Geotechnical Assessment

Project: Alterations & Additions
21 Park Street, Collaroy NSW

Prepared for:
Glenn Davis & Priscila Wagner

Ref: AG 24195
10 July 2024

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WHAT TO DO WITH THIS REPORT

While your geotechnical assessment report may be a statutory requirement from council in support of your development application, it also contains information important to the structural design and construction methodology of your project. Therefore, it is critical that all relevant parties are provided with a copy of this report.

We suggest you give a copy of your geotechnical assessment report to:

- ☐ **Your Architect/Building Designer**
- ☐ **Your Certifier**
- ☐ **Your Excavation Contractor**
- ☐ **Your Structural/Stormwater/Civil Engineer**
- ☐ **Your Project Manager**
- ☐ **Your Builder**

We would also suggest that if any of your project team have questions regarding the contents of this report, that we be contacted for clarification.

NEXT CRITICAL STAGES

Keep in mind that you will need AscentGeo again at different stages of your project. This may include:

- ☐ **Review or endorsement of structural plans/architectural plans for a Construction Certificate**
- ☐ **Foundation/Footing inspection during construction**
- ☐ **Excavation hold point inspection, usually at hold points not exceeding 1.5m drops**
- ☐ **Final inspection and certification for an Occupation Certificate upon completion of works**

GENERAL ADVICE

If after reading this report you have any questions, are unsure what to do next or when you need to get in touch, please reach out to us.

Given AscentGeo can't be on site the whole time, we recommend that you or/and your builder take a lot of progress photos, especially during excavation. Many of the potential problems that may pop up can be resolved if we have clear photos of the work that's been done.

A lot can change on site during a construction project: some of these changes are normal and innocuous, while others can be symptoms of larger or more serious issues. For this reason, it's important to contact us to discuss any changes you notice on site that you aren't sure about. This could include but not be limited to changes to ground or surface water, movement of structures, and settlement of paths or landscaping elements.

We're here to help.

The AscentGeo Team

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Geotechnical Assessment

For **Alterations & Additions** at

21 Park Street, Collaroy NSW

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<tr><th colspan="3">Document Status</th><th colspan="2">Approved for Issue</th></tr>
<tr><th>Version</th><th colspan="2">Author</th><th>Reviewer</th><th>Date</th></tr>
<tr><td>1</td><td colspan="2">Cameron Young
BEnvSci Geol MAIG</td><td>Ben Morgan
BScGeol MAIG RPGeo</td><td>10.07.2024</td></tr>
<tr><th colspan="5">Document Distribution</th></tr>
<tr><th>Version</th><th>Copies</th><th>Format</th><th>To</th><th>Date</th></tr>
<tr><td>1</td><td>1</td><td>PDF</td><td>Glenn Davis & Priscila Wagner</td><td>10.07.2024</td></tr>
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Limitations

This report has been prepared for the owners Glenn Davis & Priscila Wagner in accordance with AscentGeo's fee proposal dated 14 May 2024.

The report is provided for the exclusive use of the property owner and their nominated agents for the specific development and purpose as described in the report. This report must not be used for purposes other than those outlined in the report or applied to any other projects.

The information contained within this report is considered accurate at the time of issue with regard to the current conditions on site as identified by AscentGeo and the documentation provided by others.

The report should be read in its entirety and should not be separated from its attachments or supporting notes. It should not have sections removed or included in other documents without the express approval of AscentGeo.

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Contents

1 Overview

1.1 Background

This report presents the findings of a geotechnical assessment carried out at 21 Park Street, Collaroy (the 'Site'), by AscentGeo. This geotechnical assessment has been prepared to meet Northern Beaches Council lodgement requirements for a Development Application (DA), as well as informing detailed structural design and construction methodology.

1.2 Proposed Development

The proposed development will take place on Lot 24 in DP 843218, being 21 Park Street, Collaroy as per the survey by ARP Surveyors, dated 10 April 2024.

Details of the proposed development are outlined in a series of draft architectural drawings provided to AscentGeo that are undated and unnumbered. The findings and recommendations of this report are based on the information provided, if the design documentation is updated, this report must be updated to reflect the plans being lodged with council.

The works comprise the following:

- Demolition of the existing dwelling. Partial demolition of pool and surrounding structures. Site preparation including removal / partial removal of sandstone boulders and preparation of new footings.
- Construction of new three storey dwelling
- Construction of refurbished pool and associated works, with spa, decking and outdoor kitchen and WC
- Associated hard and soft landscaping.

1.3 Relevant Instruments

This geotechnical assessment has been prepared in accordance with the following relevant guidelines and standards:

- Northern Beaches Council – Warringah Local Environment Plan (WLEP) 2011 and Warringah Development Control Plan (WDCP) 2011
- Australian Geomechanics Society's 'Landslide Risk Management Guidelines' (AGS 2007)
- Australian Standard 1726–2017 Geotechnical Site Investigations
- Australian Standard 2870–2011 Residential Slabs and Footings
- Australian Standard 1289.6.3.2–1997 Methods of Testing Soils for Engineering Purposes
- Australian Standard 3798–2007 Guidelines on Earthworks for Commercial and Residential Developments.

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2 Site Description

2.1 Summary

A summary of site conditions identified at the time of our assessment is provided in Table 1.

Table 1. Summary of site conditions

Parameter	Description
Site visit	Cameron Young, Engineering Geologist – 25/6/2024
Site address	21 Park Street, Collaroy – Lot 24 in DP 843218
Site area m^2 (approx.)	603m^2 (by SIX Maps calc.)
Existing development	3 storey brick/clad cottage
Slope Aspect	North-east
Average gradient	~20 degrees
Vegetation	Lawn areas. Small shrubs, palms and trees and ground covering plants
Retaining structures	Concrete wall upslope of the pool is cracking (Photo 7). Concrete crib wall and concrete block wall upslope of the parking area appears to be in good condition.
Neighbouring environment	Residentially developed to the north and east. Park Street to the west. Public path between Park Street and Stuart Street runs along the southern boundary.

Figure 1. Site location – 21 Park Street, Collaroy NSW (© SIX Maps NSW Gov)

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2.2 Site Description

The subject site is situated in a residential area, has an irregular shape and is bounded by residential dwellings to the north and east. The site is on the low side of Park Street and is on a moderately sloping ground with north-easterly aspect, which becomes steep along the western and southern boundaries. A site plan is included in Appendix A.

The existing building at the site is a three-storey house which is in dilapidated condition and shows signs of differential settlement, particularly at the southwestern corner where the brickwork has cracked and rotated (Photo 4). The pool and surrounding area is in poor condition, with a significant crack observed in the concrete wall upslope of the western side of the pool (Photo 7).

There are three very large sandstone boulders are present within the southern portion of the site (Photos 5 & 6). The pool has been founded partly on the boulder of Photo 6. The boulders are embedded within the soil profile and are likely to have originated from the Hawkesbury Sandstone unit represented in the current escarpment of Collaroy Plateau in an historical (>1000 year) rock fall event. A fourth boulder is present at the south-western corner of the house, under the concrete slab and where the brickwork of the existing house has been cut to fit, the boulder sits upon uncontrolled fill, sandy materials and brick pieces and is indirect contact with the brickwork (Photo 7). Bedrock was not outcropping on the subject site.

The photos presented in Appendix B show the general conditions of the site on the day of the site visit conducted by AscentGeo.

2.3 Geology and Geological Interpretation

The Sydney 1:100,000 Geological Sheet 9130 (NSW Dept. Mineral Resources, 1983) indicates that the site is underlain by Middle Triassic Hawkesbury Sandstone (Rh). The Hawkesbury rocks are typically comprised of medium to course-grained quartz sandstone, minor shale and laminite lenses. Based on the topography of the site and the results of our ground testing, we infer that the site is underlain by the upper Newport Formation of the Narrabeen Group (Rnn). The Newport Formation bedrock is typically comprised of interbedded laminite, shale and quartz to lithic quartz sandstone.

The soil profile consists of shallow uncontrolled fill and silty topsoil (O & A Horizons), sandy clay / clayey sand (B Horizon) and weathered bedrock (C Horizon) which is likely to be a low strength shale with interbedded sandstone layers. Based on our observations and the results of testing on site, we would expect weathered bedrock to be found between 2-3 metres below current surface levels across the area of the proposed works and potentially deeper where filling has been carried out. Large to very large sandstone floaters are present on the slope and are entrained withing the shallow soil profile. These rocks are interpreted to have originated from the capping sandstone units above the site.

Note: The local geology is comprised predominantly of sandstones and shales. The sandstone and shale bedrock are often found in benched terraces, subsequently ground conditions on site may alter significantly across short distances. This variability should be anticipated and accounted for in the design and construction of any new foundations.

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2.3 Fieldwork

A site visit and investigation was undertaken on 25 June 2024, which included a geotechnically focused visual assessment of the property and its surrounds; geotechnical mapping; photographic documenting; and a limited subsurface investigation including hand auger borehole and dynamic cone penetrometer (DCP) testing.

Hand Auger Borehole Testing

One hand auger borehole (BH01) test was drilled at the approximate location shown on the site plan to visually identify the subsurface material. An engineering log of the hand auger borehole is presented in Appendix C. The soil profile was exposed in the unsupported cut batter for the driveway, as such, a second auger was deemed unnecessary for identification of soil materials.

Dynamic Cone Penetrometer (DCP) Testing

Eight (8) DCP tests were carried out to assess the in situ relative density of the shallow soils and the depth to weathered rock. These tests were carried out in accordance with the Australian Standard for ground testing: AS 1289.6.3.2–1997 'Methods of testing soils for engineering purposes'. Test locations were constrained by existing structures, possible buried hard surfaces and the presence of utilities.

The location of these tests is shown on the site plan provided in Appendix B and a summary of the test results is presented below in Table 2, with the full details presented in the engineering logs in Appendix C.

Table 2. Summary DCP test results

Test	Summary
DCP 1	Refusal @ 0.6m Bouncing on possible buried boulder or hard fill.
DCP 2	Refusal near surface, possible buried boulder or hard fill.
DCP 3	Practical Refusal @2.1m, minimal progress in inferred weathered bedrock.
DCP 4	Refusal @ 0.6m Bouncing on possible buried boulder or hard fill.
DCP 5	Refusal near surface, possible buried boulder or hard fill.
DCP 6	Refusal @ 2.8m Bouncing on possible inferred bedrock.
DCP 7	Practical Refusal @ 2.2m, minimal progress in inferred weathered bedrock.
DCP 8	Practical Refusal @ 2.1m, minimal progress in inferred weathered bedrock.

Note: The equipment chosen to undertake ground investigations provides the most cost-effective method for understanding the subsurface conditions given site access constraints. Our interpretation of the subsurface conditions is limited to the results of testing undertaken and the known geology in the area. While care is taken to identify the subsurface conditions on site, variation between the interpreted model presented herein and the actual conditions on site may occur. Should actual ground conditions vary from those anticipated, we recommend that the geotechnical engineer at AscentGeo is informed as soon as possible to advise if modifications to our recommendations are required.

3 Geotechnical Assessment

3.1 Geological Model

Based on the results of our site assessment, ground testing, geological mapping and our experience in the area, the subsurface conditions encountered on site may be summarised as follows in Table 3.

Table 3. Interpreted geological model

Unit	Material	Comments
1	**Topsoil / Fill**	Sandy topsoil and fill material. Unit 1 is inferred to be uncontrolled and poorly compacted
2	**Sandy Clay / Clayey Sand**	Low plasticity clay with a high sand content. Unit 2 is inferred to be generally soft consistency.
3	**Shale**	Generally, highly weathered, very low-low strength interbedded shale and sandstone (Class V – IV*).

* Pells, PJN, Mostyn, G & Walker, F, 1998 (Dec). 'Foundations on sandstone and shale in the Sydney region'. *Australian Geomechanics Journal,* vol. 33, no. 3, pp. 17–29.

3.2 Site Classification

Due to the steep natural slope, large sandstone boulders, and the presence of uncontrolled fill the Site is classified as **"P"** in accordance with AS 2870–2011, however provided the recommendations provided in Table 7 of this report are adopted and all new footings are taken to and socketed into the underlying bedrock, the site may be reclassified as "A".

Table 4. Site classification table for residential slabs and footings (AS2870-2011)

Site Classification	Soil description	Expected range of movement
A	Most sand and rock sites with little or no ground movement from moisture changes.	
S	Slight reactive clay sites, which may experience only slight ground movement from moisture changes.	0–20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes.	20–40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes.	40–60mm

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Site Classification	Soil description	Expected range of movement
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes.	60–75mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes.	>75mm
P	May consist of any of the above soil types, but in combination with site conditions produce undesirable foundations. P sites may also include fill, soft soils, mine subsidence, collapsing soils, prior or potential landslip, soils subject to erosion, reactive sites subject to abnormal moisture conditions, or sites which cannot be classified otherwise.	

3.3 Groundwater

Very moist soils were was encountered during testing, this is likely as a result of normal seepage following recent heavy rainfalls.

Whilst dedicated groundwater monitoring was not within the scope of this assessment, due to the site elevation and position of the site relative to the slope and the underlying geology, no significant standing water table is expected to influence the site. The groundwater regime is not expected to be significantly affected by the proposed works and it is considered unnecessary to undertake preconstruction or construction stage groundwater monitoring.

Groundwater seepage during and after periods of inclement weather should be anticipated through permeable soil layers, close to the interface with weathered rock and from joints and discontinuities deeper in the weathered rock. Appropriate ground support measures should be utilised in soils overlying rock to manage any localised groundwater inflows and prevent ground loss due to saturated/fluidised sands.

3.4 Surface Water

Overland or surface flows entering the site from the adjoining areas were not identified at the time of our inspection; however, normal overland runoff could enter the site from adjacent areas during heavy or extended rainfall. Appropriate surface water diversions should be implemented to prevent overland runoff entering the site from adjacent areas during heavy or extended rainfall.

3.5 Slope Instability

A landslide hazard assessment of the existing slope has been undertaken in general accordance with Australian Geomechanics Society's 'Practice Note Guidelines for Landslide Risk Management', published in March 2007.

- No evidence of significant soil creep, tension cracks or landslip instability were identified across the site or on adjacent properties as viewed from the subject site at the time of our inspection.
- The large to very large sandstone boulders across the site may have been originally mobilised by historical (>1000 years) rock fall events, which are not interpreted to present a current instability risk to the site.

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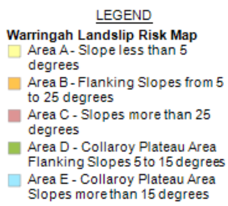
- The damage observed in the existing structure (photo 4) is attributed to inadequate and inconsistent foundation materials, potentially in combination with point loads from the boulder shown in Photo 6 which is in direct contact with the brickwork, as opposed to slope instability more generally.
- The property is classified as **Area D & E** with reference to Northern Beaches Council WLEP – Warringah Landslip Risk Map (**Image 2**).

Image 2. Warringah Landslip Risk Map:
21 Park Street, Collaroy NSW (© **NBC Maps**)



3.6 Geotechnical Hazards and Risk Analysis

No significant geotechnical hazards were identified above, beside or below the subject site, including but not limited to the immediately adjoining residential properties, and the road reserve.

The scope of the proposed excavations on site, and the local geology make this site susceptible to instability during the proposed construction works. Careful control of all site works will be required during the installation of any required retention systems, excavations, and the construction of the proposed structures to maintain the stability of the block, and adjacent land.

Based on observation made during our site assessment, the following geological/geotechnical hazards have been identified in relation to the proposed works:

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- **Hazard One:** Failure of the proposed excavations.
- **Hazard Two:** The potential mobilisation of detached sandstone boulders on site.

Table 5. Risk analysis summary

HAZARDS	HAZARD ONE	HAZARD TWO
TYPE	Failure of the proposed excavations	The potential mobilisation of detached sandstone boulders on site.
LIKELIHOOD	'Possible' (10^{-3})	'Rare' (10^{-5})
CONSEQUENCES TO PROPERTY	'Minor' (5%)	'Medium' (40%)
RISK TO PROPERTY	'Moderate' (2×10^{-3})	'Low' (2×10^{-5})
RISK TO LIFE	4.5×10^{-4}/annum	1.08×10^{-7}/annum
COMMENTS	Following implementation of the recommendations outlined in Section 3.7, the above risk levels would reduce to 'Acceptable' levels within the site.	This level of risk to life and property is **'ACCEPTABLE'.**

3.7 Conclusion and Recommendations

The proposed development is considered to be suitable for the site. The existing conditions and proposed development are considered to constitute an '**ACCEPTABLE**' risk to life and a '**LOW**' risk to property ***provided that the recommendations outlined in Table 6 are adhered to during design and construction.***

Table 6. Geotechnical recommendations

Recommendation	Description
General	It is strongly recommended that a builder and excavation contractor with demonstrable experience in this type of project be engaged to undertake the proposed works. Specifically, contractors familiar and experienced working in the steep terrain and complex geology of the upper peninsula. We recommend that a site meeting be scheduled between the principal contractor, the excavator operator, and AscentGeo to discuss types of suitable plant, excavation and construction methodology, shoring systems, and necessary construction hold points for inspections.
Dilapidation Reporting	We recommend that detailed dilapidation reporting, undertaken by others (typically by a structural engineer or licenced building inspector), be prepared for all adjacent structures, infrastructure, and pavements before any demolition, installation of shoring systems or excavations commence on site.

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Recommendation	Description
	The aim of the dilapidation surveys is to establish a detailed condition report prior to commencement of works to allow an accurate assessment of claims of damage resulting from construction related activities.
Soil Excavation	Soil excavation will be required to establish pad levels and new footings across the site. It is anticipated that these excavations will encounter shallow uncontrolled fill and sandy topsoil, clayey sand / sandy clay and weathered bedrock. The excavation of soil, clay and extremely weathered rock should be possible with the use of bucket excavators and rippers, or for piered footings, traditional auger attachments. Temporary batter slopes may be considered where setbacks from existing structures and property boundaries permits. For shallow excavations (<1.0m), provided the residual soil is battered back to a minimum of 35 degrees, they should remain stable without support for a short period until permanent support is in place. Unsupported batter slopes in sandy soil will be prone to erosion in inclement weather. If permanent batters are proposed, the unsupported batter must not be steeper than 30 degrees and should be protected from erosion by geotextile fabric pinned to the slope and planted with soil binding vegetation.
Rock Excavation	All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's *Code of Practice: Excavation Work*, published in October 2018. It is essential that any excavation through rock that cannot be readily achieved with a bucket excavator or ripper should be carried out initially using a rock saw to minimise the vibration impact and disturbance on the adjoining properties, existing structures and any previously installed supporting systems. Any rock breaking must be carried out only after the rock has been sawed, and in short bursts (2–5 seconds), to prevent the vibration amplifying. The break in the rock from the saw must be between the rock to be broken and the closest adjoining structure. All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.
Sandstone Boulder Excavation / Removal	AscentGeo should be contacted once the specific details of the proposed sandstone boulder removal are decided upon. Generally, we would recommend the boulders be demolished in a staged, top-down approach, with consideration to be given to portions of the slope or structures (i.e. the pool) that that the boulders may be supporting. Where the geometry of the boulder are unknown (e.g. where the boulder is deeply embedded in the soil, or covered by the pool structure) and where significant removal of rock is proposed, we will recommend the boulder be removed in its entirety to eliminate uncertainties about the geometry and

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Recommendation	Description
	weight distribution of the remaining boulder. This may necessitate underpinning of the pool and/or slope stabilisation measures. We recommend that the boulder shown in Photo 6 be removed in its entirety. This boulder is sitting on uncontrolled fill materials including sands and brick pieces and is in direct contact with the brickwork at the south-western corner of the house. The boulder may be applying point loads to the structure and may be a contributing factor in the damage noted in Photo 4. Given this boulder is sitting on uncontrolled fill materials, it has a much greater potential for movement than the other large sandstone boulders on the site. Where large floaters are to be removed methods for removal may vary depending on their location, orientational geometry, and proximity to structures to be retained. Methods may include, rock breaking, rock sawing, or methodical break-up with expanding grout.
Vibrations	The Australian Standard AS2670.1–2001 'Evaluation of human exposure to whole-body vibration General requirements. Part 1: General requirements', suggests a daytime limit of 5mm/s component PPV for human comfort is acceptable. In general, vibration criteria for human disturbance are more stringent than vibration criteria for effects on building contents and building structural damage. Hence, compliance with the more stringent limits dictated for human exposure, would ensure that compliance is also achieved for the other two categories. Furthermore, it is noted that this approach satisfies the requirements of Appendix J of AS2187.2–2006 'Explosives – storage and use', which also limits PPV to 5mm/s for residential settings. As such, we would suggest that the recommendations for method and/or equipment presented in the table below be adopted to maintain an allowable vibration limit of 5mm/s PPV.

	Maximum Peak Particle Velocity 5mm/sec	
Distance from adjoining structure (m)	**Equipment**	**Operating Limit (% of Maximum Capacity)**
1.5 – 2.5	Hand operated jackhammer only	100
2.5 – 5.0	300kg rock hammer	50
5.0 – 10.0	300kg rock hammer or 600kg rock hammer	100 (300kg) or 50 (600kg)

It may be necessary to move to smaller rock hammers or to rotary grinders or rock saws if vibrations limits cannot be met. (Manufactures of the plant should be contacted for information regarding peak vibration output.)

The propagation of vibrations can be mitigated by pulsing the use of rock hammers, i.e., short bursts, utilising line sawing along boundaries.

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Recommendation	Description
	It is essential that at all times excavation equipment must be operated by experienced personnel, according to the manufacturer's instructions and in a manner consistent with minimising vibration effects.
Excavation Support	Due to the gradient and composition of the site, excavations >1.0m are to be supported by permanent supporting systems. The demolition of the existing residence will remove support for the slope materials under the existing driveway we would recommend that a spaced pile shoring system be installed prior to the demolition of the lower level of the house. As the demolition progresses reinforced shotcrete infill panels with vertical strip drains can be installed. The detailed design of retaining walls is to be provided by the structural engineer. Any structural underpinning existing structures to be retained is to be designed by the structural engineer.
Retaining Structures	We recommend the concrete wall on the western side of the pool be replaced with a retaining structure built to current standards as part of the proposed works. Retention systems should be designed by a qualified structural engineer in accordance with Australian Standard AS 4678 using the following geotechnical parameters:

			Earth Pressure Coefficients		
(Unit) Material	**Bulk Unit Weight (kN/m^3)**	**Friction Angle (°)**	**Active K_a**	**At Rest K_0**	**Passive K_p**
(Unit 1) Fill / Topsoil	18	29	0.38	0.60	-
(Unit 2) Clay	19	28	0.33	0.55	2.50
(Unit 3) Shale	22	26	0.30	0.45	3.00

Retention systems should be designed to prevent hydrostatic pressure from developing behind the wall. As such, retaining walls to be constructed as part of the site works are to incorporate back wall subsoil drainage pipes, and are to be backfilled with suitable free-draining materials wrapped in a non-woven geotextile fabric (i.e. Bidim A34 or similar) to prevent the clogging of the drainage with fine-grained sediment.

Design of appropriate retention systems should consider potential surcharges from sloping land above the walls, soil creep, adjacent structures and footings, and construction related activities such as compaction of fill, traffic of vehicles and construction plant.

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Recommendation	Description
	Whilst not a requirement of this report, we suggest that consideration be given to the construction of a retaining wall along the upslope side of the driveway cut batter (Photo 8). We note that this area may be outside the site boundary and may require permissions from neighbours.
Footings	We recommend that all new footings are taken to and socketed no less than 500mm into the underlying shale bedrock (Unit 3) using piers as required. The allowable bearing pressure for footings taken to competent weathered bedrock of at least low strength is **600kPa**. Higher allowable bearing capacities may be achievable subject to inspection and certification of excavated footings by AscentGeo. Pier footings should be of sufficient diameter to enable effective base cleaning to be carried out during construction. Small diameter piers that cannot be cleaned should be designed for shaft friction, resulting in a longer rock socket. To mitigate the risk of differential settlement, it is essential that all footings are founded on competent bedrock of similar consistency. **It is essential that the foundation materials of all footing excavations be inspected and approved before steel reinforcement and concrete is placed. This inspection should be scheduled while excavation plant and operators are still on site, and before steel reinforcement has been fixed or the concrete booked.**
Fills	Any fill that may be required is to comprise local sand, clay, and weathered rock. Existing organic topsoil is to be cleared in preparation for the introduction of fill. Any new fill material is to be placed in layers not more than 250mm thick and compacted to not less than 95% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content. If supporting pavements or slabs, any new fill must be compacted to not less than 98% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content for the uppermost 300mm. All new fill placement is to be carried out in accordance with AS 3798–2007 'Guidelines on earthworks for commercial and residential developments.' Fill should not be placed on the site outside of the lateral extent of new engineered retaining walls. The retaining walls should be in place prior to the placement of new fill, with suitable permanent and effective drainage of backfill.
Sediment and Erosion Control	Appropriate design and construction methods shall be required during site works to minimise erosion and provide sediment control. In particular, siltation fencing, and barriers will be required and are to be designed by others.

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Recommendation	Description
Stormwater Disposal	The effective management of ground and surface water on site is an important factor in maintaining the long-term performance of built structures, and the stability of the block more generally. It is essential that gutters, downpipes, drains, pipes, and connections are appropriately sized, functioning effectively, and discharging appropriately via non-erosive discharge. All stormwater collected from hard surfaces is to be collected and piped directly to the council stormwater network through any storage tanks or on-site detention that may be required by the regulating authorities, and in accordance with all relevant Australian Standards and the detailed stormwater management plan by others. Where discharge to council curb and gutter stormwater system, or easement, is not available, on-site stormwater management via non-erosive discharge such and dispersion, or absorption systems may be achievable subject to further testing to establish soil infiltration rates (if necessary), and the detailed stormwater management plan by others. Saturation of soils is one of the key triggers for many landslide events and a significant factor in destabilisation of structures over time. As such, the review and design of stormwater systems must consider climate change and the increased potential for periods of concentrated heavy rainfall.
Inspections	We recommend that a site visit be organised with the principal contractor and excavation contractor to discuss staging, construction methodology and hold points prior to commencement of works. Excavation hold points will be required at drops not exceeding 1.5m to visually inspect excavation faces and retention systems and to determine if additional supporting measures are required. It is essential that the foundation materials of all footing excavations be visually assessed and approved by AscentGeo before steel reinforcement and concrete is placed. **Failure to engage AscentGeo for the required hold point/ excavation/ foundation material inspections will negate our ability to provide final geotechnical sign off or certification.**
Conditions Relating to Design and Construction Monitoring	To comply with Northern Beaches Council conditions and/or Private Certifier requirements it may be necessary at the following stages for AscentGeo to: ● Review the geotechnical content of all structural designs prior to the issue of Construction Certificate. ● Complete the abovementioned excavation hold point and/or foundation material inspections during construction to ensure compliance to design with respect to stability and geotechnical design parameters.

Recommendation	Description
	• By Occupation Certificate stage (project completion), AscentGeo must have inspected and certified excavation/foundation materials. A final site inspection will be required at this stage before the issue of the Occupation Certificate.

Should you have any queries regarding this report, please do not hesitate to contact the author of this report, undersigned.

For and on behalf of **AscentGeo,**

Cameron Young BEnvSci Geol MAIG
Engineering Geologist

Ben Morgan BScGeol MAIG RPGeo
Managing Director | Engineering Geologist

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4 References

Australian Geomechanics Society Landslide Taskforce, Landslide Practice Note Working Group 2007 (Mar). 'Practice Note Guidelines for Landslide Risk Management 2007'. *Australian Geomechanics Journal,* vol. 42, no. 1, pp. 63–114.

Herbert C., 1983, Sydney 1:100 000 Geological Sheet 9130, 1st edition. Geological Survey of New South Wales, Sydney.

NSW Department of Finance, Services and Innovation, Spatial Information Viewer, maps.six.nsw.gov.au.

Northern Beaches Council, Online mapping, Warringah Landslip Risk Map (WLEP 2011).

NSW Department of Finance, Services and Innovation, Spatial Information Viewer, maps.six.nsw.gov.au.

Pells, PJN, Mostyn, G & Walker, F, 1998 (Dec). 'Foundations on sandstone and shale in the Sydney region'. *Australian Geomechanics Journal,* vol. 33, no. 3, pp. 17–29.

Safe Work Australia, 2018 (Oct), *Code of Practice: Excavation Work*, Safe Work Australia.

Standards Australia 1997, *Methods of Testing Soils for Engineering Purposes*, AS1289.6.3.2:1997, Standards Australia, NSW.

Standards Australia 2001, *Evaluation of human exposure to whole-body vibration. Part 1: General requirements,* AS2670.1:2001, Standards Australia, NSW.

Standards Australia 2002, *Earth-retaining structures,* AS4678:2002, Standards Australia, NSW.

Standards Australia 2007, *Guidelines for Earthworks for Commercial and Residential Developments.* AS3798:2007, Standards Australia, NSW.

Standards Australia 2011, *Residential Slabs and Footings*, AS2870:2011, Standards Australia, NSW.

Standards Australia 2017, *Geotechnical Site Investigations*, AS1726:2017, Standards Australia, NSW.

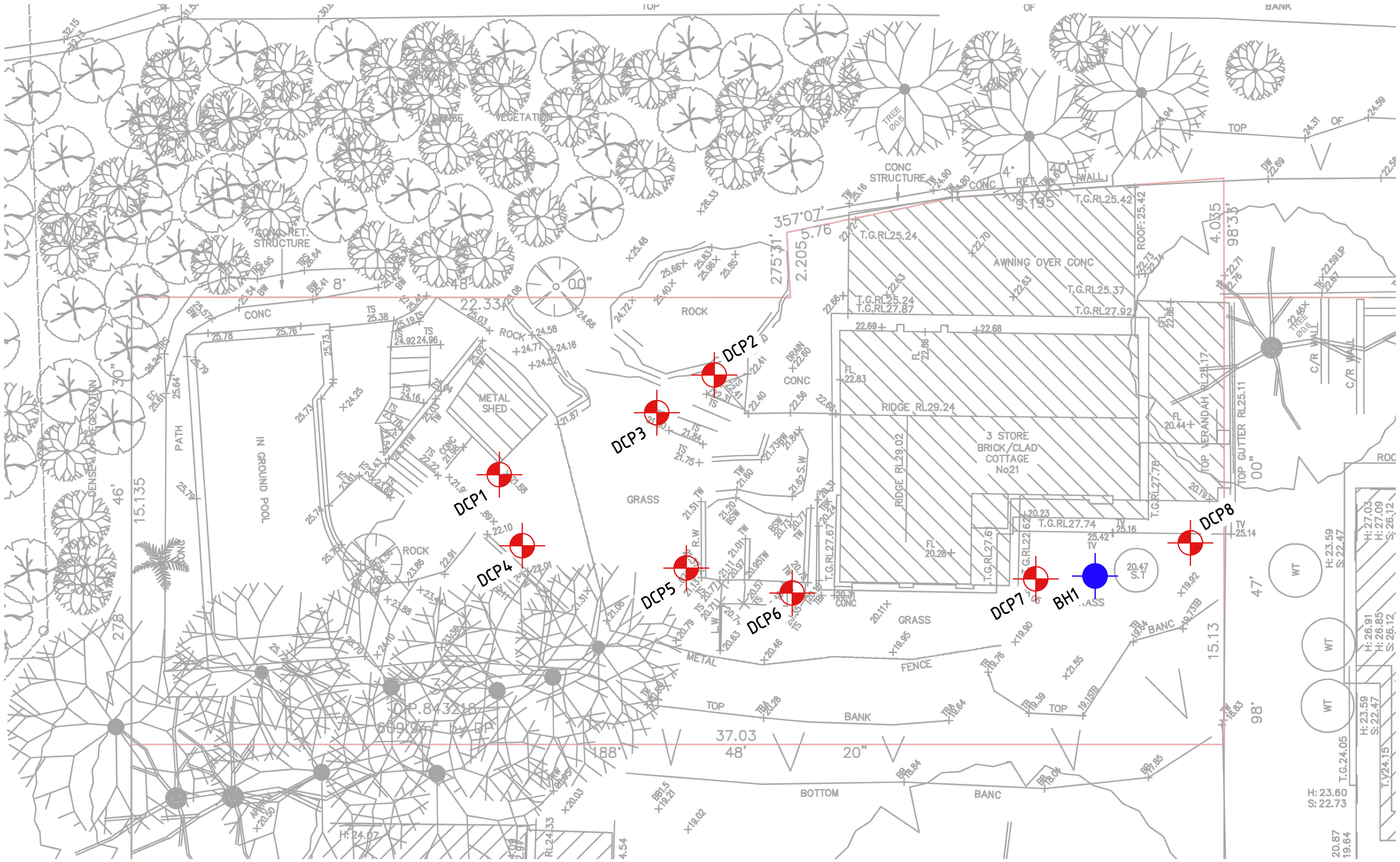
Appendix A

Site plans

LEGEND

DCP LOCATIONS

BOREHOLE LOCATION



SITE PLAN/GROUND TEST LOCATIONS

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	10.07.24	PRELIMINARY ISSUE	VT	BM

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CLIENT:
PRISCILA WAGNER & GLENN DAVIS

SITE PLAN/GROUND TEST LOCATIONS AT 21 PARK STREET COLLAROY NSW

DATE: 10/07/2024

SCALE: AS SHOWN @ A3

DRAWING TITLE: SITE PLAN

DRAWING NO: AG 24195- S1

Appendix B

Site photos

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 **Photo 1:** Eastern side of residence	 **Photo 2:** Southern side of residence
 **Photo 4:** Cracking and rotation of brickwork in south-western corner of the residence	 **Photo 5:** Sandstone boulder under pool
 **Photo 5:** Two large sandstone boulders to the south west of the residence	 **Photo 6:** Sandstone boulder under the slab at the south-western corner of the house sits upon uncontrolled fill, sandy materials and brick pieces.

 Photo 7: Cracking in the concrete wall on the western side of the pool	 Photo 8: Uncontrolled slope on the western side of the driveway access

Appendix C

Bore Logs | DCP Test Results

Northing : 0.00 Logged By : Cameron Young Client : Glenn Davis & Priscila Wagner

Total Depth : 1.8 m Date : 25/06/2024 Project : Alterations & Additions

Depth (m)	Water	Graphic Log	Drilling Method	Material Description	Consistency	Moisture	Classification Code	DCP graph
				Fill SAND SW: dark brown, fine to medium grained, trace low plasticity clay, slightly moist, grass rootlets.		SLM	SW	
1				**Natural Sandy CLAY CL: soft to firm, low plasticity, yellow and grey, medium grained sand, inorganic, moist, interbedded layers of slightly higher sand content / slightly higher clay content. the profile towards the base of the sample displays a bedding like structure (i.e. potentially extremely weathered rock).**	S-F	M	CL	
2				**BH1 Terminated at 1.8m (End test at max depth of equipment. Bedrock not encountered)**				

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Dynamic Cone Penetration Test Report

Client:	Glenn Davis & Priscila Wagner	**Job No:**	AG 24195
Project:	Alterations & Additions	**Date:**	25/6/2024
Location:	21 Park Street, Collaroy NSW	**Operator:**	CY & RT
Test Procedure:	AS 1289.6.3.2 – 1997		

Test Data

Test No: DCP 1		Test No: DCP 2		Test No: DCP 3		Test No: DCP 4		Test No: DCP 5	
Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan	
RL:		RL:		RL:		RL:		RL:	
Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification: P	
Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0 – 0.3	5	0.0 – 0.3	Rs	0.0 – 0.3	2	0.0 – 0.3	6	0.0 – 0.3	Rs
0.3 – 0.6	7 Rs	0.3 – 0.6		0.3 – 0.6	3	0.3 – 0.6	7 Rs	0.3 – 0.6	
0.6 – 0.9		0.6 – 0.9		0.6 – 0.9	7	0.6 – 0.9		0.6 – 0.9	
0.9 – 1.2		0.9 – 1.2		0.9 – 1.2	12	0.9 – 1.2		0.9 – 1.2	
1.2 – 1.5		1.2 – 1.5		1.2 – 1.5	17	1.2 – 1.5		1.2 – 1.5	
1.5 – 1.8		1.5 – 1.8		1.5 – 1.8	21	1.5 – 1.8		1.5 – 1.8	
1.8 – 2.1		1.8 – 2.1		1.8 – 2.1	25	1.8 – 2.1		1.8 – 2.1	
2.1 – 2.4		2.1 – 2.4		2.1 – 2.4	45 Pr	2.1 – 2.4		2.1 – 2.4	
2.4 – 2.7		2.4 – 2.7		2.4 – 2.7		2.4 – 2.7		2.4 – 2.7	
2.7 – 3.0		2.7 – 3.0		2.7 – 3.0		2.7 – 3.0		2.7 – 3.0	
3.0 – 3.3		3.0 – 3.3		3.0 – 3.3		3.0 – 3.3		3.0 – 3.3	
3.3 – 3.6		3.3 – 3.6		3.3 – 3.6		3.3 – 3.6		3.3 – 3.6	
3.6 – 3.9		3.6 – 3.9		3.6 – 3.9		3.6 – 3.9		3.6 – 3.9	
3.9 – 4.2		3.9 – 4.2		3.9 – 4.2		3.9 – 4.2		3.9 – 4.2	
4.2 – 4.5		4.2 – 4.5		4.2 – 4.5		4.2 – 4.5		4.2 – 4.5	
4.5 – 4.8		4.5 – 4.8		4.5 – 4.8		4.5 – 4.8		4.5 – 4.8	
DCP 1: Refusal @ 0.6m Bouncing on possible buried boulder or hard fill.		DCP 2: Refusal near surface, possible buried boulder or hard fill.		DCP 3: Practical Refusal @2.1m, minimal progress in inferred weathered bedrock.		DCP 4 : Refusal @ 0.6m Bouncing on possible buried boulder or hard fill.		DCP 5: Refusal near surface, possible buried boulder or hard fill.	

Remarks: No groundwater encountered.	Weight:	9 kg
	Drop:	510 mm
	Rod Diameter	16 mm

Rs = Solid ring/Hammer bouncing
Pr = Practical Refusal. Rods progressingly slowly through weathered bedrock.
D = Equipment dropping under own weight

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Dynamic Cone Penetration Test Report

Client:	Glenn Davis & Priscila Wagner	**Job No:**	AG 24195
Project:	Alterations & Additions	**Date:**	25/6/2024
Location:	21 Park Street, Collaroy NSW	**Operator:**	CY & RT
Test Procedure:	AS 1289.6.3.2 – 1997		

Test Data

Test No: DCP 6		Test No: DCP 7		Test No: DCP 8		Test No:		Test No:	
Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location:		Test Location:	
RL:		RL:		RL:		RL:		RL:	
Soil Classification: P		Soil Classification: P		Soil Classification: P		Soil Classification:		Soil Classification:	
Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0 – 0.3	5	0.0 – 0.3	1-D	0.0 – 0.3	1-D				
0.3 – 0.6	5	0.3 – 0.6	1-D	0.3 – 0.6	1-D				
0.6 – 0.9	4	0.6 – 0.9	1-D	0.6 – 0.9	1-D				
0.9 – 1.2	9	0.9 – 1.2	21	0.9 – 1.2	8				
1.2 – 1.5	10	1.2 – 1.5	12	1.2 – 1.5	10				
1.5 – 1.8	11	1.5 – 1.8	12	1.5 – 1.8	22				
1.8 – 2.1	13	1.8 – 2.1	21	1.8 – 2.1	25 Pr				
2.1 – 2.4	12	2.1 – 2.4	45 Pr	2.1 – 2.4					
2.4 – 2.7	11	2.4 – 2.7		2.4 – 2.7					
2.7 – 3.0	11 Rs	2.7 – 3.0		2.7 – 3.0					
3.0 – 3.3		3.0 – 3.3		3.0 – 3.3					
3.3 – 3.6		3.3 – 3.6		3.3 – 3.6					
3.6 – 3.9		3.6 – 3.9		3.6 – 3.9					
3.9 – 4.2		3.9 – 4.2		3.9 – 4.2					
4.2 – 4.5		4.2 – 4.5		4.2 – 4.5					
4.5 – 4.8		4.5 – 4.8		4.5 – 4.8					
DCP 6: Refusal @ 2.8m Bouncing on possible inferred bedrock.		DCP 7: Practical Refusal @ 2.2m, minimal progress in inferred weathered bedrock.		DCP 8: Practical Refusal @ 2.1m, minimal progress in inferred weathered bedrock.					

Remarks: No groundwater encountered.	Weight:	9 kg
	Drop:	510 mm
	Rod Diameter	16 mm

Rs = Solid ring/Hammer bouncing

Pr = Practical Refusal. Rods progressingly slowly through weathered bedrock.

D = Equipment dropping under own weight

Appendix D

Information Sheets

General Notes About This Report

INTRODUCTION

These notes have been prepared by Ascent Geotechnical Consulting Pty Ltd (Ascent) to help our Clients interpret and understand the limitations of this report. Not all sections below are necessarily relevant to all reports.

SCOPE OF SERVICES

This report has been prepared in accordance with the scope of services set out in Ascent's proposal under Ascent's Terms and Conditions, or as otherwise agreed with the Client. The scope of work may have been limited by a range of factors including time, budget, access and/or site constraints.

RELIANCE ON INFORMATION PROVIDED

In preparing the report, Ascent has necessarily relied upon information provided by the Client and/or their Agents. Such data may include surveys, analyses, designs, maps and design plans. Ascent has not verified the accuracy or completeness of the data except as stated in this report.

GEOTECHNICAL AND ENVIRONMENTAL REPORTING

Geotechnical and environmental reporting relies on the interpretation of factual information, based on judgment and opinion, and is far less exact than other engineering or design disciplines.

Geotechnical and environmental reports are prepared for a specific purpose, development, and site, as described in the report, and may not contain sufficient information for other purposes, developments, or sites (including adjacent sites), other than that described in the report.

SUBSURFACE CONDITIONS

Subsurface conditions can change with time and can vary between test locations. For example, the actual interface between the materials may be far more gradual or abrupt than indicated.

Therefore, actual conditions in areas not sampled may differ from those predicted, since no subsurface investigation, no matter how comprehensive, can reveal all subsurface details and anomalies.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations can also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. Ascent should be kept informed of any such events, and should be retained to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

GROUNDWATER

Groundwater levels indicated on borehole and test pit logs are recorded at specific times. Depending on ground permeability, measured levels may or may not reflect actual levels if measured over a longer time period. Also, groundwater levels and seepage inflows may fluctuate with seasonal and environmental variations and construction activities.

INTERPRETATION OF DATA

Data obtained from nominated discrete locations, subsequent laboratory testing and empirical or external sources are interpreted by trained professionals in order to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions in accordance with any relevant industry standards, guidelines or procedures.

SOIL AND ROCK DESCRIPTIONS

Soil and rock descriptions are based on AS 1726 – 1993, using visual and tactile assessment, except at discrete locations where field and / or laboratory tests have been carried out. Refer to the accompanying soil and rock terms sheet for further information.

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FURTHER ADVICE

Ascent would be pleased to further discuss how any of the above issues could affect a specific project. We would also be pleased to provide further advice or assistance including:

- Assessment of suitability of designs and construction techniques;
- Contract documentation and specification;
- Construction advice (foundation assessments, excavation support).

Abbreviations, Notes & Symbols

SUBSURFACE INVESTIGATION

METHOD

Borehole Logs

AS#	Auger screwing (#-bit)
AD#	Auger drilling (#-bit)
B	Blank bit
V	V-bit
T	TC-bit
HA	Hand auger
R	Roller/tricone
W	Washbore
AH	Air hammer
AT	Air track
LB	Light bore push tube
MC	Macro core push tube
DT	Dual core push tube

Excavation Logs

BH	Backhoe/excavator bucket
NE	Natural exposure
HE	Hand excavation
X	Existing excavation

Cored Borehole Logs

NMLC	NMLC core drilling
NQ/HQ	Wireline core drilling

SUPPORT

Borehole Logs

C	Casing
M	Mud

Excavation Logs

S	Shoring
B	Benched

SAMPLING

B	Bulk sample
D	Disturbed sample
U#	Thin-walled tube sample (#mm diameter)
ES	Environmental sample
EW	Environmental water sample

FIELD TESTING

PP	Pocket penetrometer (kPa)
DCP	Dynamic cone penetrometer
PSP	Perth sand penetrometer
SPT	Standard penetration test
PBT	Plate bearing test
s_u	Vane shear strength peak/residual (kPa) and vane size (mm)
N*	SPT (blows per 300mm)
Nc	SPT with solid cone
R	Refusal

**denotes sample taken*

BOUNDARIES

_______	Known
_ _ _ _ _	Probable
---------	Possible

SOIL

MOISTURE CONDITION

D	Dry
M	Moist
W	Wet
Wp	Plastic Limit
Wl	Liquid Limit
MC	Moisture Content

CONSISTENCY

VS	Very Soft
S	Soft
F	Firm
St	Stiff
VSt	Very Stiff
H	Hard
Fb	Friable

DENSITY INDEX

VL	Very Loose
L	Loose
MD	Medium Dense
D	Dense
VD	Very Dense

USCS SYMBOLS

GW	Well graded gravels and gravel-sand mixtures, little or no fines
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures
SW	Well graded sands and gravelly sands, little or no fines
SP	Poorly graded sands and gravelly sands, little or no fines
SM	Silty sand, sand-silt mixtures
SC	Clayey sand, sand-clay mixtures
ML	Inorganic silts of low plasticity, very fine sands, rock flour, silty or clayey fine sands
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays
OL	Organic silts and organic silty clays of low plasticity
MH	Inorganic silts of high plasticity
CH	Inorganic clays of high plasticity
OH	Organic clays of medium to high plasticity
PT	Peat muck and other highly organic soils

ROCK

WEATHERING

RS	Residual Soil
XW	Extremely Weathered
HW	Highly Weathered
MW	Moderately Weathered
DW*	Distinctly Weathered
SW	Slightly Weathered
FR	Fresh

**covers both HW & MW*

STRENGTH

EL	Extremely Low
VL	Very Low
L	Low
M	Medium
H	High
VH	Very High
EH	Extremely High

ROCK QUALITY DESIGNATION (%)

$$= \frac{\text{sum of intact core pieces > 100mm}}{\text{total length of section being evaluated}} \times 100$$

CORE RECOVERY (%)

$$= \frac{\text{core recovered}}{\text{core llft}} \times 100$$

NATURAL FRACTURES

Type

JT	Joint
BP	Bedding plane
SM	Seam
FZ	Fractured zone
SZ	Shear zone
VN	Vein

Infill or Coating

Cn	Clean
St	Stained
Vn	Veneer
Co	Coating
Cl	Clay
Ca	Calcite
Fe	Iron oxide
Mi	Micaceous
Qz	Quartz

Shape

pl	Planar
cu	Curved
un	Undulose
st	Stepped
ir	Irregular

Roughness

pol	Polished
slk	Slickensided
smo	Smooth
rou	Rough

Soil & Rock Terms

SOIL

MOISTURE CONDITION

Term	Description
Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through the hand.
Moist	Feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist, but with free water forming on hands when handled.

For cohesive soils, moisture content may also be described in relation to plastic limit (W_P) or liquid limit (W_L). [>> much greater than, > greater than, < less than, << much less than].

CONSISTENCY

Term	c_u (kPa)	Term	c_u (kPa)
Very Soft	< 12	Very Stiff	100 - 200
Soft	12 - 25	Hard	> 200
Firm	25 - 50	Friable	-
Stiff	50 - 100		

DENSITY INDEX

Term	I_D (%)	Term	I_D (%)
Very Loose	< 15	Dense	65 – 85
Loose	15 – 35	Very Dense	> 85
Medium Dense	35 – 65		

PARTICLE SIZE

Name	Subdivision	Size (mm)
Boulders		> 200
Cobbles		63 - 200
Gravel	coarse	20 - 63
	medium	6 - 20
	fine	2.36 - 6
Sand	coarse	0.6 -2.36
	medium	0.2 - 0.6
	fine	0.075 - 0.2
Silt & Clay		< 0.075

MINOR COMPONENTS

Term	Proportion by Mass coarse grained	fine grained
Trace	≤ 5%	≤ 15%
Some	5 - 2%	15 - 30%

SOIL ZONING

Layers	Continuous exposures
Lenses	Discontinuous layers of lenticular shape
Pockets	Irregular inclusions of different material

SOIL CEMENTING

Weakly	Easily broken up by hand
Moderately	Effort is required to break up the soil by hand

SOIL STRUCTURE

Massive	Coherent, with any partings both vertically and horizontally spaced at greater than 100mm
Weak	Peds indistinct and barely observable on pit face. When disturbed approx. 30% consist of peds smaller than 100mm
Strong	Peds are quite distinct in undisturbed soil. When disturbed >60% consists of peds smaller than 100mm

ROCK

SEDIMENTARY ROCK TYPE DEFINITIONS

Rock Type	**Definition** (more than 50% of rock consists of….)
Conglomerate	… gravel sized (> 2mm) fragments
Sandstone	… sand sized (0.06 to 2mm) grains
Siltstone	… silt sized (<0.06mm) particles, rock is not laminated
Claystone	… clay, rock is not laminated
Shale	… silt or clay sized particles, rock is laminated

STRENGTH

Term	Is50 (MPa)	Term	Is50 (MPa)
Extremely Low	< 0.03	High	1 – 3
Very Low	0.03 – 0.1	Very High	3 – 10
Low	0.1 – 0.3	Extremely High	> 10
Medium	0.3 – 1		

WEATHERING

Term	Description
Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident
Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water. Fabric of original rock is still visible
Highly Weathered	Rock strength usually highly changed by weathering; rock may be highly discoloured
Moderately Weathered	Rock strength usually moderately changed by weathering; rock may be moderately discoloured
Distinctly Weathered	See 'Highly Weathered' or 'Moderately Weathered'
Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh	Rock shows no signs of decomposition or staining

NATURAL FRACTURES

Type	Description
Joint	A discontinuity or crack across which the rock has little or no tensile strength. May be open or closed
Bedding plane	Arrangement in layers of mineral grains of similar sizes or composition
Seam	Seam with deposited soil (infill), extremely weathered insitu rock (XW), or disoriented usually angular fragments of the host rock (crushed)
Shear zone	Zone with roughly parallel planar boundaries, of rock material intersected by closely spaced (generally < 50mm) joints and /or microscopic fracture (cleavage) planes
Vein	Intrusion of any shape dissimilar to the adjoining rock mass. Usually igneous

Shape	Description
Planar	Consistent orientation
Curved	Gradual change in orientation
Undulose	Wavy surface
Stepped	One or more well defined steps
Irregular	Many sharp changes in orientation

Infill or Coating	Description
Clean	No visible coating or discolouring
Stained	No visible coating but surfaces are discoloured
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	Visible coating ≤ 1mm thick. Ticker soil material described as seam

Roughness	Description
Polished	Shiny smooth surface
Slickensided	Grooved or striated surface, usually polished
Smooth	Smooth to touch. Few or no surface irregularities
Rough	Many small surface irregularities (amplitude generally < 1mm). Feels like fine to coarse sandpaper

Note: soil and rock descriptions are generally in accordance with AS1726-1993 Geotechnical Site Investigations

Graphic Symbols Index

Soil

- Fill
- Peat, Topsoil
- Clay
- Silty Clay
- Gravelly Clay
- Sandy Clay
- Silt
- Sandy Silt
- Clayey Silt
- Gravelly Silt
- Gravel
- Sandy Gravel
- Clayey Gravel
- Silty Gravel
- Sand
- Gravelly Sand
- Silty Sand
- Clayey Sand

Rock

- Sandstone
- Shale
- Clayey Shale
- Siltstone
- Conglomerate
- Claystone
- Dolerite, Basalt
- Granite
- Limestone
- Tuff
- Coarse grained Metamorphic
- Medium grained Metamorphic
- Fine grained Metamorphic
- Coal

Other

- Asphalt
- Concrete
- Brick

Water Measurements

- Level at time of drilling
- Level after drilling
- Inflow
- Outflow

Foundation Maintenance and Footing Performance: A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

Tree root growth

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

Erosion and saturation

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

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

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

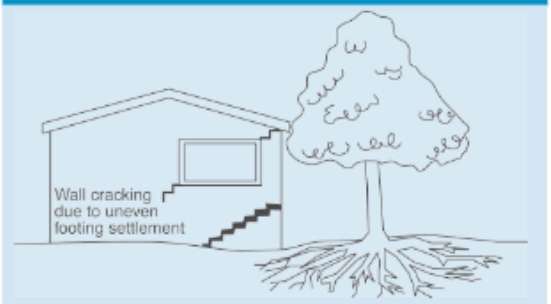
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

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

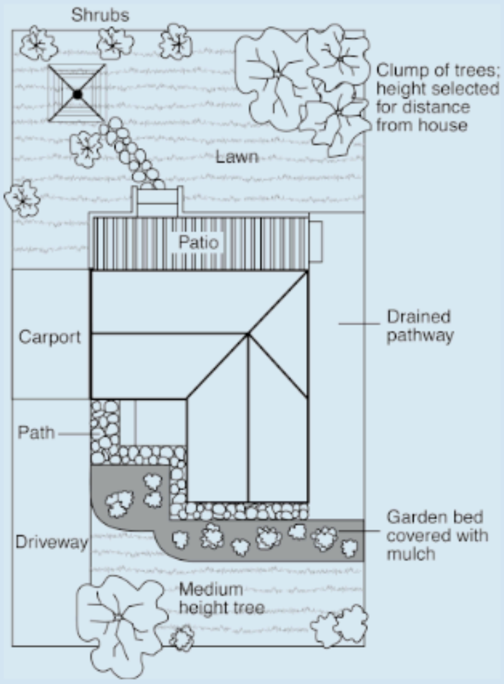
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

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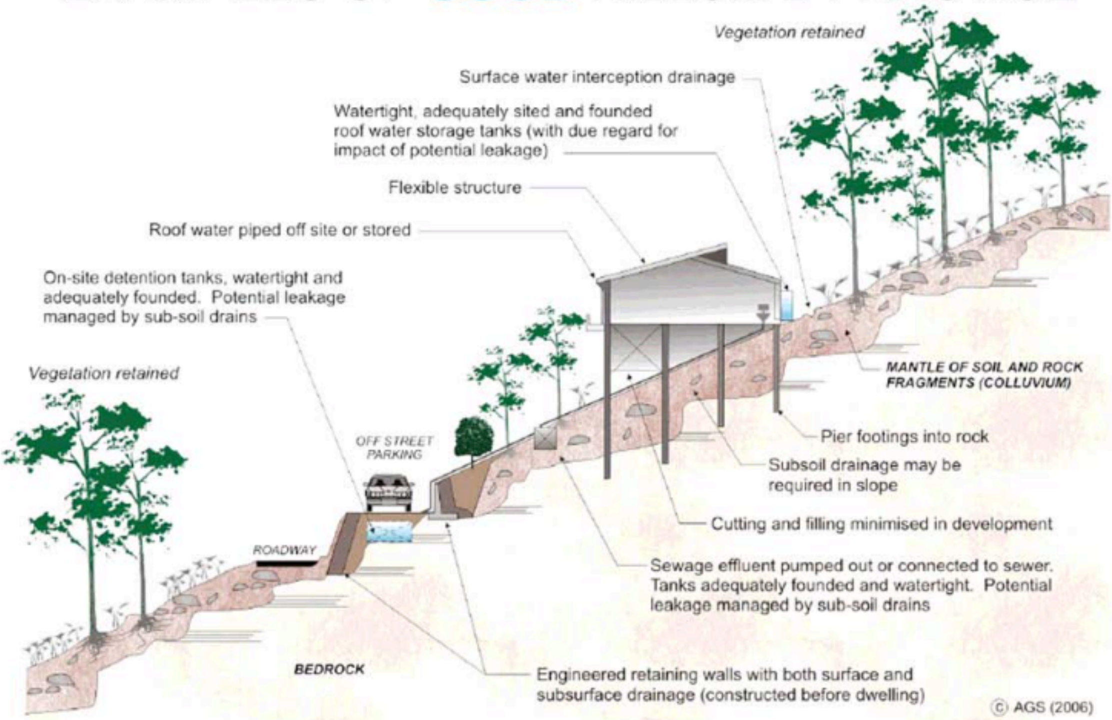
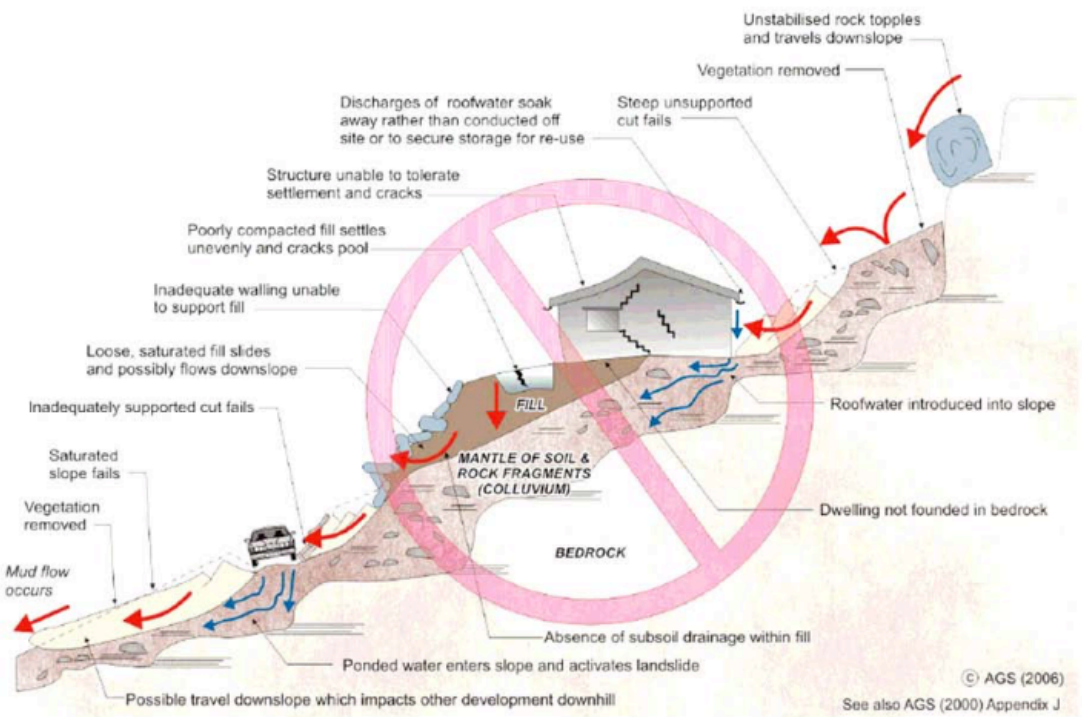
EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



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

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.