GEOTECHNICAL INVESTIGATION REPORT

FORTIFY
GEOTECH

Proposed Development

CLIENT

Gardoxi Pty Ltd

ADDRESS

40 Myoora Road, Terrey Hills, NSW

DATE

September 2024

39 Sydenham Road, Marrickville, NSW 2204
PO Box 9225, Deakin ACT 2600

Consulting Engineers

(02) 9188 4033
FortifyGeotech.com.au

18 September 2024
Our ref: JS/S1694 Rev1

Gardoxi Pty Ltd
c/o Isaac Family Office
Via: tom@isaacproperty.com.au

Attention: Tom Ugarkovic

Proposed Development – 40 Myoora Road, Terrey Hills, NSW

Geotechnical Investigation Report

We are pleased to present our geotechnical investigation and slope instability risk assessment report for the proposed commercial development, located at 40 Myoora Road, Terrey Hills, NSW.

The report outlines the methods and results of exploration, describes site subsurface conditions, undertakes a qualitative slope instability risk assessment, and provides recommendations for building footing design, excavation conditions, preparation of subgrades, temporary and permanent excavation support, provides indicative design CBR values, and site drainage advice.

Yours faithfully
Fortify Geotech

Written by;	Reviewed by;
	Manuel Neves
Jordan Smyth	**Manuel Neves**
Graduate Geotechnical Engineer	Senior Geotechnical Engineer
	MICE CEng RPEQ RPEV PhD Registered PE of Queensland (RPEQ) # 32190 VIC PE Registration # PE0006524 NSW PE Registration # PRE0002314

About us

We work with our clients to provide practical advice and solutions tailored to each project. Our professional services are reliable, responsive and efficient.

Our highly capable Geotechnical Engineers and Geologists have a comprehensive understanding of the industry. We provide the best engineering solution for complicated geotechnical engineering issues. This has earned us a solid reputation with our Construction Industry, Municipal and Government clients

INDUSTRIES WE WORK IN

- Residential
- Commercial
- Transport Infrastructure
- Industrial Developments of all sizes.

SERVICES

- Geotechnical Site Investigations and Reporting;
- Engineering Geology;
- Mining/Rock Geotechnics;
- Foundation Engineering;
- Dam Engineering; Embankment Design and Specification;
- Geotechnical Design Recommendations;
- Pavement Engineering and Design;
- Pavement Condition Surveys;
- Slope Stability and Risk Assessments;
- Geotechnical and Hydrological Instrumentation and Monitoring;
- Footing and Excavation Supervision and Certifications;
- Excavated soil/rock assessments and VENM assessments;
- Supervision and Certification of Earthworks and Controlled Fill, including Level 1 supervision;
- Geotechnical Construction Specifications;
- Deep Excavation Support; and
- Slope/Retaining Structure Analysis and Design

Table of Contents

FORTIFY
GEOTECH

Proposed Development

QUALITY INFORMATION

Revision history

Reference/ Revision	Description	Date	Author	Reviewer
JS/S1694	First Issue	30/05/2023	JS	JM
JS/S1694 Rev1	Inclusion of slope instability assessment	18/09/2024	JOR	MN

Proposed Development – 40 Myoora Road, Terrey Hills

Geotechnical Investigation Report

1. INTRODUCTION

At the request of Gardoxi Pty Ltd, Fortify Geotech Pty Ltd (Fortify) carried out a geotechnical investigation for the proposed development 40 Myoora Road, Terrey Hills.

The project is understood to comprise a mixed-use hospitality development. The primary use of the site is for the purpose of a restaurant with ancillary back of house, servicing and loading areas and an underground car parking area. According to the information provided by the Client, excavations are expected to extent up to ~10m depth.

As part of the revision to this report the following additional information has been provided by the Client:

- Cut and Fill Plan, *Project: 40 Myoora Road Terrey Hills, NSW 2084*, produced by Richmond + Ross Pty Limited, drawing No. CM03 Rev A, dated December 2023.
- Architectural Drawing set for Development Approval, *Project: 40 Myoora Road*, produced by H&E Architects, dated 03/09/2024.

The aim of the investigation was to:

i. Identify subsurface conditions including the extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.

ii. Provide site classification to AS2870 “Residential Slabs & Footings”.

iii. Advise on suitable footings systems, founding depths, allowable bearing pressures and design parameters for piles.

iv. Advise on excavation conditions and provide design parameters for temporary and permanent excavation support.

v. Advise on stable batter slopes and provide low retaining wall design parameters.

vi. Advise on pavement subgrade preparation and provide indicative design CBR values

vii. Provide earthquake Site Factor and sub-soil class.

viii. Drainage and other geotechnical advice.

As part of the revision of this report, Fortify has been requested to carry out a slope instability assessment for the site, in accordance with Clause 6.4 (3) (a) of the Warringah Local Environmental Plan (LEP) 2011. The Landslip Risk Map of the Warringah LEP identifies the property as an Area A classification (*slope under 5°*)

2. SITE DESCRIPTION & GEOLOGY

The site is located at 40 Myoora Road, in Terrey Hills. The proposed location of the site is currently occupied by multiple single storey structures at the south-eastern end of the site and is otherwise covered by dense vegetation and undeveloped. The site has an area of approximately ~1.57ha, and is rectangular in shape, with Mona Vale Road to the south-east, Myroora Road to the north-west and existing development to the north-east and south-west. The site slopes gently to the north-west at between 5º and 10º. Figure 1 shows the site locality.

The geological information provided by the Department of Regional NSW (Reference 1) indicates the area to be underlain by Middle Triassic age Hawkesbury Sandstone, which consists of medium to coarse grained quartz sandstone with minor shale and laminite lenses.

3. INVESTIGATION METHODS

The site investigation was conducted on the 2nd and 3rd of May 2023, comprising twenty boreholes, designated BH1 to BH20. The boreholes were excavated using a 5 tonne Mini Excavator with a 300mm diameter attachment, terminating at a target depth of ~4m depth or at shallower near refusal in extremely to highly weathered (XW/HW) sandstone bedrock. Eight Dynamic Cone Penetrometer (DCP) tests were also conducted adjacent to some of the boreholes. The locations of the boreholes and DCP tests are shown on Figure 2, and the detailed borehole logs are included in Appendix A.

The soil profiles were visually logged in accordance with the Unified Soil Classification System (USCS). Definitions of geotechnical engineering terms used in the report on the borehole logs, including a copy of the USCS chart, are provided in Appendix C.

4. INVESTIGATION RESULTS

The subsurface conditions of the proposed residence were investigated by twenty boreholes, designated BH1 to BH20. The borehole logs in Appendix A can be referred to for more detail.

4.1 SUBSURFACE CONDITIONS – NORTHERN SECTION (BH1 TO BH11)

Investigation boreholes BH1 to BH11 found the subsurface profile at the northern section of the lot to comprise:

TABLE 4-1 – Subsurface Conditions

Geological Profile	Typical Depth Interval	Description
TOPSOIL/FILL	0m to 0.05m/0.3m	GRAVEL; SANDY TO GRAVELLY CLAY, SILTY SAND, MULCH; coarse gravel, fine to medium sized gravel, fine to coarse sized gravel, fine to medium grained sand, fine to coarse grained sand, medium plasticity, grey to red, brown trace orange and red, brown, dry, w<PL, w=PL, dry to moist, loose to medium dense, firm.
ALLUVIUM/ RESIDUAL SOIL	0.05m/0.3m to 1.5m/3.7m	SAND, CLAYEY SAND, SANDY CLAY, SANDY SILT; fine to medium grained, fine to coarse grained, low plasticity, Low to medium plasticity, medium plasticity, trace low to medium plasticity clay, trace low plasticity clay, brown trace grey, pale grey mottled orange trace brown, pale grey trace orange and brown, dark brown, grey trace dark grey, grey, pale grey white trace brown, pale grey white trace orange, orange brown, brown, grey trace orange, dry, dry to moist, moist, moist to wet, w<PL, w=PL, loose to medium dense, soft to firm, medium dense, medium dense to dense
WEATHERED BEDROCK	Below 1.5m/3.7m	Extremely weathered sandstone, SAND; medium to coarse grained, trace low to medium plasticity clay, orange trace red pale grey and white, pale grey trace orange, wet, dense.

Boreholes BH1 – BH11 were terminated near refusal in extremely to highly weathered (XW/HW) sandstone bedrock at ~1.7m/3.7m.

4.2 SUBSURFACE CONDITIONS – SOUTHERN SECTION (BH12 TO BH20)

Investigation boreholes BH12 to BH20 found the subsurface profile at the southern section of the lot to comprise:

TABLE 4-2 – Subsurface Conditions

Geological Profile	Typical Depth Interval	Description
TOPSOIL/FILL	0m to 0.15m/0.3m	MULTCH, SILTY SAND; fine to medium grained, trace fine to medium sized gravel, dark brown, dry to moist, loose to medium dense,
ALLUVIUM/ RESIDUAL SOIL	0m/0.3m to 1.8m/3.8m	SAND, SANDY to GRAVELLY CLAY, SANDY CLAY, CLAYEY SAND, CLAYEY to SANDY GRAVEL; fine to medium grained sand, low to medium plasticity, medium plasticity, fine to coarse sized gravel, trace fine to medium sized gravel, trace low plasticity clay, brown, orange brown trace red, orange brown, pale grey brown trace orange and red, pale grey white with pale orange trace grey, grey white trace pale red and pale orange, pale grey white trace orange, dry to moist, moist, moist to wet, w=PL, loose to medium dense, medium dense, medium dense to dense, dense, soft to firm
WEATHERED BEDROCK	Below 2.8m/3.9m	Extremely weathered sandstone, SAND; medium to coarse grained, trace low plasticity, red pale grey white orange, pale grey white and red, moist to wet, dry medium dense to dense, dense.

Boreholes BH12 & BH18 were terminated in ironstone gravels at ~1.8m & ~1.05m respectively.

Boreholes BH13–BH17 & BH19 were terminated in extremely to highly weathered (XW/HW) sandstone bedrock at ~2.8m/3.9m.

4.3 DYNAMIC CONE PENETROMETER (DCP) TESTING

To determine the density/relative consistency of the subsurface profile, one Dynamic Cone Penetrometer (DCP) test was conducted on 27th September 2022 in accordance with AS1289.6.3.2 “Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer test”. The DCP results are shown in Table 4-3 below. The DCP test was taken from existing groundsurface levels adjacent to their corresponding borehole numbers. The approximate location of the DCP tests is shown in Figure 2.

TABLE 4-3 - DCP Testing Results

Depth below existing groundsurface (m)	Blows per 100mm penetration							
	BH3	BH6	BH11	BH12	BH13	BH16	BH18	BH20
0.1	5	2	2	2	2	2	1	3
0.2	4	2	2	4	2	2	4	2
0.3	3	2	2	4	2	2	3	4
0.4	2	3	4	7	3	0	4	4
0.5	1	3	3	7	6	1	4	2
0.6	1	3	2	3	4	2	4	1
0.7	3	3	2	9	2	>25	6	1
0.8	4	2	1	10	1		6	5
0.9	4	1	0	11	3		5	5
1.0	2	2	2	14	9		4	5
1.1	2	2	11	6	6		2	6
1.2	2	2	3	6	3		>25	12
1.3	3	5	3	4	4			25
1.4	2	7	3	8	5			12
1.5	2	10	2	2	2			7
1.6	3	9	2	5	5			
1.7	3		1	>25	4			
1.8	4		2		5			
1.9	5		2		5			
2.0	7		5		8			
2.1	8		5		9			
2.2	9		13					
2.3			11					

The results for the DCP tests indicate the subsurface profile to comprise:

- BH3: loose to medium dense soils to 1.5m depth, over medium dense soils to 2.0m depth, over dense soils at ~2.0m depth.
- BH6: loose to medium dense soils to 1.2m depth, over medium dense to dense soils at ~1.2m depth.
- BH11: loose to medium dense soils to 1.9m depth, over medium dense soils to 2.2m depth, over dense soils at ~2.2m depth.
- BH12: medium dense soils to 0.6m depth, over dense soils to 1.4m depth, over medium dense soils to 1.7m depth, over very dense soils/ironstone at ~1.7m depth.
- BH13: loose to medium dense soils to 0.9m depth, over medium dense soils to 2.0m depth, over dense soils at ~2.0m depth.
- BH16: loose soils to 0.6m depth, over very dense/gravelly soils at ~0.7m depth.
- BH18: medium dense soils to 1.1m depth, over very dense soils/ironstone at ~1.1m depth.
- BH20: loose to medium dense soils to 0.7m depth, over medium dense soils to 1.1m depth, over dense soils at ~1.1m depth.

4.4 CBR TEST RESULTS

Four representative samples of the soil from auger holes, designated BH3/1D, BH7/1D, BH12/1D and BH20/1D, were sampled on the 2nd and 3rd of May 2023, and have been tested in a NATA laboratory for standard compaction and four-day soaked CBR value.

Results of modified compaction and soaked CBR laboratory test performed on the soil sample is summarised in Table 4-4 below. The CBR test specimens were compacted to a nominal 98%StdMDD at about optimum moisture content, and soaked for four days prior to testing. The NATA certificates are attached.

TABLE 4-4 - Laboratory Test Results Summary

Sample No.	BH3/1D	BH7/1D	BH12/1D	BH20/1D
Depth of sample	**0.5m – 0.8m**	**0.4m – 0.7m**	**0.5m – 0.8m**	**0.4m – 0.7m**
Material Description	**ALLUVIUM;** Clayey Sand, fine to coarse grained sand, low plasticity clay, pale grey to white trace brown, dry to moist, loose to medium dense	**ALLUVIUM;** Sand, fine to coarse grained sand, trace low to medium plasticity clay, brown, moist, loose to medium dense	**ALLUVIUM;** Sandy to Gravelly Clay, low to medium plasticity clay, fine to coarse sized gravel, fine to medium grained sand, orange brown trace red, w~PL, soft to firm	**ALLUVIUM;** Clayey to Gravelly Sand, fine to coarse grained sand, fine to medium size gravel, low to medium plasticity clay, orange brown trace red, moist, medium dense
USCS (visually assessed)	SC	SW	CL-CI	SC
Std. Max. Dry Density (t/m^3)	1.93	2.01	2.04	2.05
Opt. Moisture Content (%)	10.5	9.0	10.0	10.5
Placement Moisture Content (%)	10.6	9.2	10.1	10.6
Placement Density Ratio (%)	98.0	97.5	97.5	98.0
CBR Value (4-day soak) (%)	**17**	**17**	**25**	**4.5**

4.5 GROUNDWATER

Permanent groundwater was not encountered within the investigation depth (approximately 3 m), however some of the encountered soils were moist and moist to wet due to perched seepages at shallower depths. Temporary, perched seepages could be encountered at shallower depths following rainfall within the more pervious soils.

Although the depth of excavation has significantly increased from the date of undertaking the site investigation for the site, from up to 3 m to up to 10 m below current surface levels, NSW publicly available groundwater monitoring wells in proximity to the site report groundwater levels in the area at depths greater than 45m below surface levels. This suggests that is it unlikely that groundwater will be intersected during excavation works.

5. SLOPE INSTABILITY ASSESSMENT

Natural hill slopes are formed by processes that reflect the site geology, environment and climate. These processes include down slope movement of the near surface soil and rock. In geological time all slopes are 'unstable'. The area of influence of these down slope movements may range from local to regional and are rarely related to property boundaries. The natural processes may be affected by human intervention in the form of construction, drainage, fill placement and other activities.

5.1 METHOD OF RISK ASSESSMENT

The following sections of the report outline the slope instability risk assessment carried out for the site. The assessment is qualitative, based on the guidelines provided in the Australian Geomechanics Journal Vol 42 March 2007, and has been adopted by the NSW Department of Infrastructure, Planning and Natural Resources. This uses a matrix approach to determine the risk level of each hazard based on the likelihood and consequences of each hazard occurring.

The risk assessment is undertaken by the recognition of surface features supplemented by information on the regional and local subsurface profile and with the benefit of experience gained in similar geological environments. It involves the following components:

- Identification on the potential site slope hazards that may damage property and/or cause loss of life (Hazard Identification).
- Estimation of the likelihood of each hazard occurring (Likelihood of Hazards Occurring).
- Assessment of the potential consequences to property and people of these hazards occurring (Consequences of Hazards).
- Evaluation of the significance of the assessed risks against criteria of acceptability (Significance of Risks).

Following the risk assessment, options for the treatment of the risk are provided as a guide to the owner, administrator and regulatory authorities who will need to decide whether to avoid or accept the risk, or to treat the site to reduce the likelihood and/or consequences of the hazards.

A flowchart, included in the Australian Geomechanics Journal, Vol 42, March 2007, paper on "Landslide Risk Management Concept & Guidelines" 2007 (Reference 6), which shows the processes of risk assessment/risk management is copied here in Appendix E. Appendix F provides guidelines for hillside construction.

5.2 HAZARD IDENTIFICATION

A landslide is defined as “the movement of a mass of rock, debris or earth down a slope”. Apart from ground subsidence and collapse, this definition is open to the movement of material types including rock, earth and debris down slope. The causes of landslides can be complex. However, two common factors include the occurrence of a failure of part of the soil or rock material on a slope and the resulting movement is driven by gravity. For further information regarding types of landslides please refer to the Landslide Terminology from Australian Geomechanics Practice Note Guidelines For Landslide Risk Management 2007.

For 40 Myoora Road, Terrey Hills, the potential hazards listed in TABLE 5-1 have been considered in this assessment.

TABLE 5-1: Landslide Hazard Identification

Hazard Description	Justification
Large Scale Translational Slide	To our knowledge, no landslips have been recorded in the immediate vicinity of 40 Myoora Road, Terrey Hills, and no major landslides have been recorded in recent history in the greater Terrey Hills area. The existing trees on the upper portion of the site and on adjacent properties are all vertical, with little to no slanted growth. For a large-scale slide to happen there would need to be an extreme combination of unfavourable triggering conditions such as earthquakes, extreme rainfall, saturated soils, mass clearance of vegetation, unsupported excavations etc. Given the moderate slopes on and around the property and no known history of slope instability in this geological formation, such an event is considered “**Unlikely**”.
Circular / Shallow Translational Failure in Underlying Soil Mass	Near horizontal vegetation and fallen trees are present along the Myoora Road boundary, which suggest evidence of unstable batter slopes. Given the depth to rock in this area (inferred as 1.8m to 2.8 m in accordance with the findings of boreholes BH1 and BH2), site observation suggests that either localised circular failures or shallow translational failures have occurred and/or are in progress, resulting in the downslope movement of soil and vegetation towards the roadside stormwater drain, which in turns connects to an existing culvert under Myoora road. The current development proposals indicate minor cutting/filling in the area (±1m in relation to existing surface levels). The steep slopes in this area, in combination with adverse site conditions, i.e. saturated soils post a rainfall event and/or rainwater run-off, are likely the cause of the observed signs of instability. As such, this event is considered “**Almost Certain**”.
Surface Erosion	For much of the site, there are presently no signs of surface erosion, probably in part due to the surface vegetation and good surface drainage. This is with exception of the above-mentioned batter slope along the Myoora Road boundary. Surface runoff during high rainfall could be substantial along this boundary, so if the vegetation were to be removed and surface water-flow paths were allowed to develop, surface erosion would be “**Likely**”.
Failure of Retaining Wall	There are no retaining walls within the property. However, there is a sandstone block retaining wall (circa 3.5 m in height), set ~1.5 m back from the property boundary in 38 Myoora Road. Based on the provided Architectural DA plans, the proposed basement excavation appears to be outside of the zone of influence of the wall and therefore unlikely to undermine the existing wall. However, this should be confirmed prior to construction. Visual inspection suggests no signs of deterioration or undue stress on the wall. Given the above, the likelihood of a retaining wall failure along the property boundary is considered “**Unlikely**”.

Hazard Description	Justification
Soil Creep	Soil Creep can occur where residual clayey/silty soils overlie shallow bedrock. In this case, the gradient slope angle along the majority of the site is relatively gentle. However, soil creep is evident along the lower batter slope on the Myoora Road, with tilted vegetation and evidence of sliding soil over the visible shallow bedrock along this boundary. Such an event is considered "**Almost Certain**".

5.3 CONSEQUENCES OF HAZARDS OCCURING

For 40 Myoora Road, the consequences of the potential hazards listed in TABLE 5-1 have been summarised in TABLE 5-2 and classified using the AGS table of qualitative measures of vulnerability and consequences in Appendix D of this report.

TABLE 5-2: Landslide Hazard Consequence

Hazard Description	Justification
Large Scale Translational Slide	Theoretically, a large-scale slide could occur with little or no warning, and the consequences to property and people would depend on the volume of the slide material, its velocity, and whether or not people are present, or in the downslope dwelling at the time. We consider the consequences of such a rare event to be "**Medium**", i.e. theoretically, there is the possibility of a fatality in the dwelling and/or the imposition of moderate damage to some of the structure in the rare event of this occurring.
Circular / Shallow Translational Failure in Underlying Soil Mass	The consequence of a circular/shallow translational failure in underlying soil mass along the Myoora Road boundary occurring is inferred to be "**Medium**". In the case of such a failure, the stormwater drainage and culvert along Myoora Road would be impacted, along with any vehicles or persons at the top of the slope at the time of the failure event. The chance or temporal probability of persons being in the area during an earth slump is low, and therefore the risk of loss of life is unlikely. The consequences for persons are therefore rated as "**Minor**".
Surface Erosion	If such an event develops and occurs, small cobbles may wash out of erosion gully slides and rolled downhill. The consequential damage to a structure and persons would be "**Insignificant**".
Failure of Retaining Wall	If a retaining wall failed, damage may well result to the structures above, depending on many factors. In general, the consequences can be rated as "**Major**". The chance of persons being injured or of loss of life is moderate and the consequences to persons are therefore also rated as "**Major**".
Soil Creep	The risk of soil creep has only been identified at the northern boundary of the site and no foundations of structures above the slope are likely to be affected by this hazard. Therefore, the consequential damage to a structure or persons is considered "**Insignificant**".

5.3 RISK ESTIMATION

A summary of estimated risk to property and life for each of the potential hazards identified in the previous sections is provided in TABLE 5-3. The resulting risk level was derived using the AGS risk analysis matrix presented in Appendix D.

TABLE 5-3: Estimated Risk Levels of Hazards

Potential Hazard	Assessed Likelihood	Assessed Consequences	Risk Level
Large-Scale Translational Slide	Unlikely	To Dwelling - Medium	Low
		To People in/adjacent to dwelling – Medium	Low
Circular / Shallow Translational Failure in Underlying Soil Mass	Almost Certain *(Unlikely*)*	To Dwelling - Medium	Very High *(Low*)*
		To People in/adjacent to dwelling - Minor	High *(Low*)*
Surface erosion	Likely	To Dwelling – Insignificant	Low
		To People in/adjacent to dwelling - Insignificant	Low
Failure of Retaining Wall	Unlikely	To Dwelling – Major	Medium
		To People in/adjacent to dwelling – Major	Medium
Soil Creep	Almost Certain *(Unlikely*)*	To Dwelling - Insignificant	Low *(Very Low*)*
		To People in/adjacent to dwelling - Insignificant	Low *(Very Low*)*

* Should the risk treatment measures presented in Section 5.6 be adopted, the assessed likelihood and risk level will be adjusted as listed.

5.5 SIGNIFICANCE OF RISKS (RISK EVALUATION)

Risk evaluation is the process by which owners, administrators and relevant regulatory authorities can decide whether the potential risks (See TABLE 5-3) are acceptable, and/or whether these can be feasibly eliminated or reduced by remedial treatment. Implications of each level of risk are described in Appendix D.

In this case, the overall risk to property and people is assessed to be “Low” to “Very High”. However, provided the proposed developments on the site incorporate accepted procedures for hillside construction and adequate remedial measures (refer to Section 5.6) are implemented across the site to reduce the potential hazards’ likelihoods, the overall risk to property and people to be reduced to “Very Low” to “Medium”.

Therefore, provided the design and construction of the proposed development is undertaken in accordance with accepted procedures for hillside construction, and treatments are carried out to reduce the potential hazards, the risk is no higher than normally acceptable for the development.

5.6 RISK TREATMENT

To maintain and/or reduce the risk level of slope stability during the construction of the proposed new development, the following measures are recommended to be implemented:

- The unstable slope along Myoora Road (northern boundary of the site) is to be cleared of all fallen trees and loose soil, and regraded to a suitable batter angle for a permanent slope, as recommended in Section 6.5. Any new material placed on the slope should be adequately benched into the existing slope to prevent the creation of preferential failure planes and the slope should be inspected an experienced geotechnical engineer to assess its stability prior to any filling operations. If the proposed development does not allow for less steep slopes to be incorporated in the design, additional stabilisation measures may be required. Several options are available depending on budget, time constraints, and the desired outcome. Fortify Geotech can offer potential solutions, including terracing, soil removal and recompaction, geocells or retaining walls.

- Maintain adequate drainage across the site, including rainwater surface collection, and ensure drains are free-flowing (including drainage systems of existing retaining walls).

- Where possible, maintain the existing vegetation cover.

Some useful guidelines on hillside construction, prepared by the Australian Geomechanics Society, are presented in Appendix F.

6. DISCUSSION & RECOMMENDATIONS

6.1 SITE CLASSIFICATION

The upper (low to medium plasticity) soils are slightly to moderately reactive in terms of potential shrink-swell movements that may occur due to seasonal ground moisture changes. The characteristic ground surface movement “Ys”, as defined by AS2870 for the range of extreme dry to extreme wet moisture conditions is estimated to be between 20mm to 40mm. The site is therefore Class “M” (moderately reactive).

Deemed-to-comply footing designs provided by AS2870 are applicable specifically to residential-style one and two-storey structures, or buildings with similar loads and superstructure stiffness.

6.2 BUILDING FOOTINGS

AS2870 provides “deemed-to-comply” footing/slab designs, which for a Class “M” site includes stiffened rafts, stiffened footing slabs, waffle rafts, and strip and/or pad footings with above ground floors. Footings and slabs should be in accordance with the principles of AS2870 (Reference 2).

For structures founded at existing grade or with a single level basement, footings, including thickened sections of slabs forming footings should be founded below the topsoil/fill material and any loose or moisture affected soil, and founded in medium dense alluvial/residual soils or weathered sandstone bedrock. A depth of ~0.25m/2.8m depth below existing surface levels may be required to reach a suitable founding stratum. Shallow footings could be founded in any newly placed controlled fill (see Section 6.6). Alternatively, bored piers founded in weathered bedrock could be used. It is expected that a ~3.5m deep basement excavation will encounter extremely to highly weathered (XW/HW) and less weathered bedrock at the base of the excavation.

Recommended allowable end-bearing pressures and shaft adhesion values for various footing systems and likely foundation materials are provided in Table 6.

TABLE 6 – Recommended Allowable End-Bearing Pressures for Footings

Foundation Material Type	Depth Below Existing Surface Level	Allowable End-Bearing Pressure			Allowable Shaft Adhesion on Bored Piers and Anchors	
		Strips	Pads	Bored Piers	Downward Loading	Uplift
Newly Placed Controlled Fill	-	100kPa	125kPa	N/A	N/A	N/A
Medium Dense Alluvial/Residual Soils	~0.25m/2.8m	75kPa	100kPa	125kPa	12kPa	6kPa
XW/HW or less weathered Bedrock	~1.7m/3.9m (BH1-BH11, BH14-BH19)	500kPa	600kPa	700kPa	70kPa	35kPa

All footings should be inspected and approved by an experienced geotechnical engineer to confirm the foundation material and design values, and to ensure the excavations are clean and stable.

Groundslabs can be constructed on the natural soils or newly placed controlled fill (see Section 6.6). Following excavation to required level, slab areas on soil should be proof-rolled by a pad foot roller to check for any weak, wet or deforming soils that may require replacement.

If required for design of groundslabs, a modulus of subgrade reaction of 50kPa/mm can be assumed for a natural soil or controlled fill foundation.

6.3 EXCAVATION CONDITIONS & USE OF EXCAVATED MATERIAL

It is understood that excavations to ~10m are required for the proposed basement. The excavations are expected to be through existing topsoil/fill, alluvial/residual material and into weathered sandstone bedrock (or better). The topsoil/fill material and alluvial/residual soils are readily diggable by backhoe and medium sized excavator to at least ~1.7m/3.9m depth. Moderately weathered and less weathered bedrock may be encountered below 1.7m/3.9m depth and would require heavy excavator, bulldozer ripping and rock hammering.

Any low/medium plasticity alluvial and residual soils can be used in controlled fill construction of building platforms, provided any rock particles are broken down to <75mm size and the fill is environmentally suitable for re-use on site. Topsoil and existing uncontrolled fill material and any medium to high and high plasticity, clayey soils should not be used in controlled fill construction.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

6.4 BASEMENT EXCAVATION TEMPORARY SUPPORT

Temporary basement excavations to 1.5m depth in fill and any moisture affected soils should be cut back at 1(H):1(V). Deeper temporary cuts should be formed no steeper than 1(H):1(V) or benched at 1.5m intervals in natural soils and XW bedrock and 0.5(H):1(V) in MW and less weathered bedrock. A geotechnical engineer should inspect all cut batters during construction to confirm stability. The soil batter surfaces should be temporarily protected against deterioration due to the weather by covering in plastic, held by pinned chain-link mesh.

Where space limitations preclude battering back to stable slopes, temporary support options include sheet piles or contiguous soldier piers with tie-back anchors, and horizontal lagging or reinforced shotcrete supporting the spaces between piers. Given the sandy nature of the soils and shallow groundwater, sheet piling is expected to be the most practical method of temporary excavation support (shoring). Sheet piles would typically be installed from existing surface levels prior to bulk excavation. The excavation could then proceed in maximum 3m depth stages, with tie-back anchors installed and tensioned prior to excavation of the next level. Lateral support would also be provided by the passive and cantilever resistance of sheet pile sections socketing below final excavation level.

6.4.1 Lateral Pressure on Temporary Support Systems

The loads in anchors or struts for tied-back walls used in the temporary support of vertical excavations, such as soldier piers tied back by tensioned ground anchors or internally strutted to the basement floor, can be calculated using a trapezoidal pressure distribution given by:

$$\sigma_h = \left(5H \text{ x } \frac{4z)}{H}\right) + 0.4q \qquad \text{For } z < 0.25H$$

$$\sigma_h = (5H) + 0.4q \qquad \text{For } z > 0.25H$$

where,

σ_h	is the apparent horizontal earth/rock pressure acting on the back of the wall, in kPa
H	is the total height of the full excavation to be supported, in metres
z	is the distance from the top of the excavation, in metres
q	is any uniformly distributed vertical surcharge acting on the ground surface at the top of the excavation, in kPa

The above expression takes no account of groundwater pressure, as it is assumed the temporary walls will be fully drained. Where the walls are to be covered by shotcrete and/or where these will be incorporated into a permanent basement wall, synthetic drainage strips should be installed vertically against the excavated face, draining to collector pipes at the base of the excavation, taken to a basement pump-out sump.

6.4.2 Resistance Parameters for Temporary Support Systems

The allowable horizontal passive resistance provided by socketed sections of soldier piers or other retaining systems in hard soils below the basement excavation floor level can be calculated as:

$$\sigma_p = 50z \qquad \text{(Medium dense soil socket only)}$$

$$\sigma_p = 100z \qquad \text{(Class V bedrock socket only)}$$

where,

σ_p	is the allowable passive pressure acting on the front of the pier/footing at depth z, in kPa
z	is the pier socket length below excavation level in weathered bedrock, in metres

The effective width of a socketed pier for calculation of allowable passive resistance can be assumed to be equivalent to twice its actual width, except where the centre-to-centre distance between the piers is two diameters or less, in which case the soldier piers can be considered to act as one continuous wall.

If internal struts are used, propped to anchor blocks in the basement floor, the allowable passive resistance provided by the anchor blocks can be calculated using the same pressure distribution given above, although the effective width of the footing or block can be taken as 1.5 times its actual width. In addition, an allowable base friction factor (tanδ) of 0.35, and allowable base adhesion (c) of 50kPa can be used for calculation of sliding resistance of concrete anchor blocks in the very weak weathered bedrock.

An average ultimate bond value of 30kPa can be assumed for cement-grouted ground anchors in the hard soils. It is important that at least a few of the anchors should be proof-tested by pull-out tests to confirm or adjust bond values. It is recommended that ground anchors be inclined downward at between 5° and 20°, and that the “fixed” (anchored) section be assumed to extend beyond a line inclined upward from the batter toe at 45°. Tensioned multi-strand cable anchors are recommended rather than using passive (non-tensioned) anchors.

6.5 BASEMENT AND EXCAVATION PERMANENT SUPPORT

Permanent unsupported batters in soil would need to be formed no steeper than 2(H):1(V). Permanent batters should be protected against erosion by stone pitching, shotcreting, or other suitable means.

Permanent basement walls can be integrated into the temporary excavation support systems, or constructed separately from these, but with the space between backfilled or spanned by horizontal struts.

The walls and floor slabs for basement walls incorporated with or strutted to the temporary excavation supports should be designed to cater for the pressures given in Section 6.4.1.

Where basement walls are constructed in open excavation and backfilled later, the wall and floor slabs can be designed to resist lateral pressure using a distribution given by:

$$\sigma_h = (8d) + 0.4q$$

$$\sigma_h = (7d) + 0.4q \text{ (In HW or less weathered rock)}$$

where,

d is the depth below the top of the backfill or retained ground, in metres

q is any uniformly distributed surcharge acting on the surface of the backfill, in kPa

The first term of the expression is a triangular pressure distribution, the second a uniform pressure distribution. The design pressure takes no account of hydrostatic pressure, as it is assumed that the walls will be provided with permanent backfill drainage, and that any groundwater is drawn below the level of the lower basement. Backfill materials for walls constructed in open excavation should be clean, granular and free-draining, and preferably the upper backfill can be a clayey soil to reduce infiltration of surface water.

6.6 CONTROLLED FILL CONSTRUCTION

For construction of any new fill foundation platforms and road subgrades, it is recommended that:

- Areas be fully stripped of all existing uncontrolled fill, any loose and moisture affected soils. A general stripping depth of 0.25m/2.8m is expected. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9 tonne static mass to check for any weak or wet areas that would require replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation.

- Controlled fill comprising suitable site excavated or imported materials of not greater than 75mm maximum particle size, be compacted in not greater than 150mm layers to not less than 98%StdMDD at about OMC. Any unsuitable existing fill (e.g. silty soils) is not to be used as controlled fill.

- Fill placement and control testing be overviewed and certified by a geotechnical engineer at Level 1 or 2 involvement of AS3798 – 2007 “Guidelines on Earthworks for Commercial & Residential Developments” (Reference 3).

6.7 PAVEMENT SUBGRADES

Pavement subgrades should be prepared as outlined in Section 6.6. Natural soil or controlled fill subgrades can be designed using a CBR value of 4%. Prepared subgrades should be inspected by a geotechnical engineer to confirm whether these are structurally sound, and to confirm a suitable design CBR value.

6.8 EARTHQUAKE SITE FACTOR

The Geoscience Australia Earthquake Hazard Map (Reference 4) indicates the earthquake acceleration coefficients (with an annual probability of exceedance of 1/500) for Australia to be used in structural design. These values are equivalent to hazard factor, Z. The Terrey Hills area has an acceleration coefficient of 0.06g. AS1170.4 – 2007 – Minimum Design Loads on Structures – Part 4 Earthquake Loads (Reference 4) allows a minimum value of 0.08 to be used for the hazard factor, Z.

Section 4.2 of AS1170.4 “Minimum Design Loads on Structures – Part 4: Earthquake Loads” lists the site sub-soil classes to be considered in structural design. The site is classified as a “Class C_e – Shallow Soil Site”.

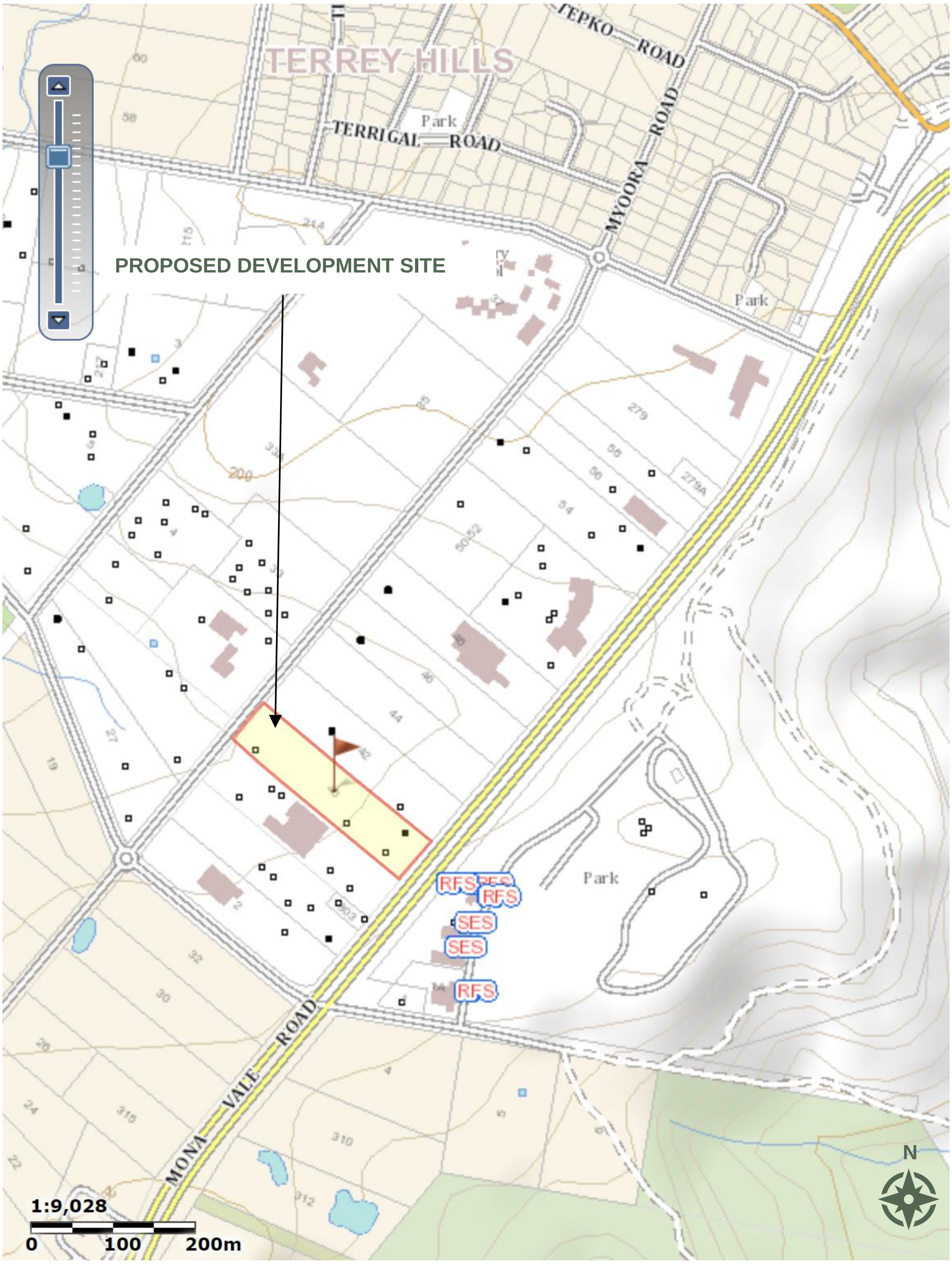
6.9 SITE DRAINAGE

Permanent groundwater was not encountered within the investigation depth, however some of the encountered soils were moist and moist to wet due to perched seepages at shallower depths. The permanent groundwater table is expected to be below the proposed excavations, although temporary perched seepages may be present following rain.

Suitable surface drainage should be provided to ensure rainfall run-off or other surface water cannot pond against buildings or pavements. Drainage should be provided behind all retaining walls, and subsoil drains should be installed along the upslope sides of access roads and carparks.

7. REFERENCES

Reference 1	MinView – geological map - https://minview.geoscience.nsw.gov.au - Accessed 25/05/2023
Reference 2	Standards Australia, “AS2870 – Residential Slabs & Footings”, 2011.
Reference 3	AS3798 - 2007, “Guidelines on earthworks for commercial and residential developments”.
Reference 4	Geoscience Australia – earthquake hazards map - http://www.ga.gov.au/darwin-view/hazards.xhtml# - Accessed 25/05/2023
Reference 5	Standards Australia, “AS1170.4 – 2007 – Minimum Design Loads on Structures – Part 4 Earthquake Loads”.
Reference 6	Landslide Risk Management Concepts and Guidelines 2007 - https://landsliderisk.org/wp-content/uploads/2017/04/ags_2007c2.pdf - Accessed 4/04/2024



SITE LOCALITY	S1694	FIGURE 1

LEGEND:

Borehole Locations (depth to XW/HW Bedrock) - ⊗
Approximate Location of Unstable Batter Slope – 🟨

PHOTOGRAPH AND BOREHOLE LOCATIONS	S1694	FIGURE 2

Appendix A

Borehole logs BH1 to BH20

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH01

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 2m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.05	Fill	▩	GP	Fill GRAVEL (GP) : loose to medium dense, grey red, coarse sized, dry.	D	L-MD		
	0.2	Fill	▩	CI	Fill sandy to gravelly CLAY (CI) : firm, medium plasticity, brown trace orange and red, fine to medium sized gravel, fine to medium grained sand, inorganic, w < pl to w ≈ pl.		F		
	0.4	Alluvial	░	SW	Alluvial SAND: fine to medium grained, with low to medium plasticity clay, brown trace grey.	D	L-MD		
	0.5 0.8	Alluvial	▨	SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, pale grey mottled orange trace brown.	M-D	L-MD		
	1 1.5 1.8	Alluvial	▨	CL-CI	Alluvial sandy CLAY: low to medium plasticity, fine to medium grained sand, pale grey trace orange and brown.		S-F		
	2	Residual	▨	SC	Residual clayey SAND: fine to medium grained, low to medium plasticity, pale grey mottled brown.	M-D	MD		
	2.5 3 3.5 4				**BH01 refusal at 2m (EOH in XW/HW Sandstone)**				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH02

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 2.9m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.25	Fill	▩	CI	Fill sandy to gravelly CLAY (CI) : firm, medium plasticity, brown with orange and grey, fine to coarse sized gravel, fine to coarse grained sand, inorganic, w < pl to w ≈ pl.		F		
	0.5 1 1	Alluvial	▨	CI	Alluvial sandy CLAY: medium plasticity, fine to medium grained sand, trace fine to medium sized gravel, pale brown orange, (trace roots) .		S-F		
	1.5 1.6	Alluvial	░	SM	Alluvial sandy SILT: low plasticity, fine grained sand, dark brown.	w < PL	S-F		
	2 2	Alluvial	▨	CL-CI	Alluvial sandy CLAY: low to medium plasticity, fine to coarse grained sand, grey trace dark grey.	w ≈ PL	S-F		
	2.5 2.5	Alluvial	▨	CI	Alluvial sandy CLAY: medium plasticity, fine to medium grained sand, grey.	w ≈ PL	S-F		
	2.8	Alluvial	▧	SC	Alluvial clayey SAND: fine to coarse grained, medium plasticity, grey dark grey, (trace roots, organic smell) .	W-M	L-MD		
		Rock	⁘	SST	Extremely weathered,rock SAND: medium to coarse grained, trace low to medium plasticity clay, orange trace red pale grey and white.	W	D		
	0				**BH02 refusal at 2.9m (EOH in XW/HW Sandstone)**				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH03

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 2.7m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
	0.3	Fill	▩	CI	Fill sandy to gravelly CLAY (CI) : firm, medium plasticity, brown with orange and grey, fine to coarse sized gravel, fine to coarse grained sand, inorganic, w < pl to w ≈ pl.		F	5 4 3	
	0.5	Alluvial	▧	SC	Alluvial clayey SAND: fine to coarse grained, low plasticity, brown.	M-D	L-MD	2 1	
	0.5 1 1.2	Alluvial	▧	SC	As above, but pale grey white trace brown.	M-D	L-MD	1 3 4 4 2 2 2	
	1.5 2	Alluvial	▨	CL-CI	Alluvial sandy CLAY: low to medium plasticity, fine to medium grained sand, pale grey white trace brown.	w ≈ PL	S-F	3 2 2 3 3 4 5 7	
	2 2.5 2.6	Residual	▧	SC	Residual clayey SAND: fine to medium grained, low plasticity, pale grey white trace orange.	M	MD	8 9	
		Rock	▒	SST	Extremely weathered,rock SAND: medium to coarse grained, trace low plasticity clay, pale grey white trace orange.	M	MD		
	0				**BH03 refusal at 2.7m (Refusal in XW/HW Sandstone)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH04

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 1.9m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.2	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown, (grass roots at surface) .	M-D	L-MD		
	0.5 0.6	Alluvial		SW	Alluvial SAND: fine to coarse grained, with low plasticity clay, pale grey trace orange and pale brown.	M-D	L-MD		
	1 1	Alluvial		SW	As above, but	M	L-MD		
	1.3	Residual		SC	Residual clayey SAND: fine to coarse grained, low plasticity, pale grey white trace orange.	M	MD		
	1.5 1.6	Residual		SW	Residual SAND: medium to coarse grained, with low plasticity clay, pale grey trace orange and red.	M	MD		
	1.8	Residual		SC	Residual clayey SAND: medium to coarse grained, low to medium plasticity, grey red orange.	W-M	MD		
		Rock		SST	Extremely weathered,rock SAND: medium to coarse grained, with low to medium plasticity clay, grey orange red.	W-M	D		
	2				**BH04 refusal at 1.9m (EOH at 1.9m in XW/HW Sandstone)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH05

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 2.4m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.2	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown.	M-D	L-MD		
	0.3	Alluvial		SW	Alluvial SAND: fine to medium grained, brown.	M-D	L-MD		
	0.5	Alluvial		SW	Alluvial SAND: fine to medium grained, orange brown.	M	L-MD		
	1.1	Alluvial		SW	Alluvial SAND: fine to coarse grained, pale grey trace orange.	M	MD		
	2	Alluvial		SC	Alluvial clayey SAND: fine to coarse grained, low plasticity, pale grey trace orange.	M	L-MD		
	2.3	Alluvial		SW	Alluvial SAND: medium to coarse grained, trace low plasticity clay, grey trace orange.	M-D	MD		
		Rock		SST	Extremely weathered,rock SAND: medium to coarse grained, with low plasticity clay, pale grey trace orange.	M-D	D		
					BH05 refusal at 2.4m (Refusal in XW/HW Sandstone)				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH06

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 1.7m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
		Topsoil	▥	SM	Topsoil silty SAND: fine to medium grained, brown.	M-D	L-MD	2	
	0.05	Alluvial	░	SW	Alluvial SAND: fine to coarse grained, brown, (trace roots) .	M-D	L-MD	2 2	
	0.25	Alluvial	░	SW	Alluvial SAND: fine to coarse grained, trace low plasticity clay, orange brown.	M	L-MD	3 3	
	0.5	Alluvial	▨	SC	Alluvial clayey SAND: fine to coarse grained, low plasticity, pale grey trace orange red.	M	L-MD	3 3 2 1 2	
	1	Alluvial	░	SW	Alluvial SAND: fine to coarse grained, with low plasticity clay, pale grey trace orange red.	M	L-MD	2 2	
	1.2	Residual	░	SW	Residual SAND: medium to coarse grained, trace low plasticity clay, grey red orange.	M	MD	5 7 10	
	1.5	Rock	▓	SST	Extremely weathered,rock SAND: fine to coarse grained, with low plasticity clay, pale grey orange red.	M	D	9	
					BH06 refusal at 1.7m (EOH at 1.7m in XW/HW Sandstone)				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH07

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 2.3m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.05	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown, (grass roots at surface) .	M-D	L-MD		
	0.4	Alluvial	░	SW	Alluvial SAND: fine to coarse grained, brown.	M-D	L-MD		
	0.5 0.7	Alluvial	░	SW	Alluvial SAND: fine to coarse grained, trace low to medium plasticity clay, brown.	M	L-MD		
	1 1.2	Alluvial	▨	SC	Alluvial clayey to gravelly SAND: fine to medium grained, fine to medium sized gravel, medium plasticity, grey brown trace pale grey mottled orange.	M	L-MD		
	1.5 1.5	Alluvial	▨	SC	Alluvial clayey SAND: fine to medium grained, low to medium plasticity, with fine to medium sized gravel, pale grey mottled orange.	M	MD		
	2 2	Residual	▨	SC	Residual clayey SAND: fine to coarse grained, low plasticity, pale grey trace orange.	M	MD		
		Rock	▒	SST	Extremely weathered,rock SAND: fine to coarse grained, pale grey and yellow.	D	MD		
	2.5 0				**BH07 refusal at 2.3m (EOH in XW/HW Sandstone)**				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH08

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 2.5m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.05	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown, (grass roots at surface) .	M-D	L-MD		
	0.4	Alluvial		SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, brown, (trace roots) .	M	L-MD		
	0.5 0.9	Alluvial		SW	Alluvial SAND: fine to medium grained, trace low plasticity clay, pale brown and orange brown.	M	L-MD		
	1 1.4	Alluvial		SC	Alluvial clayey SAND: fine to medium grained, medium plasticity, with fine to medium sized gravel, pale brown mottled red and orange.	M	MD		
	1.5 1.8	Residual		SC	As above, but residual	M	MD		
	2	Residual		SC	Residual clayey SAND: fine to coarse grained, low plasticity, pale grey white trace orange.	M	MD		
	2.3	Residual		SW	Residual SAND: medium to coarse grained, pale grey white and pale orange.	M-D	MD-D		
	2.5	Rock		SST	Extremely weathered,rock SAND: medium to coarse grained, pale grey white.	D	D		
	0				**BH08 refusal at 2.5m (EOH in XW/HW Sandstone)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH09

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.7m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.1	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown, (grass roots at surface) .	M-D	L-MD		
	0.4	Alluvial		SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, brown.	M-D	L-MD		
	0.8	Alluvial		SW	As above, but	M	L-MD		
	1.1	Alluvial		CI	Alluvial sandy CLAY: medium plasticity, fine to medium grained sand, orange brown.	w ≈ PL	F		
	1.4	Alluvial		CL-CI	Alluvial sandy CLAY: low to medium plasticity, fine to coarse grained sand, pale orange and pale grey.	w ≈ PL	F		
	2.2	Alluvial		CL-CI	As above, but pale grey and orange.	w ≈ PL	F		
	2.8	Residual		CL-CI	Residual sandy CLAY: low to medium plasticity, fine to coarse grained sand, grey with red and orange.		S		
	3.5	Residual		SC	Residual clayey SAND: medium to coarse grained, low to medium plasticity, pale grey with red and orange.	W-M	MD-D		
		Residual		SW	Residual SAND: medium to coarse grained, with low to medium plasticity clay, pale grey white red orange.	W	D		
					BH09 refusal at 3.7m (EOH at 3.7m in XW/HW Sandstone)				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH10

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 2.6m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.1	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown.	M-D	L-MD		
	0.35	Alluvial		SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, trace low plasticity clay, brown.	M-D	L-MD		
	0.5 1	Alluvial		SC	Alluvial clayey SAND: fine to coarse grained, low plasticity, orange brown trace red.	M	MD		
	1 1.5 2	Alluvial		SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, pale orange pale brown trace grey.	M	L-MD		
	2 2.4	Residual		SC	Residual clayey SAND: fine to coarse grained, low to medium plasticity, pale grey white mottled orange trace brown.	M	MD		
	2.5	Residual		SC	Residual clayey SAND: medium to coarse grained, low to medium plasticity, pale grey white red trace orange.	W-M	MD		
	2.5	Rock		SST	Extremely weathered,rock SAND: medium to coarse grained, pale grey , red and orange.	W-M	D		
	0				**BH10 refusal at 2.6m (EOH in XW/HW Sandstone)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH11

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 2.9m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
	0.1	Topsoil		SM	Topsoil silty SAND: fine to medium grained, brown.	M-D	L-MD	2	
	0.35	Residual		SW	Residual SAND: fine to medium grained, trace fine to medium sized gravel, brown.	M-D	L-MD	2 2 4	
	0.5 1	Alluvial		CL	Alluvial sandy CLAY: low plasticity, fine to coarse grained sand, orange brown.		F	3 2 2 1 0 2	
	1 1.5 2	Alluvial		SC	Alluvial clayey SAND: fine to medium grained, low plasticity, trace fine to medium sized gravel, orange brown.	M-D	MD	11 3 3 3 2 2 1 2 2 5	
	2 2.3	Alluvial		SC	As above, but orange brown trace red.	M	MD	5 13 11	
	2.5	Residual		SW	Residual SAND: fine to coarse grained, with low plasticity clay, pale grey pale brown mottled red trace dark red.	M	MD-D		
	2.5	Residual		SW	As above, but trace fine to coarse sized gravel, pale grey pale brown mottled red trace dark red and orange, ((trace ironstone gravels)) .	M	MD-D		
	3				**BH11 refusal at 2.9m (EOH in XW/HW Rock)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH12

UTM	:	**Driller Rig**	: Excavator	**Job Number**	: S1694
Easting	: 0.0	**Driller Supplier**	: Bayview Mini Excavations	**Client**	: Gardoxi Pty Ltd
Northing	: 0.0	**Logged By**	: Joe Stuart	**Project**	: Proposed Commercial Development
RL	: N/A	**Reviewed By**	:	**Location**	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 1.8m	**Date**	: 02/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
		Non-Soil		Mulch	Mulch			2 4	
	0.15	Alluvial		SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, brown.	M-D	L-MD	4 7 7	
	0.5	Alluvial		CL-CI	Alluvial sandy to gravelly CLAY: low to medium plasticity, fine to coarse sized gravel, fine to medium grained sand, orange brown trace red.	w ≈ PL	S-F	3 9 10 11 14 6 6 4 8 2 5 >25	
	1 1.5								
	2				**BH12 refusal at 1.8m (EOH at 1.8m in Ironstone gravels)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH13

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.8m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
	0.25	Alluvial	░	SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, brown, (trace roots) .	M-D	L-MD	2 2	
	1	Alluvial	▨	CL-CI	Alluvial sandy to gravelly CLAY: low to medium plasticity, fine to coarse sized gravel, fine to medium grained sand, orange brown.	w ≈ PL	S-F	2 3 6 4 2 1 3 9	
	1.6	Alluvial	▨	CL-CI	Alluvial sandy CLAY: low to medium plasticity, fine to medium grained sand, with fine to coarse sized gravel, orange brown.	w ≈ PL	S-F	6 3 4 5 2 5	
	2.5	Alluvial	▨░	SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, orange brown trace red.	M-D	MD	4 5 5 8 9	
	3	Alluvial	▨░	SC	As above, but	M-D	MD		
	3.4	Alluvial	▨░	SC	As above, but pale grey pale brown trace orange and red.	M	MD		
	3.6	Residual	░	SW	Residual SAND: fine to coarse grained, pale grey white with pale orange trace grey.	W-M	MD-D		
		Residual	░	SW	As above, but pale grey white pale orange and red.	W-M	MD-D		
	4				**BH13 Terminated at 3.8m (EOH at Target in XW Sandstone)**				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH14

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.3m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.05	Non-Soil		Mulch	Mulch				
	0.3	Topsoil		SM	Topsoil silty SAND: fine to medium grained, trace fine to medium sized gravel, dark brown.	M-D	L-MD		
	0.4	Alluvial		SW	Alluvial SAND: fine to medium grained, brown.	M-D	L-MD		
	0.5 1	Alluvial		CL-CI	Alluvial sandy to gravelly CLAY: low to medium plasticity, fine to coarse sized gravel, fine to medium grained sand, orange brown trace red.	w ≈ PL	S-F		
	1 1.5 1.6	Alluvial		CL-CI	Alluvial sandy to gravelly CLAY: low to medium plasticity, fine to coarse sized gravel, fine to medium grained sand, orange brown.		S		
	2 2	Alluvial		SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, grey white trace pale pale red and pale orange.	M	MD		
	2.4	Residual		SC	Residual clayey SAND: fine to medium grained, medium plasticity, trace fine to medium sized gravel, pale grey white with red and orange.	M	MD-D		
	2.5 3 3.1	Residual		SW	Residual SAND: fine to medium grained, pale grey white trace orange.	M-D	MD		
		Rock		SST	Extremely weathered,rock SAND: medium to coarse grained, trace low plasticity clay, red pale grey white orange.	W-M	MD-D		
	3.5 4				**BH14 refusal at 3.3m (EOH in XW/HW Sandstone)**				

FORTIFY GEOTECH

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH15

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 2.8m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 02/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.15	Non-Soil		Mulch	Mulch				
	0.3	Fill	▦	SW	Fill SAND (SW) : loose to medium dense, brown, fine to coarse grained, trace fine to medium sized gravel, moist to dry.	M-D	L-MD		
	1.3	Alluvial	▨	CL-CI	Alluvial sandy to gravelly CLAY: low to medium plasticity, fine to coarse sized gravel, fine to medium grained sand, orange brown trace red.	w ≈ PL	S-F		
	2	Alluvial	▨	SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, pale grey white mottled orange and red.	M	MD-D		
	2.6	Residual	▨	SC	Residual clayey SAND: fine to coarse grained, low plasticity, pale grey white trace red and orange.	W-M	MD-D		
		Residual	▨	SC	As above, but	W-M	D		
					BH15 refusal at 2.8m (EOH in XW/HW Sandstone)				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH16

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.7m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 03/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
								DCP	
	0.15	Topsoil	▥	SM	Topsoil silty SAND: fine grained, trace fine to medium sized gravel, dark brown.	M-D	MD	2 2	
	0.5	Alluvial	▨	SC	Alluvial clayey to gravelly SAND: fine to medium grained, fine to medium sized gravel, low plasticity, orange brown.	M-D	L-MD	2 0 1	
	1.1	Alluvial	▨	GC	Alluvial clayey to sandy GRAVEL: fine to coarse sized, fine to medium grained sand, low to medium plasticity, orange brown.	M-D	MD	2 >25	
	1.5	Alluvial	▨	GC	Alluvial clayey to sandy GRAVEL: fine to coarse sized, fine to coarse grained sand, low plasticity, pale red trace orange, (ironstone) .	M-D	MD		
	2.2	Alluvial	▨	SC	Alluvial clayey to gravelly SAND: medium to coarse grained, fine to coarse sized gravel, low plasticity, pale grey white red orange.	M	MD		
	2.6	Alluvial	▨	SC	Alluvial clayey to gravelly SAND: medium to coarse grained, fine to coarse sized gravel, low plasticity, pale grey white red orange.	W-M	MD		
	3	Residual	▨	SC	Residual clayey SAND: fine to medium grained, low to medium plasticity, pale grey white trace red.	M	MD		
	3.4	Residual	░	SW	Residual SAND: fine to coarse grained, trace low plasticity clay, pale grey white.	M-D	MD-D		
		Rock	▒	SST	Extremely weathered,rock SAND: medium to coarse grained, trace low plasticity clay, pale grey white and red, (xw/hw sandstone) .	D	D		
					BH16 refusal at 3.7m (EOH in XW/HW Sandstone)				

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015

Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH17

UTM	:	Driller Rig	: Excavator	Job Number	: S1694
Easting	: 0.0	Driller Supplier	: Bayview Mini Excavations	Client	: Gardoxi Pty Ltd
Northing	: 0.0	Logged By	: Joe Stuart	Project	: Proposed Commercial Development
RL	: N/A	Reviewed By	:	Location	: 40 Myoora Road, Terrey Hills NSW
Total Depth	: 3.9m	Date	: 03/05/2023		

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.15	Topsoil		SM	Topsoil silty SAND: fine grained, trace fine to medium sized gravel, dark brown, (grass roots at surface) .	M-D	L-MD		
	0.25	Alluvial		SW	Alluvial SAND: fine to medium grained, trace fine to medium sized gravel, dark brown, (trace roots) .	M-D	L-MD		
	0.5 0.5	Alluvial		SW	Alluvial SAND: fine to medium grained, with fine to medium sized gravel, with low to medium plasticity clay, orange brown.	M-D	L-MD		
	0.8	Alluvial		SC	Alluvial clayey to gravelly SAND: fine to medium grained, fine to medium sized gravel, low plasticity, orange brown.	M	L-MD		
	1 1.1	Alluvial		GC	Alluvial clayey to sandy GRAVEL: fine to coarse sized, fine to medium grained sand, low to medium plasticity, orange brown trace red.	M	MD		
	1.5 2 2.1	Alluvial		GW	Alluvial sandy GRAVEL: fine to coarse sized, fine to coarse grained sand, trace low plasticity clay, dark red trace orange, (ironstone) .	M-D	MD		
	2.4	Alluvial		SC	Alluvial clayey to gravelly SAND: medium to coarse grained, fine to coarse sized gravel, low plasticity, pale grey white red orange.	M	MD		
	2.5 2.7	Residual		SC	Residual clayey SAND: fine to medium grained, low plasticity, pale grey white trace red.	M	MD		
	3 3.2	Residual		SW	Residual SAND: fine to coarse grained, trace low plasticity clay, pale grey white.	M-D	MD-D		
	3.4	Residual		SW	As above, but with low plasticity clay, pale grey white trace red.	M-D	MD-D		
	3.5	Residual		SW	As above, but trace low plasticity clay.	M-D	MD-D		
	4				**BH17 Terminated at 3.9m (EOH in XW/HW Sandstone)**				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH18

UTM :	**Driller Rig** : Excavator	**Job Number** : S1694
Easting : 0.0	**Driller Supplier** : Bayview Mini Excavations	**Client** : Gardoxi Pty Ltd
Northing : 0.0	**Logged By** : Joe Stuart	**Project** : Proposed Commercial Development
RL : N/A	**Reviewed By** :	**Location** : 40 Myoora Road, Terrey Hills NSW
Total Depth : 1.05m	**Date** : 03/05/2023	

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
	0.2	Topsoil		SM	Topsoil silty SAND: fine grained, trace fine to medium sized gravel, dark brown.	M	L-MD	1 4	
	0.4	Alluvial		SW	Alluvial SAND: fine to medium grained, with fine to medium sized gravel, with low plasticity clay, orange brown.	M-D	L-MD	3 4	
	0.5 0.8	Alluvial		SC	Alluvial clayey to gravelly SAND: fine to medium grained, fine to medium sized gravel, low plasticity, orange brown.	M-D	L-MD	4 4 6 6	
	1	Alluvial		GC	Alluvial clayey to sandy GRAVEL: fine to coarse sized, fine to medium grained sand, low to medium plasticity, orange brown.	M-D	MD	5 5 4	
	1.5 2				**BH18 refusal at 1.05m (EOH in Ironstone)**			2 >25	

FORTIFY
GEOTECH

Fortify Geotech

U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH19

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.9m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 03/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing	Samples
	0.15	Fill	▦	GW	Fill sandy GRAVEL (GW) : medium dense, dark grey brown, fine to coarse sized, fine to coarse grained sand, dry.	D	MD		
	0.35	Fill	▦	CI	Fill sandy to gravelly CLAY (CI) : firm to stiff, medium plasticity, grey brown trace orange , black, fine to coarse sized gravel, fine to medium grained sand, inorganic, w ≈ pl.	w ≈ PL	F-St		
	0.6	Alluvial	░	SW	Alluvial SAND: fine to medium grained, with fine to medium sized gravel, trace low plasticity clay, orange brown.	M-D	L-MD		
	0.9	Alluvial	▨	SC	Alluvial clayey to gravelly SAND: fine to coarse grained, fine to coarse sized gravel, low plasticity, orange brown.	M-D	MD		
	1.2	Alluvial	▨	GC	As above, but clayey to sandy GRAVEL: fine to coarse sized, fine to coarse grained sand, orange brown trace red.	M-D	MD		
		Ironstone	░						
	2.4	Alluvial	▨	SC	Alluvial clayey SAND: fine to coarse grained, low to medium plasticity, with fine to coarse sized gravel, pale grey orange red.	M	MD		
	2.6	Alluvial	░	SW	As above, but with low to medium plasticity clay, orange red.	M	MD		
	3	Residual	░	SW	Residual SAND: medium to coarse grained, pale grey white and orange.	M-D	MD-D		
	3.2	Residual	░	SW	Residual SAND: medium to coarse grained, trace low plasticity clay, pale grey white.	M-D	MD-D		
		Residual	░	SW	Residual SAND: medium to coarse grained, pale grey white and orange, (xw sandstone) .	M-D	MD-D		
					BH19 Terminated at 3.9m (EOH in XW/HW Sandstone)				

Fortify Geotech
U2/538 Gardeners Road, Alexandria NSW 2015
Phone: 02 9188 4033

Engineering Log - Borehole

Borehole No: BH20

UTM :
Easting : 0.0
Northing : 0.0
RL : N/A
Total Depth : 3.9m

Driller Rig : Excavator
Driller Supplier : Bayview Mini Excavations
Logged By : Joe Stuart
Reviewed By :
Date : 03/05/2023

Job Number : S1694
Client : Gardoxi Pty Ltd
Project : Proposed Commercial Development
Location : 40 Myoora Road, Terrey Hills NSW

Water	Depth (m)	Soil Origin	Graphic Log	Classification Code	Material Description	Moisture	Consistency	Testing DCP	Samples
	0.05	Non-Soil		Mulch	Mulch			3	
	0.25	Fill		SM	Fill silty SAND (SM) : loose to medium dense, dark brown, fine to medium grained, trace fine to medium sized gravel, moist to dry.	M-D	L-MD	2	
	0.7	Alluvial		SC	Alluvial clayey to gravelly SAND: fine to coarse grained, fine to medium sized gravel, low to medium plasticity, orange brown trace red.	M	MD	4 4 2 1 1	
	1.4	Alluvial		GC	Alluvial clayey to sandy GRAVEL: fine to medium sized, fine to coarse grained sand, low to medium plasticity, orange brown trace red, (ironstone gravels) .	M	MD	5 5 5 6 12 25 12	
	1.7	Alluvial		CL	Alluvial sandy CLAY: low plasticity, fine to coarse grained sand, orange brown.		S	7	
	2.5	Alluvial		SC	Alluvial clayey SAND: fine to coarse grained, low plasticity, pale grey white mottled red and orange.	W-M	MD		
	2.8	Residual		SC	As above, but residual pale grey white trace red and orange.	W-M	MD-D		
	3.8	Residual		SC	Residual clayey SAND: fine to medium grained, low plasticity, pale grey white.	M-D	MD		
		Residual		SC	As above, but	M-D	D		
					BH20 Terminated at 3.9m (EOH at Target)				

Depth scale: 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4

Appendix B

CBR Laboratory Test Results

Material Test Report

J & A Geotech Testing Pty Ltd

Canberra Laboratory
Unit 2, 25 Dacre Street Mitchell ACT 2911
Phone: (02) 6255 5363
Email: justin.smith@jageotech.com.au

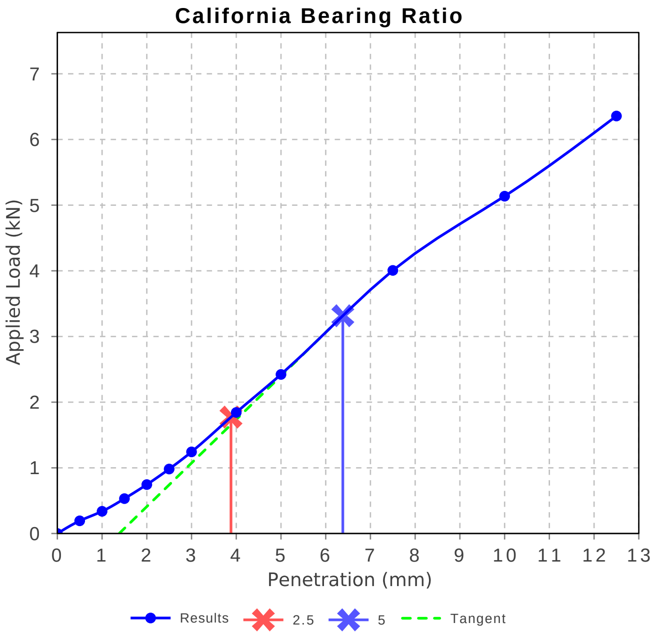
Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Ben Charlton
Assistant Manager
NATA Accredited Laboratory Number: 19979

Report Number: **CP231443-1**
Issue Number: 1
Date Issued: 17/05/2023
Client: Fortify Geotech Pty Ltd
PO Box 9225, Deakin ACT 2600
Project Number: CP231443
Project Name: 40Myoora Road
Project Location: Terry Hills NSW
Client Reference: S1694
Work Request: 7906
Sample Number: CS7906A
Date Sampled: 03/05/2023
Dates Tested: 05/05/2023 - 16/05/2023
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: AS 1289.1.1 - Sampling and preparation of soils
Site Selection: Selected by Client
Sample Location: **BH3/1D, Depth: 0.5m-0.8m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**17**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	1.93		
Optimum Moisture Content (%)	10.5		
Laboratory Density Ratio (%)	98.0		
Laboratory Moisture Ratio (%)	100.5		
Dry Density after Soaking (t/m^3)	1.88		
Field Moisture Content (%)	13.8		
Moisture Content at Placement (%)	10.6		
Moisture Content Top 30mm (%)	13.0		
Moisture Content Rest of Sample (%)	12.4		
Mass Surcharge (kg)	9.0		
Soaking Period (days)	4		
Curing Hours	48.4		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		



Material Test Report

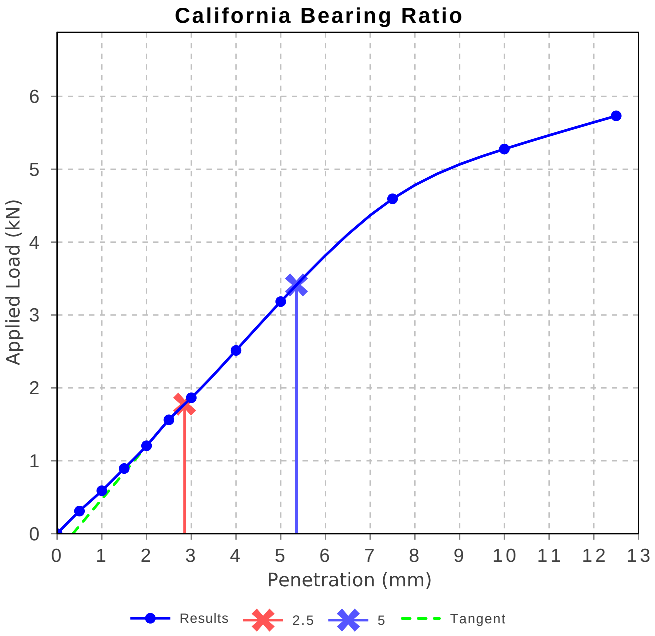
J & A Geotech Testing Pty Ltd

Canberra Laboratory
Unit 2, 25 Dacre Street Mitchell ACT 2911
Phone: (02) 6255 5363
Email: justin.smith@jageotech.com.au
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Ben Charlton
Assistant Manager
NATA Accredited Laboratory Number: 19979

Report Number: **CP231443-1**
Issue Number: 1
Date Issued: 17/05/2023
Client: Fortify Geotech Pty Ltd
PO Box 9225, Deakin ACT 2600
Project Number: CP231443
Project Name: 40Myoora Road
Project Location: Terry Hills NSW
Client Reference: S1694
Work Request: 7906
Sample Number: CS7906B
Date Sampled: 03/05/2023
Dates Tested: 05/05/2023 - 16/05/2023
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: AS 1289.1.1 - Sampling and preparation of soils
Site Selection: Selected by Client
Sample Location: **BH7/1D, Depth: 0.4m-0.7m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**17**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	2.01		
Optimum Moisture Content (%)	9.0		
Laboratory Density Ratio (%)	97.5		
Laboratory Moisture Ratio (%)	100.5		
Dry Density after Soaking (t/m^3)	1.95		
Field Moisture Content (%)	12.4		
Moisture Content at Placement (%)	9.2		
Moisture Content Top 30mm (%)	12.1		
Moisture Content Rest of Sample (%)	11.5		
Mass Surcharge (kg)	9.0		
Soaking Period (days)	4		
Curing Hours	48.4		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		



Material Test Report

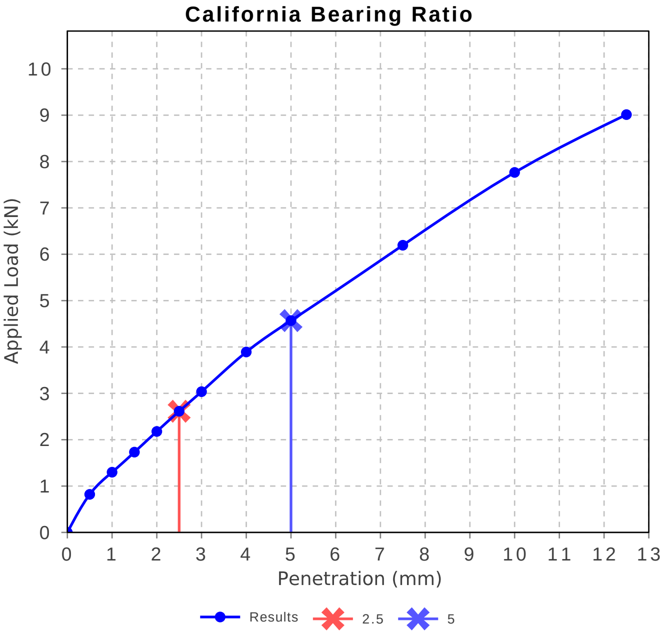
J & A Geotech Testing Pty Ltd
Canberra Laboratory
Unit 2, 25 Dacre Street Mitchell ACT 2911
Phone: (02) 6255 5363
Email: justin.smith@jageotech.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Ben Charlton
Assistant Manager
NATA Accredited Laboratory Number: 19979

Report Number: **CP231443-1**
Issue Number: 1
Date Issued: 17/05/2023
Client: Fortify Geotech Pty Ltd
PO Box 9225, Deakin ACT 2600
Project Number: CP231443
Project Name: 40Myoora Road
Project Location: Terry Hills NSW
Client Reference: S1694
Work Request: 7906
Sample Number: CS7906C
Date Sampled: 03/05/2023
Dates Tested: 05/05/2023 - 16/05/2023
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: AS 1289.1.1 - Sampling and preparation of soils
Site Selection: Selected by Client
Sample Location: **BH12/1D, Depth: 0.5m-0.8m**

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**25**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	2.04		
Optimum Moisture Content (%)	10.0		
Laboratory Density Ratio (%)	97.5		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.98		
Field Moisture Content (%)	13.2		
Moisture Content at Placement (%)	10.1		
Moisture Content Top 30mm (%)	14.4		
Moisture Content Rest of Sample (%)	12.1		
Mass Surcharge (kg)	9.0		
Soaking Period (days)	4		
Curing Hours	48.5		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	10.5		



Material Test Report

Report Number: **CP231443-1**
Issue Number: 1
Date Issued: 17/05/2023
Client: Fortify Geotech Pty Ltd
PO Box 9225, Deakin ACT 2600
Project Number: CP231443
Project Name: 40Myoora Road
Project Location: Terry Hills NSW
Client Reference: S1694
Work Request: 7906
Sample Number: CS7906D
Date Sampled: 03/05/2023
Dates Tested: 05/05/2023 - 16/05/2023
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: AS 1289.1.1 - Sampling and preparation of soils
Site Selection: Selected by Client
Sample Location: **BH20/1D, Depth: 0.4m-0.7m**

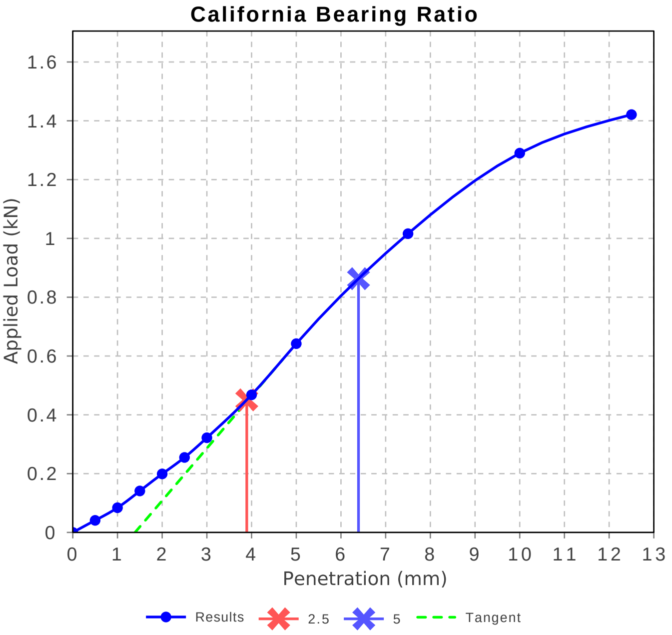
J & A Geotech Testing Pty Ltd
Canberra Laboratory
Unit 2, 25 Dacre Street Mitchell ACT 2911
Phone: (02) 6255 5363
Email: justin.smith@jageotech.com.au

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Ben Charlton
Assistant Manager
NATA Accredited Laboratory Number: 19979

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**4.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	visual		
Maximum Dry Density (t/m^3)	2.05		
Optimum Moisture Content (%)	10.5		
Laboratory Density Ratio (%)	98.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	2.01		
Field Moisture Content (%)	11.6		
Moisture Content at Placement (%)	10.6		
Moisture Content Top 30mm (%)	12.2		
Moisture Content Rest of Sample (%)	11.6		
Mass Surcharge (kg)	9.0		
Soaking Period (days)	4		
Curing Hours	48.4		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	3.3		



FORTIFY
GEOTECH

Appendix C

Engineering terms and Definitions

DESCRIPTION AND CLASSIFICATION OF SOIL

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 2017, Geotechnical site investigations. In general, soils are described along the following characteristics: soil name, plasticity or behavioural or particle characteristics of the primary soil component, colour, secondary soil components' plasticity or behavioural or particle characteristics, condition, structure, inclusions, strength or density and origin.

GENERAL DEFINITION - SOIL

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System.

SOIL ORIGIN

Soil origins fall into the following categories:

Residual soil:	Soils which have been formed in-situ by the chemical weathering of parent rock. These soils no longer retain any visible structure or fabric of the parent soil or rock material.
Extremely weathered material:	Formed directly from in situ weathering of geological formations. Although this material of soil strength it retains the structure and/or fabric of the parent rock material.
Alluvial soil:	Deposited by streams and rivers.
Estuarine soil:	Deposited in coastal estuaries, and including sediments carried by inflowing rivers and streams, and tidal currents.
Marine soil:	Deposited in a marine environment.
Lacustrine soil:	Deposited in freshwater lakes.
Aeolian soil:	Carried and deposited by wind.
Colluvial soil:	Soil and rock debris transported down slopes by gravity, with or without the assistance of flowing water.
Topsoil:	Mantle of surface and/or near-surface soil often but not always defined by high levels of organic material, both dead and living.
Fill:	Any material which has been placed by anthropogenic processes.

SOIL CLASSIFICATION

PARTICLE SIZE DEFINITIONS

Soil components are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

Classification	Components	Subdivision	Particle Size (mm)
Oversize	Boulders		>200
	Cobbles		63 to 200
Coarse grained soil	Gravel	Coarse	19 to 63
		Medium	6.7 to 19
		Fine	2.36 to 6.7
	Sand	Coarse	0.6 to 2.36
		Medium	0.21 to 0.6
		Fine	0.075 to 0.21
Fine grained soil	Silt		0.002 to 0.075
	Clay		<0.002

MOISTURE CONDITION

Coarse Grained Soil		**Fine Grained Soil**	
Dry (D)	Non-cohesive and free-running.	Moist, dry of plastic limit ($w<W_P$)	Hard and friable or powdery.
Moist (M)	Soil feels cool, darkened in colour. Soil tends to stick together.	Moist, near plastic limit ($w \approx W_P$)	Soils can be moulded at a moisture content approximately equal to the plastic limit.
Wet (W)	As for moist, with free water forming when handled.	Moist, wet of plastic limit ($w>W_P$)	Soils usually weakened and free water forms on hands when handling.
		Wet, near liquid limit ($w \approx W_L$)	Near liquid limit.
		Wet, wet of liquid limit ($w>W_L$)	Wet of liquid limit.

CONSISTENCY/RELATIVE DENSITY

Cohesive soils are classified on the ease by which the soil can be remoulded and can be either assessed in the field by tactile means, by laboratory testing or through mechanical determination methods. Non-cohesive soils are classified on the basis of relative density, generally from the results of in-situ penetration tests and terms for both are defined as below:

Cohesive Soils			**Non-cohesive Soils**	
Consistency	**Indicative Undrained Shear Strength s_u(kPa)**	**Field Guide to Consistency**	**Term**	**Relative Density (%)**
Very soft (VS)	≤12	Exudes between the fingers when squeezed in hand.	Very Loose (VL)	≤15
Soft (S)	>12 - ≤25	Can be moulded by light finger pressure.	Loose (L)	>15 - ≤35
Firm (F)	>25 - ≤50	Can be moulded by strong finger pressure.	Medium Dense (MD)	>35 - ≤65
Stiff (St)	>50 - ≤100	Cannot be moulded by fingers.	Dense (D)	>65 - ≤85
Very Stiff (VSt)	>100 - ≤200	Can be indented by thumb nail.	Very Dense (VD)	>85
Hard (H)	>200	Can be indented with difficulty by thumb nail.		
Friable (Fr)	-	Can be easily crumbled or broken into small pieces by hand.		

MINOR COMPONENTS

Descriptive Term	Assessment Guide	Proportion of minor component in:
With	Easily detectable by visual or tactile means and little difference between general properties and properties of primary component.	Coarse grained soils: Fines – 5 to 12% Accessory coarse component – 15 to 30% Fine grained soils: Coarse component - 15 to 30%
Trace	Detectable by visual or tactile means but little or no difference between general properties and properties of primary component.	Coarse grained soils: Fines – <5% Accessory coarse component – <15% Fine grained soils: Coarse component - <15%

CEMENTATION

Where cementation is present in soils, they can be either weakly cemented where they are easily disaggregated by hand in air or water or moderately cemented where effort is required to disaggregate the soil by hand in air or water.

SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.
2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 “Testing Soils for Engineering Purposes” – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63kg hammer having a free fall of 750mm.

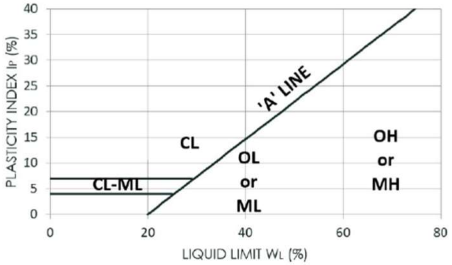
The “N” value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

Unified Soil Classification System (Metricated)
Data for Description Identification and Classification of Soils

MAJOR DIVISIONS				DESCRPTION				FIELD IDENTIFICATION								LABORATORY CLASSIFICATION					
				Group Symbol	Graphic Symbol	TYPICAL NAME	DESCRIPTIVE DATA				GRAVELS AND SANDS				Group Symbol		% < 0.075 mm	PLASTICITY OF FINE FRACTION	Coefficient of Uniformity C_U	Coefficient of Curvature C_C	Notes
											GRADATIONS		NATURE OF FINES	DRY STRENGTH							
COARSE GRAINED SOILS	More than 65% by dry mass, less than 63mm is greater than 0.075mm.	GRAVELS	More than 50% of coarse grains are greater than 2.36mm.	GW	●	Well graded gravels and gravel-sand mixtures, little or no fines	Give soil name, indicate approximate percentages of sand and gravel, particle characteristics including particle size subdivision, particle shape, colour, secondary component characteristics and other pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure including zoning, defects and cementing, moisture condition, and relative density. Example: (SP) SAND, trace silt, grey, medium grained, medium dense; dry; Tomago Sand Beds.	COARSE GRAINED SOILS	More than 65% of material less than 63mm is greater than 0.075mm.	A 0.075mm particle is about the smallest particle visible to the naked eye.	GOOD	Wide range in grain size	"Clean" materials (not enough fines to bond coarse grains)	None	GW	Use the gradation curve of material passing 63mm for classification of fractions according to criteria for major component.	0-5	-	>4	Between 1 and 3	1. Identify fines by the method given for fine grained soils. 2. For fines contents between 5% and 12%, the soil shall be given a dual classification comprising the two group symbols separated by a dash, e.g. for a gravel with between 5% and 12% silt fines, the classification is GP-GM. 3. Soils that are dominated by boulders, cobbles or peat (Pt) are described separately and are not classified.
				GP	○	Poorly graded gravels and gravel-sand mixtures, little or no fines					POOR	Predominantly one size or range of sizes			GP		0-5	-	Fails to comply with above		
		GRAVELLY SOILS		GM	○	Silty gravels, gravel-sand-silt mixtures					GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are silty (1)	None to medium	GM		12-50	Below 'A' line and $I_P > 7$	-	-	
				GC	▨	Clayey gravels gravel-sand-clay mixtures							Fines are clayey (1)	Medium to high	GC		12-50	Above 'A' line and $I_P > 7$	-	-	
		SANDS	More than 50% of coarse grains are less than 2.36mm.	SW	⁘	Well graded sands and gravelly sands, little or no fines					GOOD	Wide range in grain size	"Clean" materials (not enough fines to bond coarse grains)	None	SW		0-5	-	>6	Between 1 and 3	
				SP	∴	Poorly graded sands, little or no fines					POOR	Predominantly one size or range of sizes			SP		0-5	-	Fails to comply with above		
		SANDY SOILS		SM	⁚	Silty sand, sand-silt mixtures					GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are silty (1)	None to medium	SM		12-50	Below 'A' line or $I_P < 4$	-	-	
				SC	▨	Clayey sands, sand-clay mixtures							Fines are clayey (1)	Medium to high	SC		12-50	Above 'A' line and $I_P > 7$	-	-	

									SILT AND CLAY FRACTION						
									Fraction smaller than 0.2 mm AS sieve size						
									DRY STRENGTH	DILANTANCY	TOUGHNESS				
FINE GRAINED SOILS	More than 35% by dry mass, less than 63mm is less than 0.075mm.	Liquid Limit less than 50%.	ML	∣∣∣	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give soil name, indicate degree and character of plasticity, colour, secondary component characteristics other pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure including zoning, defects and cementing, moisture condition, and consistency. Example: (CI) CLAY, with gravel, red-brown, medium plasticity, very stiff; gravel 20%, fine to medium, sub-rounded; moist, with desiccation cracks; residual.	FINE GRAINED SOILS	More than 35% of material less than 63mm is smaller than 0.075mm.	None to low	Slow to rapid	Low	ML		More than 35% of material is less than 63mm passing 0.075mm.	Below 'A' line
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays				Medium to high	None to slow	Medium	CL, CI			Above 'A' line
			OL	☰	Organic silts and organic silty clays of low plasticity				Low to medium	Slow	Low	OL			Below 'A' line
		Liquid Limit more than 50%.	MH	▥	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts				Low to medium	None to slow	Low to medium	MH			Below 'A' line
			CH	▨	Inorganic clays of high plasticity, fat clays				High to very high	None	High	CH			Above 'A' line
			OH	≈	Organic clays of medium to high plasticity				High to high	None to very slow	Low to medium	OH			Below 'A' line
			Pt	⁂	Peat muck and other highly organic soils		Readily identified by colour, odour, spongy feel and generally fibrous texture					PT		* Effervescence with H_2O_2	



PLASTICITY CHART
FOR CLASSIFICATION
OF FINE GRAINED SOILS

DESCRIPTION AND CLASSIFICATION OF ROCK

The methods of description and classification of rock used in this report are based on the Australian Standard 1726 – 2017, Geotechnical site investigations. In general, descriptions cover the following properties for rock – rock name, grain size, colour, fabric and texture, inclusions or minor components, moisture content, durability, rock material condition including strength and weathering and/or alteration, defects and geological description.

GENERAL DEFINITIONS – ROCK

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces. Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one. Rock material is intact rock that is bounded by defects.

DEFECT Discontinuity, fracture, break or void in the material or materials across which there is little or no tensile strength.

STRUCTURE The nature and configuration of the different defects within the rock mass and their relationship to each other.

ROCK MASS The entirety of the system formed by all of the rock material and all the defects that are present.

DESCRIPTIVE TERMS

ROCK NAME

Simple rock names are used rather than precise geological classification. Rock names fall into category types of sedimentary rocks, igneous rocks, metamorphic rocks and duricrust rocks.

PARTICLE SIZE

Grain size terms for sedimentary rocks with predominantly sand sized grains are:

Coarse grained – mainly 0.6mm to 2mm.

Medium grained – mainly 0.2mm to 0.6mm.

Fine grained – mainly 0.06mm (just visible) to 0.2mm.

In igneous and metamorphic rock types, where significant, the following terms are used to describe the dominant or average grain size and/or the grain size may be recorded in millimetres:

Coarse grained – mainly greater than 2mm.

Medium grained – mainly 0.06mm to 2mm.

Fine grained – mainly less than 0.06mm (just visible).

If readily identifiable, the minerals should be described.

FABRIC

When the arrangement of grains shows an alignment, a preferred orientation or a layering that is visible, descriptive terms for sedimentary rocks are bedding and lamination. Bedding is layering produced by changes in sedimentation. Lamination is similar to bedding but developed in layer thicknesses of less than 20mm. Fabric descriptive terms for metamorphic rocks are foliation, which is the parallel arrangement of minerals due to metamorphic processes and cleavage, which is a type of foliation developed in fine grained metamorphic rocks such as slates. For igneous rocks, flow banding is a layering produced during flow of a partially solidified igneous rock that causes crystals to become oriented.

INDISTINCT FABRIC

Where layering or fabric is just visible. There is little effect on strength properties.

DISTINCT FABRIC

Where layering or fabric is easily visible. The rock may break more easily parallel to the fabric.

ROCK WEATHERING DEFINITIONS

Extremely Weathered (XW)	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Soil Classification System, but the texture of the original rock is still evident.
Highly Weathered (HW)	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered (MW)	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered (SW)	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually limonite, has taken place. The colour and texture of fresh rock is recognisable.
Fresh (FR)	Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are of low strength, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

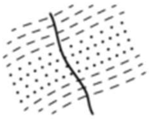
ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	**Point Load Strength Index $I_{s(50)}$ MPa**	**Field Guide**	**Approx Unconfined Compressive Strength MPa***
Very Low Strength (VL)	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30mm thick can be broken by finger pressure.	0.6 to 2
Low Strength (L)	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.	2 to 6
Medium Strength (M)	0.3 to 1	Readily scored with a knife; a piece of core 150mm long x 50mm dia. can be broken by hand with difficulty.	6 to 20
High Strength (H)	1 to 3	A piece of core 150mm long x 50mm dia. cannot be broken by hand but can be broken by a pick with a single firm blow, rock rings under hammer.	20 to 60
Very High Strength (VH)	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.	60 to 200
Extremely High Strength (EH)	more than 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.	more than 200

ROCK DEFECT TYPES

This classification applies to the range of possible rock defect types that are types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

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

The spacing, length (sometimes called persistence), aperture (openness), and seam thickness should generally be described directly in millimetres or metres.

ROCK DEFECT DESCRIPTIONS

DEFECT ROUGHNESS TERMS		DEFECT SHAPE TERMS		DEFECT COATING TERMS	
Term	**Description**	**Term**	**Description**	**Term**	**Description**
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.	Planar	The defect does not vary in orientation.	Clean	No visible coating.
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.	Curved	The defect has a gradual change in orientation.	Stained	No visible coating but surfaces are discoloured.
Smooth	Smooth to touch. Few or no surface irregularities.	Undulating	The defect has a wavy surface.	Veneer	A visible coating or soil or mineral, too thin to measure; may be patchy.
Polished	Shiny smooth surface.	Stepped	The defect has one or more well defined steps.	Coating	A visible coating up to 1mm thick. Thicker soil material should be described using appropriate defect terms (e.g. infilled seam). Thicker rock strength material should be described as a vein.
Slickensided	Grooved or striated surface, usually polished.	Irregular	The defect has many sharp changes of orientation.		

FORTIFY
GEOTECH

Appendix D

Qualitative Terminology of Risk Management

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

FORTIFY
GEOTECH

Appendix E

Flowchart for Landslide Risk Management

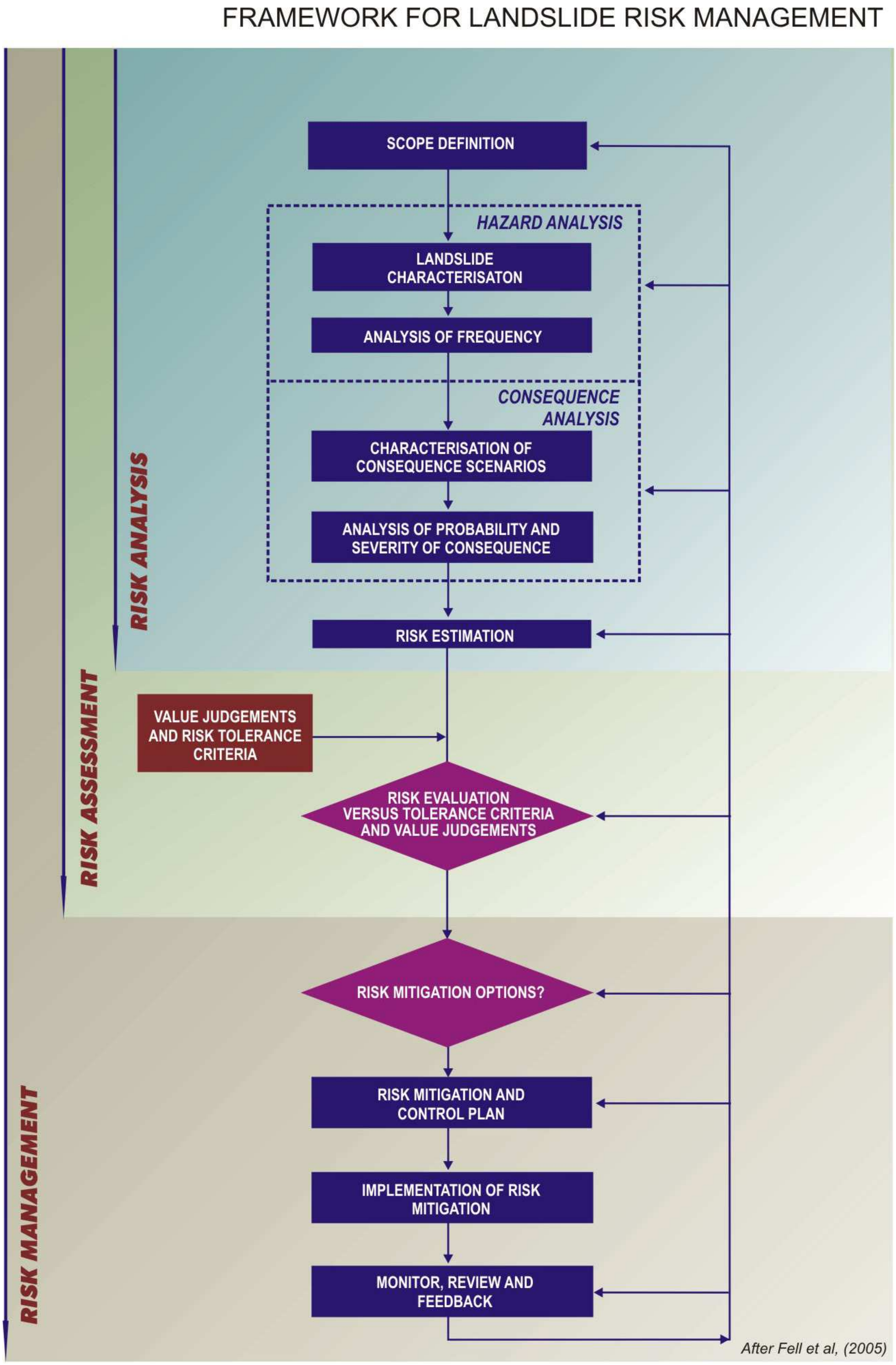


Figure 2: Abbreviated flowchart for Landslide Risk Management.
Ref: AGS (2007a, 2007c)

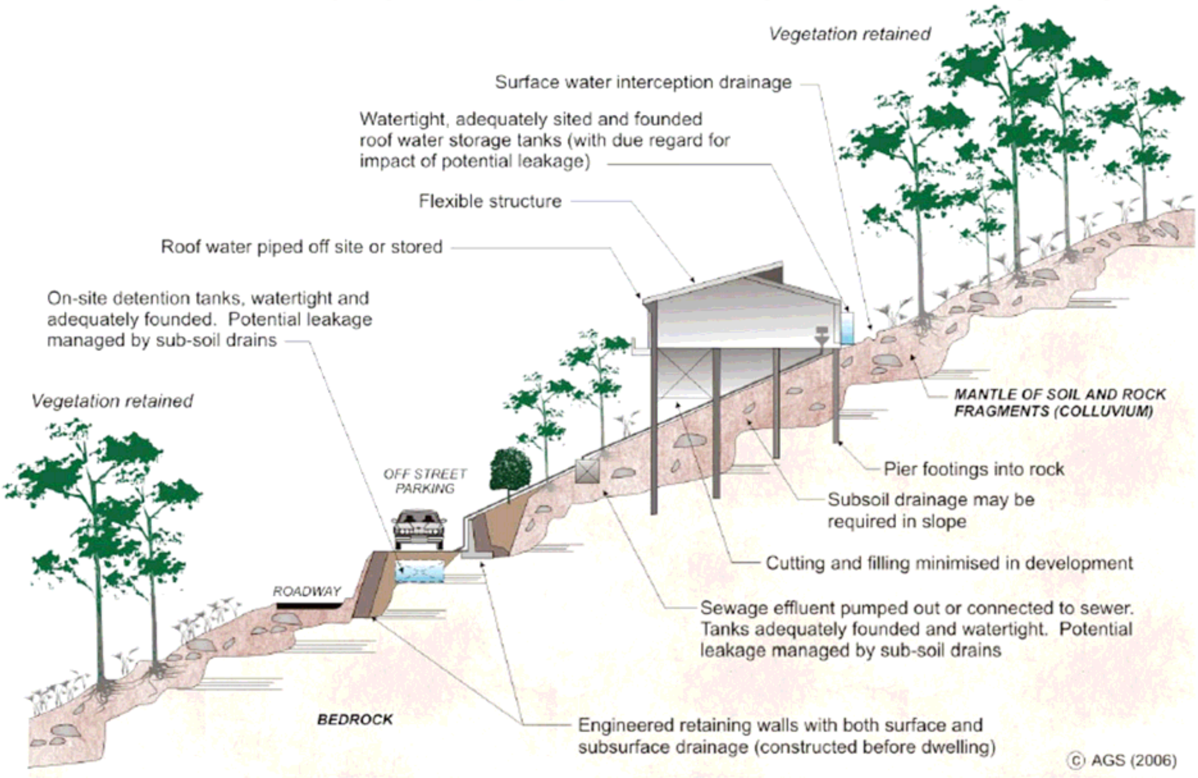
Appendix F

Guidelines for Hillside Construction

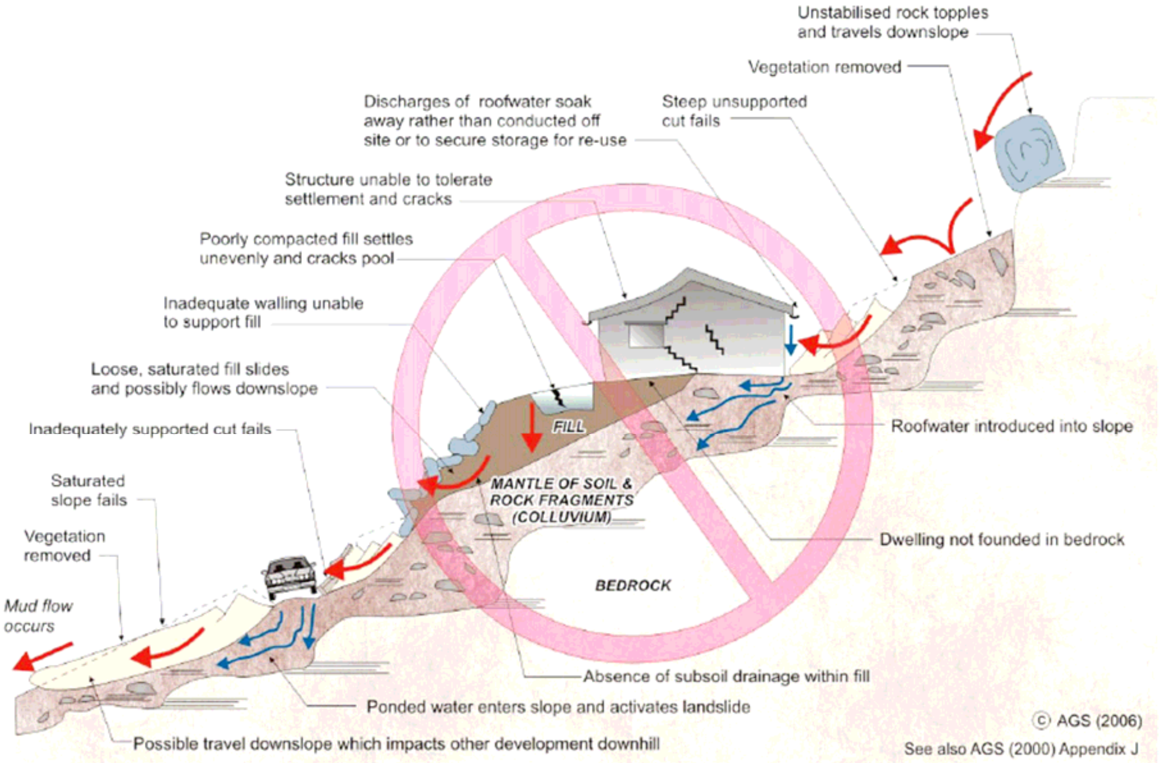
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



Foundation Maintenance and Footing Performance: A Homeowner's Guide

PUBLISHING
BTF 18-2011
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 2870-2011, 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, which may experience only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes

Notes

1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).

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.

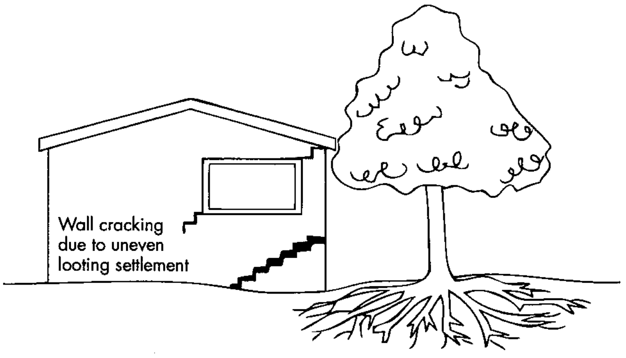
Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends 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.

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.

Trees can cause shrinkage and damage



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 causes 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 2870-2011.

AS 2870-2011 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.

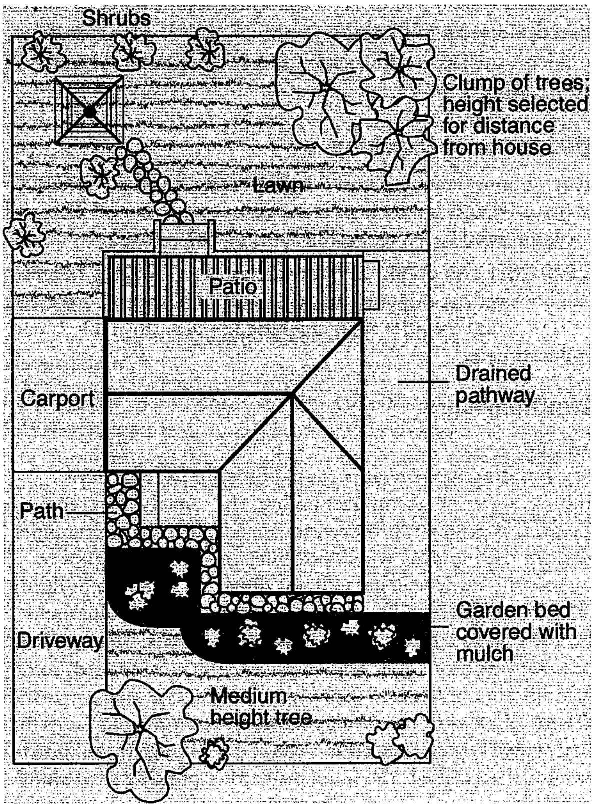
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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.

Distributed by
CSIRO PUBLISHING Locked Bag 10, Clayton South VIC 3169
Tel (03) 9545 8400 1300 788 000 www.publish.csiro.au
Email: publishing.sales@csiro.au

FORTIFY
GEOTECH

Appendix G

Limitations in the Use and Interpretation of this Report

Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors/purchasers of the site and/or for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observes in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual. Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

The boring logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations. In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations.

The data derived from the site investigation program and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.