotechnical engineer should also determine any variations between the boreholes carried out and inspected locations. Inspections should be carried out in dewatered foundations for a more accurate examination, and inspections should be carried out under satisfactory WHS requirements. Geotechnical inspections for verification capacities of the foundations should constitute as a "Hold Point".



## 8. SITE PHOTOGRAPHS



## 9. LIMITATIONS

Geotechnical Consultants Australia Pty Ltd (GCA) has based its geotechnical assessment on available information obtained prior and during the site inspection/investigation. The geotechnical assessment and recommendations provided in this report, along with the surface, subsurface and geotechnical conditions are limited to the inspection and test areas during the site inspection/investigation, and then only to the depths investigated at the time the work was carried out. Subsurface conditions can change abruptly, and may occur after GCA's field testing has been completed.

It is recommended that if for any reason, the site surface, subsurface and geotechnical conditions (including groundwater conditions) encountered during the site inspection/investigation vary substantially during construction, and from GCA's recommendations and conclusions, GCA should be contacted immediately for further testing and advice. This may be carried out as necessary, and a review of recommendations and conclusions may be provided at additional fees. GCA's advice and accuracy may be limited by undetected variations in ground conditions between sampling locations.

GCA does not accept any liability for any varying site conditions which have not been observed, and were out of the inspection or test areas, or accessible during the time of the investigation. This report and any associated information and documentations have been prepared solely for **Peter and Meredith Downey**, and any misinterpretations or reliances by third parties of this report shall be at their own risk. Any legal or other liabilities resulting from the use of this report by other parties can not be religated to GCA.

This report should be read in full, including all conclusions and recommendations. Consultation should be made to GCA for any misunderstandings or misinterpretations of this report.

For and behalf of

**Geotechnical Consultants Australia Pty Ltd (GCA)**



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Cert. IV in Building and Construction  
Geotechnical Engineer  
Director

## 10. REFERENCES

- Pells P.J.N, Mostyn, G. & Walker B.F., "Foundations on Sandstone and Shale in the Sydney Region", Australian Geomechanics Journal, 1998.
- AS 1726-2017 Geotechnical Site Investigation. Standards Australia.
- AS 2870-2011 Residential Slabs and Footings. Standards Australia.
- AS 2159-2009 Piling - Design and Installation. Standards Australia.
- NSW WorkCover "Code of Practice – Excavation Work" (July 2015).
- NSW Department of Mineral Resources (1983) Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1) Geological Survey of New South Wales. Department of Mineral Resources.
- NSW Government Environment and Heritage, Soil and Land Information, Sydney 1:100,000 Soil Landscape Series Sheet 9130la.
- Acid Sulphate Soils Assessment Guidelines - Acid Sulphate Soils Management Advisory Committee (ASSMAC) (1998).
- National Acid Sulphate Soils Guidance – National Acid Sulphate Soils Sampling and Identification Methods Manual. Department of Agriculture and Water Resources (2018).
- NSW Planning Portal.
- NSW Six Maps.
- eSPADE NSW Environment & Heritage.

## Important Information About Your Geotechnical Report

This geotechnical report has been prepared based on the scopes outlined in the project proposal. The works carried out by Geotechnical Consultants Australia Pty Ltd (GCA), have limitations during the site investigation, and may be affected by a number of factors. Please read the geotechnical investigation report in conjunction with this "Important Information About Your Geotechnical Report".

### **Geotechnical Services Are Performed for Specific Projects, Clients and Purposes.**

Due to the fact that each geotechnical investigation is unique and varies from sites, each geotechnical report is unique, and is prepared solely for the client. A geotechnical report may satisfy the needs of a structural engineer, where it will not for a civil engineer or construction contractor. No one except the client should rely on the geotechnical report without first conferring with the specific geotechnical consultant who prepared the report. The report is prepared for the contemplated project or original purpose of the investigation. No one should apply this report to any other or similar project.

### **Reading The Full Report.**

Do not read selected elements of the report or tables/figures only. Serious problems have occurred because those relying on the specially prepared geotechnical investigation report did not read it all in full context.

### **The Geotechnical Report is Based on a Unique Set of Project And Specific Factors.**

When preparing a geotechnical report, the geotechnical engineering consultant considers a number of unique factors for the specific project. These typically include:

- Clients objectives, goals and risk management preferences;
- The general proposed development or nature of the structure involved (size, location, etc.); and
- Future planned or existing site improvements (parking lots, roads, underground services, etc.);

Care should be taken into identifying the reason of the geotechnical report, where you should not rely on a geotechnical engineering report that was:

- Not prepared for your project;
- Not prepared for the specific site;
- Not prepared for you;
- Does not take into consideration any important changes made to the project; or
- Was carried out prior to any new infrastructure on your subject site.

Typical changes that can affect the reliability of an existing geotechnical investigation report include those that affect:

- The function of the proposed structure, where it may change from one basement level to two basement levels, or from a light structure to a heavily loaded structure;
- Location, size, elevation or configuration of the proposed development;
- Changes in the structural design occur; or
- The owner of the proposed development/project has changed.

The geotechnical engineer of the project should always be notified of any changes – even minor – and be asked to evaluate if this has any impact. GCA does not accept responsibility or liability for problems that occur because its report did not consider developments which it was not informed of.

### **Subsurface Conditions Can Change**

This report is based on conditions that existed at the time of the investigation, at the locations of the subsurface tests (i.e. boreholes) carried out during the site investigation. Subsurface conditions can be affected and modified by a number of factors including, but not limited to, the passage of time, man-made influences such as construction on or adjacent to the site, by natural forces such as floods, groundwater fluctuations or earthquakes. GCA should be contacted prior to submitting its report to determine if any further testing may be required. A minor amount of additional testing may prevent any major problems.

### **Geotechnical Findings Are Professional Opinions**

Results of subsurface conditions are limited only to the points where the subsurface tests were carried out, or where samples were collected. The field and laboratory data is analysed and reviewed by a geotechnical engineer, who then applies their professional experience and recommendations about the site's subsurface conditions. Despite investigation, the actual subsurface conditions may differ – in some cases significantly – from the results presented in the geotechnical investigation report, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface anomalies and details.

Therefore, the recommendations in this report can only be used as preliminary. Retaining GCA as your geotechnical consultants on your project to provide construction observations is the most effective method of managing the risks associated with unanticipated subsurface conditions.

### **Geotechnical Report's Recommendations Are Not Final**

Because geotechnical engineers provide recommendations based on experience and judgement, you should not overrely on the recommendations provided – they are not final. Only by observing the actual subsurface conditions revealed during construction may a geotechnical engineer finalise their recommendations. GCA does not assume responsibility or liability for the report's recommendations if no additional observations or testing is carried out.

### **Geotechnical Report's Are Subject to Misinterpretations**

The project geotechnical engineer should consult with appropriate members of the design team following submission of the report. You should review your design teams plans and drawings, in conjunction with the geotechnical report to ensure they have all be incorporated. Due to many issues arising from misinterpretation of geotechnical reports between design teams and building contractors, GCA should participate in pre-construction meetings, and provide adequate construction observations.

### **Engineering Borehole Logs And Data Should Not be Redrawn**

Geotechnical engineers prepare final borehole and testing logs, figure, etc. based on results and interpretation of field logs and laboratory data following the site investigation. The logs, figure, etc. provided in the geotechnical report should never be redrawn or altered for inclusion in any other documents from this report, included architectural or other design drawings.

### **Providing The Full Geotechnical Report For Guidance**

The project design teams, subcontractors and building contractors should have a copy of the full geotechnical investigation report to help prevent any costly issues. This should be prefaced with a clearly written letter of transmittal. The letter should clearly advise the aforementioned that the report was prepared for proposed development/project requirements, and the report accuracy is limited. The letter should also encourage them to confer with GCA, and/or carry out further testing as may be required. Providing the report to your project team will help share the financial responsibilities stemming from any unanticipated issues or conditions in the site.

### **Understanding Limitation Provisions**

As some clients, contractors and design professionals do not recognise geotechnical engineering is much broader and less exact than other engineering disciplines, this creates unrealistic expectations that lead to claims, disputes and other disappointments. As part of the geotechnical report, (in most cases) a 'limitations' explanatory provision is included, outlining the geotechnical engineers' limitations for your project – with the geotechnical engineers responsibilities to help other reduce their own. This should be read closely as part of your report.

### **Other Limitations**

GCA will not be liable to revise or update the report to take into account any events or circumstances (seen or unforeseen), or any fact occurring or becoming apparent after the date of the report. This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of GCA. The report should not be used if there have been changes to the project, without first consulting with GCA to assess if the report's recommendations are still valid. GCA does not accept any responsibility for problems that occur due to project changes which have not been consulted.



# Foundation Maintenance and Footing Performance: A Homeowner's Guide



CSIRO

BTF 18  
replaces  
Information  
Sheet 10/91

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

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

## Soil Types

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

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

## Causes of Movement

### Settlement due to construction

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

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

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

### Erosion

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

### Saturation

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

### Seasonal swelling and shrinkage of soil

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

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

### Shear failure

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

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

## GENERAL DEFINITIONS OF SITE CLASSES

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



### Tree root growth

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

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

### Unevenness of Movement

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

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

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

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

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

### Effects of Uneven Soil Movement on Structures

#### Erosion and saturation

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

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

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.

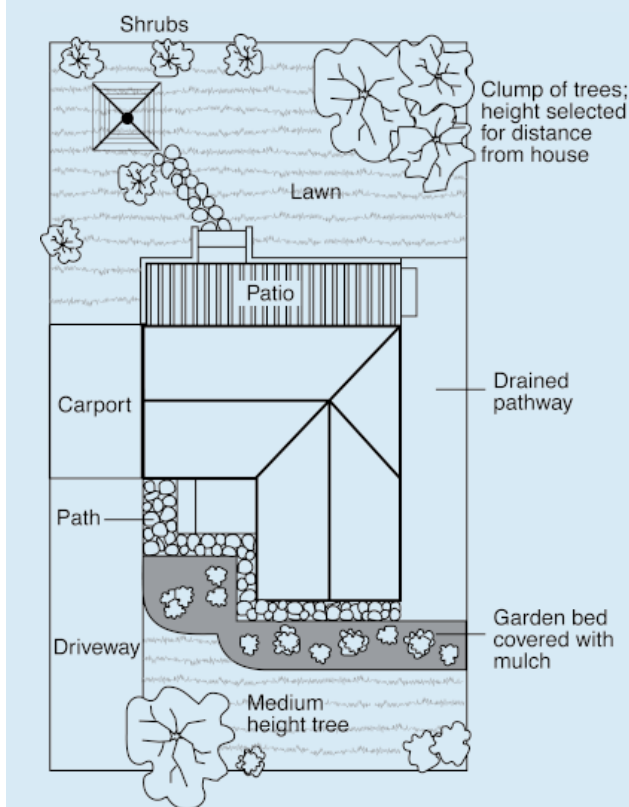
It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

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



- 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.**

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:

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.

Further professional advice needs to be obtained before taking any action based on the information provided.

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