Geotechnical Investigation Report

Project

Proposed Residential Development
888 Barrenjoey Road, Palm Beach NSW

Prepared for

Wyer & Co Pty Ltd

Date

18 May 2021

Report No

12949-GR-1-1

alliance
geotechnical & environmental solutions

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Document Control

Revision	Date	Description	Author	Reviewer
0	18/05/2021	Original issue	LT	MAG

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APPENDICES

1 Introduction

This report details the results of a geotechnical investigation undertaken on the site of proposed residential development at 888 Barrenjoey Road, Palm Beach NSW. Wyer & Co Pty Ltd, architects for the project, requested the investigation which was carried out by Alliance Geotechnical Pty Ltd (Alliance) on 7 May 2021 in accordance with our estimate No. 04859 dated 27 April 2021.

The proposed development for the front of the site comprises construction of a new double garage and storage, driveway, pedestrian access stairs and landing, retaining walls, garden and lawn, while the proposed development for the rear garden area comprises construction of an entertaining terrace, swimming pool, cabana, stairs and retaining walls. The aim of the investigation was to provide information on subsurface and site conditions for assessment of geotechnical risk and to assist with planning and design.

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

2. Site Description and Regional Geology

2.1 Site Description

The site is located on the eastern side of Barrenjoey Road in Palm Beach and consists of a single block with an area of approximately 1,003m^2 and the shape and dimensions as shown on Drawing 12949-GR-1-A in Appendix B. The site is located on the western slopes of the Palm Beach peninsular with ground slopes falling to the west, at average slopes of approximately 15 to 20 degrees. The site is bounded by Barrenjoey Road to the west and neighbouring properties to the north, south and east. Sandstone retaining walls up to 2.2m in height are located either side of a bitumen driveway (see Photo 1 in Appendix A) that leads to the one- and two-level brick and tile residence that is currently undergoing a substantial renovation (separate to this current development proposal).

The proposed location for the double garage, being the south western corner of the site, is shown in Photo 2. A concrete path and brick retaining wall is located on the eastern side (upslope) of the residence. A paved BBQ area with timber deck and gazebo is located atop the brick retaining wall and is the location of the proposed swimming pool. This area is shown in Photos 3 and 4 in Appendix A. Upslope from the proposed pool location are sandstone walls, creating terraced gardens with a small lawn area and is shown in Photo 5. A set of sandstone stairs runs adjacent to the southern boundary with terraced gardens beds on the northern side. Existing sandstone walls create the garden beds and can be seen in Photo 9. The stairs lead to an area with some seating to the south and a large sandstone outcrop to the north (shown in Photo 7). On the northern side of this area is a concrete drain that runs from the southern boundary, traversing the site from south to north. The southern end of this drain is shown in Photo 6. Further upslope and slightly north of the site is a very large sandstone outcrop, shown in Photo 8.

2.2 Regional Geology

Reference to the Sydney 1:100,000 Geological Sheet indicates that the Newport Formation (Rnn) from the Narrabeen Group, of the Triassic Period, underlies the site. The Newport Formation typically comprises interbedded laminite, shale and quartz, to lithic-quartz sandstone. The rocks of the Newport Formation typically weather to form moderately reactive clay soils, but highly reactive clay soils are possible. Further upslope towards the crest of the ridge, Hawkesbury Sandstone (Rh) of the Triassic Period is exposed. The Hawkesbury Sandstone formation typically comprises medium to coarse grained quartz sandstone with very minor shale and laminite lenses. Some outcrop from this unit are located across the site and adjacent sites. The geological units around the site are shown in the extract from the geological map below in Figure 1.

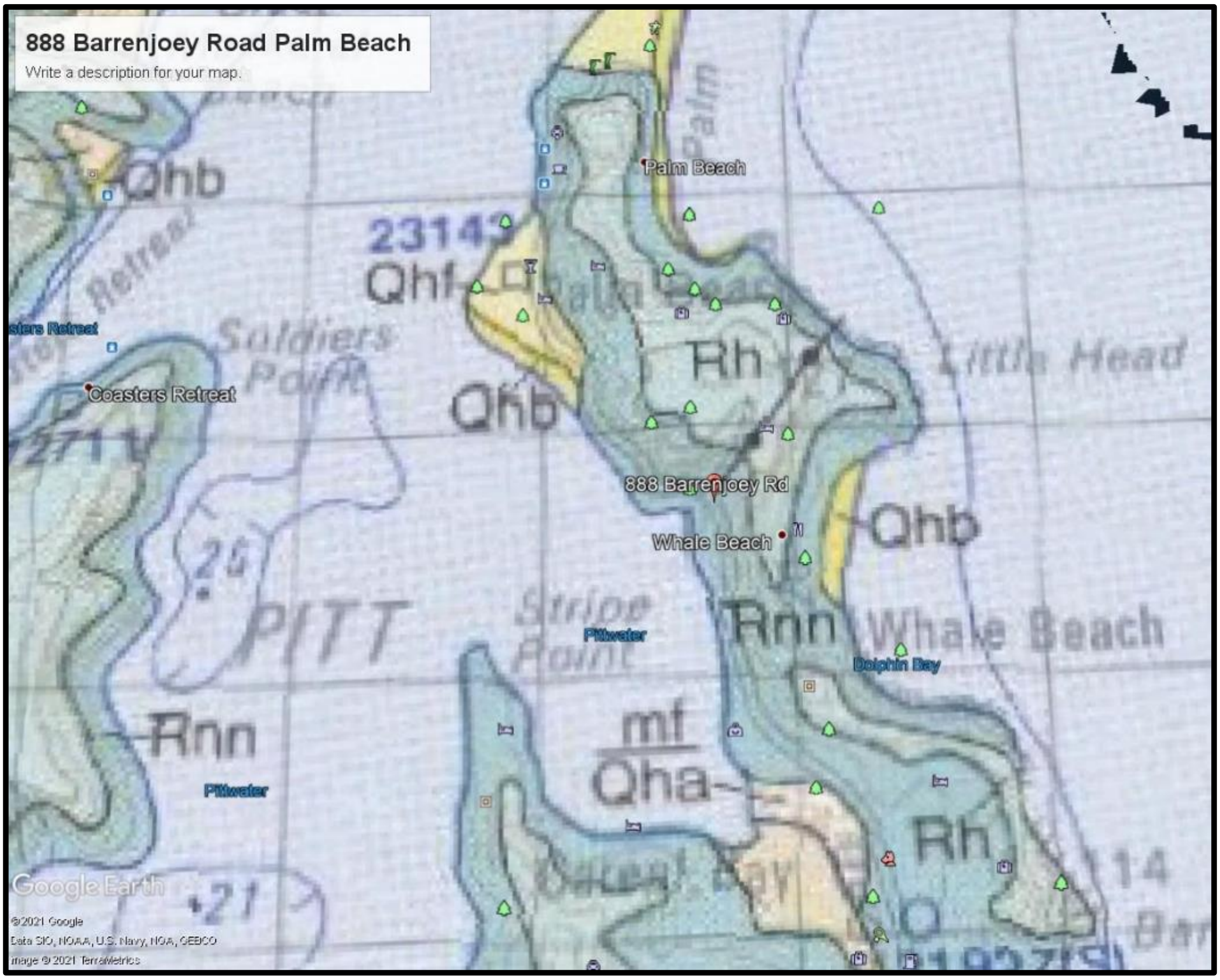

Figure 1 - Extract of Geological Map indicating site location & relevant geological units in the vicinity of the site.

The geological mapping was confirmed during the fieldwork with numerous sandstone outcrops observed on this and adjacent sites with the location of two major outcrops shown on Drawing 12949-GR-1-A in Appendix B.

3. PROPOSED DEVELOPMENT

Reference to Wyer & Co Pty Ltd development application drawings, Job No. 20.052, Drawing No. DA_1.0, DA_5.0, DA_5.1, DA_7.0, DA_7.1 and DA_7.2 all dated 4 May 2021 indicates that the proposed development for the front of the site comprises construction of a new double garage and storage, driveway, pedestrian access stairs and landing, retaining walls, garden and lawn while the proposed development for the rear garden area comprises construction of a new entertaining terrace, swimming pool, cabana, stairs and retaining walls.

4. FIELDWORK

4.1 Methods

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

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

4.2 Results

Details of the conditions encountered in the test bores are given in the borehole logs in Appendix C and are summarised below. The bores were drilled with a 50mm diameter mechanical soil sampler to a depth of 1.5m with Bore 1 advanced with a 100mm diameter hand auger to a depth of 2.0m. The locations of the test bores are shown on Drawing 12949-GR-1-A in Appendix B.

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

Bore 1 encountered filling consisting of clay with some silt and sand and sandstone gravel to 0.9m depth underlain by the original topsoil layer consisting of silty sand with some organics to a depth of 1.20m then silty sand (with some sandstone gravel from 1.8m) to 2. m where low strength sandstone (possibly a floater) was encountered. The test bore was terminated at a depth of 2.0m due to auger refusal on the sandstone.

Bore 2 encountered sandy topsoil filling to 0.1m then sandy clay filling to a depth of 0.9m underlain by silty clay to 1.2m where extremely low strength sandstone was encountered. The test bore was terminated at a depth of 1.50m being the limit of the mechanical soil sampler.

The results of the DPT's indicate that the filling was of variable compaction. The natural clayey soils underlying the site are generally in a firm to stiff condition above the upper horizon of the weathered rock profile which underlies the site at a depth of approximately 1.2 to 2.3m over the building footprint area. Sandstone (outcrops) were observed on the site and on the adjacent sites to the north, south and east.

4.3 Groundwater

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

5. AGS RISK ASSESSMENT

The Australian Geomechanics Society (AGS) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning (2007) has been used to assess the levels of land stability risks associated with a development during and after completion of its construction. The risk assessment process involves the identification of hazards that could potentially affect the stability of the site and surrounding land, as well as identification of "elements at risk" should a landslide occur. We have assessed the risk for the site in its present condition and then for post-construction. The builder will be responsible for stability during construction.

5.1 Identified Geotechnical Hazards

Based on observations made during the site visit and based on engineering experience with projects of a similar nature in areas with similar subsurface conditions, Alliance has identified the following geotechnical:

- Hazard A: Large volume (>20m^3) outcrops on sloping bedrock.
- Hazard B: Small volume (<5m^3) shallow rotational slide / slip due to saturation of slope.
- Hazard C: Small volume (<5m^3) shallow rotational slide / slip due to existing wall failure.
- Hazard D: Medium volume (<20m^3) shallow rotational slide / slip due to saturation of slope (during construction).

These hazards can be brought about by the following failure mechanisms:

- Uncontrolled and concentrated surface water flows with soil erosion.
- Shallow slide of surficial soils over sloping rockhead.
- Sliding of the base of the retaining wall.
- Structural failure of existing remedial measures.
- Rare but extreme seismic events.
- Influence of animal burrowing and tree root jacking

5.2 Risk to Property

The risk to property assessment in its existing condition is presented in Table 1. For post-construction condition, see Table 2. It has been prepared on the basis that the recommendations provided in Section 5.4 and as assessed in Section 5.2 will be carried out as per the intent of this report. Table 1 is a summary of the assessment of to the geotechnical hazards identified in Section 5.1 and assessed in Section 5.2 and indicates AG's calculated residual "Risk to Existing Property" after the risk management measured described in Section 5.4 have been implemented.

A description of the terms used in the risk assessment and the AGS 2007 risk assessment tables are provided in Appendix E, together with Drawing No. 11949-GR-1-A in Appendix B, which shows the locations of the existing sandstone mortar retaining walls and other geotechnical features associated with the risk assessment.

Table 1- AGS Risk Assessment: Risk to Property – Pre-Construction

Possible Hazards			Consequences (Note 2)	Assessed Likelihood	Risk (Note 1)	Risk Treatment and Comments
Failure Envisaged	**Failure Mode**	**Initiating Circumstances**				
A - sliding of large boulders upslope of dwelling	Translational slide	Fauna/flora (burrows / root jacking). Stormwater run-off	Medium	Barely Credible to Rare	Very Low	Control surface water run-off. Avoid large trees with shallow roots. Prevent animal burrowing under boulders. Inspect slope annually or after significant prolonged rainfall.
B - Slide in soils above rock (upslope of dwelling)	Translational slide / Rotational failure	Groundwater, moderate slope, uncontrolled cutting and filling	Minor	Unlikely	Low	Existing drain upslope of residence prevents significant overland flow thus erosion and failure unlikely
C – Failure of existing sandstone mortar walls	Translational slide / Rotational failure	Groundwater, steep slope, removal of toe support of walls	Minor	Unlikely	Low	Existing walls in good condition, some minor cracking but performing well, no sign of movement.
D – Failure of temporary excavation batters	Translational slide	Saturation of embankment, unsupported cut	Minor	Unlikely	Low	Provide buttress support to replace natural buttress.

Notes:

1. The risk assessment addresses only the consequences to property from potential landslide events considered relevant to the subject site. Injury to persons or potential for fatality from land sliding is not assessed in this table (refer Table 3). The risk assessment is based on a preliminary appraisal only, carried out by inspection. Further assessment or quantification of the assessed geotechnical risks for the subject property would require additional data and/or investigation.
2. The consequences are for a development that is designed to accommodate the potential landslide risk or has demonstrated adequate performance over many years.
3. Refer to report and associated figures for illustration of possible hazards / slope failure mechanisms.
4. Refer to attachments for definitions and explanations of terms used in the risk assessment.

Table 2- AGS Risk Assessment: Risk to Property – Post-Construction

Possible Hazards			Consequences (Note 2)	Assessed Likelihood	Risk (Note 1)	Risk Treatment and Comments
Failure Envisaged	**Failure Mode**	**Initiating Circumstances**				
A - sliding of large boulders upslope of dwelling	Translational slide	Fauna/flora (burrows / root jacking). Stormwater run-off	Medium	Barely Credible to Rare	Very Low	Control surface water run-off. Avoid large trees with shallow roots. Prevent animal burrowing under boulders. Inspect slope annually or after significant prolonged rainfall.
B - Slide in soils above rock (upslope of dwelling)	Translational slide / Rotational failure	Groundwater, moderate slope, uncontrolled cutting and filling	Minor	Unlikely	Low	Existing drain upslope of residence prevents significant overland flow thus erosion and failure unlikely
C – Failure of existing sandstone mortar walls	Translational slide / Rotational failure	Groundwater, steep slope, removal of toe support of walls	Minor	Unlikely	Low	Existing walls in good condition, some minor cracking but performing well, no sign of movement, monitor for any deterioration.
D – Excavations for swimming pool & garage	Slip / Rotation/ Structural failure of RW	Failure of stabilisation measures. Exceptional seismic event.	Medium	Rare	Low	Inspect walls on annual basis for any signs for deterioration.

Notes:

1. The risk assessment addresses only the consequences to property from potential landslide events considered relevant to the subject site. Injury to persons or potential for fatality from land sliding is not assessed in this table (refer Table 3). The risk assessment is based on a preliminary appraisal only, carried out by inspection. Further assessment or quantification of the assessed geotechnical risks for the subject property would require additional data and/or investigation.
2. The consequences are for a development that is designed to accommodate the potential landslide risk or has demonstrated adequate performance over many years.
3. Refer to report and associated figures for illustration of possible hazards / slope failure mechanisms.
4. Refer to attachments for definitions and explanations of terms used in the risk assessment.

5.3 Risk to Life

The AGS 2007 guidelines provide the following equation to be used for 'risk to life' calculations:

$$\mathbf{R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}}$$

Where:

- $R_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual).
- $P_{(H)}$ is the annual probability of the landslide.
- $P_{(S:H)}$ is the probability of spatial impact of the landslide impacting a building (location) considering the travel distance and travel direction given the event.
- $P_{(T:S)}$ is the temporal-spatial probability (e.g. of the building or location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.
- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

The geotechnical hazards with the potential to pose a risk to person/s have been considered in the 'risk to life' calculations. The selected probability values for 'risk to life' calculations are based on the worst-case terms in the risk to property assessment in Section 5.2, in terms of their impact on residents within the house and for vehicles/pedestrians on Barrenjoey Road. The results of the risk to life assessment are set out in Table 3 and 4.

Table 3 - Summary of Risk to Life Calculations Considering Risk Management Measures Pre-Development

Possible Hazard	Use of Affected Area	Likelihood	Indicative Annual Probability P (H)	Probability of Spatial Impact P (S:H)	Temporal Probability P (T:S)	Vulner-ability V (D:T)	Probability of becoming Trapped	Risk for Person Most at Risk [Risk Evaluation]	Risk Outcome: A = Acceptable T = Tolerable NT = Not Tolerable
A - sliding of large boulders upslope of dwelling	Dwelling	Barely Credible to Rare	5.0E-06	0.5	0.50	0.25	0.25	7.81E-08	A
B - Slide in soils above rock (upslope of dwelling)	Garden upslope of residence	Unlikely	1.0E-04	0.10	0.25	0.10	0.10	2.50E-08	A
C – Failure of existing sandstone mortar walls	Rear Deck & gardens and/or road reserve	Unlikely	1.0E-04	0.50	0.25	0.10	0.10	1.25E-07	A
D – Failure of temporary excavation batters	Pool Area and/or road reserve	Unlikely	1.0E-04	0.50	0.25	0.25	0.1	3.12E-07	A

Notes:

1. The appraisal of the assessed risk relative to acceptable and tolerable risks is based on Table 1 of AGS (2007) – Reference 1, for a new development.
2. Risk mitigation will be required to ensure that the assessed risk outcome during and after the proposed development is acceptable. Referred to report for further details.
3. This table must be read in conjunction with Table A.
4. Risk Outcome:

   A = Acceptable ≤ 10-6

   T = Tolerable ≤ 10-5

   NT = Not Tolerable - treatment options to be assessed and implemented

Table 4 - Summary of Risk to Life Calculations Considering Risk Management Measures Post-Development

Possible Hazard	Use of Affected Structure	Likelihood	Indicative Annual Probability P (H)	Probability of Spatial Impact P (S:H)	Temporal Probability P (T:S)	Vulner-ability V (D:T)	Probability of becoming Trapped	Risk for Person Most at Risk [Risk Evaluation]	Risk Outcome: A = Acceptable T = Tolerable NT = Not Tolerable
A - sliding of large boulders upslope of dwelling	Dwelling	Barely Credible to Rare	5.0E-06	0.5	0.50	0.25	0.25	7.81E-08	A
B - Slide in soils above rock (upslope of dwelling)	Garden upslope of residence	Unlikely	1.0E-04	0.10	0.25	0.10	0.10	2.50E-08	A
C – Failure of existing sandstone mortar walls	Rear Deck & gardens and/or road reserve	Unlikely	1.0E-04	0.50	0.25	0.10	0.10	1.25E-07	A
D – Excavations for swimming pool & garage	Dwelling & Road Reserve	Rare	1.0E-05	0.5	0.33	0.10	0.10	1.65E-08	A

Notes:

1. The appraisal of the assessed risk relative to acceptable and tolerable risks is based on Table 1 of AGS (2007) – Reference 1, for a new development.
2. Risk mitigation will be required to ensure that the assessed risk outcome during and after the proposed development is acceptable. Referred to report for further details.
3. This table must be read in conjunction with Table A in Appendix H.
4. Risk Outcome:
   A = Acceptable ≤ 10-6
   T = Tolerable ≤ 10-5
   NT = Not Tolerable - treatment options to be assessed and implemented

Note:

The values of the probability terms in Tables 2-4 have been estimated for the site by engineering judgement based on previous experience with risk assessment calculations, hillside building developments and landslide stabilisation works.

Geotechnical recommendations are provided in Section 6 for the design and construction of proposed development, which incorporate the risk management measures provided in Section 5.4.

The geotechnical hazards identified on site can be effectively managed to maintain a Low level of “Risk to Property” provided Alliance’s recommendations are followed in the construction of the proposed works.

5.4 Risk Management Measures and Residual Risks

The AGS risk assessment for the site presented in Sections 5.2 and 5.3 is based on compliance with the geotechnical recommendations provided in Section 6. It is noted that most of the identified geotechnical issues which are pertinent to the site are typical to those expected on sloping land and can be managed by established hillside construction practice (see guidelines for hillside construction and examples of both good and poor hill side construction practice in Appendix F), in conjunction with regular construction review by a geotechnical engineer. The risks associated with the hazards described in Section 5.1 can be reduced to and maintained at acceptable levels of “Very Low to Low” provided the following recommendations are implemented:

- Measures to divert and control surface and subsurface water runoff by installation of permanent drainage (see Sections 6.3 & 6.6)
- Slope surface protection against rain, erosion, and weathering (see Section 6.5).
- Measures to prevent tree root jacking and animal burrowing (see Section 6.5).
- On-going maintenance of retaining walls and drainage infrastructure (see Table A in Appendix H).

Some guidelines for hillside construction and examples of both good and poor hill side construction practice are given in Appendix F.

6. COMMENTS and RECOMMENDATIONS

6.1 Inferred Geological Profile

The results of the field work, and knowledge gained from previous work in the area, indicates that the geological profile underlying the site consists of sandy topsoil and sandy and silty clays over a relatively shallow bedrock profile consisting of fine to medium grained sandstone and interbedded siltstone from the Newport Formation with sandstone outcrops deposited from the Hawkesbury Sandstone Formation located further upslope. The results of the field work indicate that the upper horizon of the weathered bedrock profile is approximately 1.2m to 2.3m below the existing ground surface levels across the proposed building platform areas.

6.2 Excavation

Review of the DA plans indicates that excavation of approximately 3.5m will be required for construction of the double garage and excavation of approximately 3.0m will be required for creation of the space for the pool location with a further 2.0m for the pool excavation itself. Based on the results of the field work, it is expected that the materials encountered within this depth range will consist of sandy and clayey soils overlying weathered very low and low strength sandstone and siltstone bedrock, possibly grading to low and medium strength bedrock. Soils and very low and low strength bedrock are usually readily excavated using conventional earthmoving equipment such as an excavator fitted with a rock digging bucket with tiger-teeth and rippers for low strength rock. Hydraulic rock hammer equipment will be required to excavate medium and high strength bedrock, if encountered.

Vibration levels are controlled by rock strength and the size of the rock hammer used to excavate the material, therefore if medium or higher strength bedrock is encountered and hydraulic rock hammers are used, precautions will need to be put in place to limit site vibration levels. It is unlikely that significant amounts of medium or higher strength bedrock will be required to be excavated with much of the material expected to consist of silty clay and very low and low strength sandstone or siltstone.

A maximum peak particle velocity of 10mm/sec is recommended by AS 2187 Explosives Code for houses and low-rise residential buildings and this is the peak particle velocity limit recommended for this site (unless otherwise specified by Council).

If medium or higher strength rock is encountered, and hydraulic hammer equipment is used then it is suggested that a vibration monitor be set up onsite to check that vibration levels (peak particle velocity levels) are kept below the recommended peak particle velocity. Although a peak particle velocity of 1 mm/sec is recommended by the relevant Australian Standard, experience has shown that cosmetic damage to masonry structures may occur with peak particle velocities of less than 10mm/sec. If vibration levels exceed 5mm/sec cosmetic damage to neighbouring masonry structures may result. If the neighbouring structures are of significant age or show signs of foundation movement, then vibration levels should be kept below 3mm/sec.

Should larger excavation equipment be able to access the area of excavation then based on previous experience monitoring excavation of medium or higher strength sandstone in the Sydney region, vibration levels are generally kept below 5mm/sec if the excavator fitted with hydraulic hammer equipment operates at a distance greater than 3m away from any neighbouring masonry structures for a 300kg hammer, 6m for a 600kg hammer and 20m for a 900kg hammer. If the hydraulic hammer equipment is required to operate within these distances, then the hammer should be used in short durations with the hammer pointed away from the structure in question (if possible) and the size of the hammer and its power output should be minimised.

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

Table 5 - Batter Slopes

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	**Long Term/ Permanent**
Compacted Fill	1.5:1	2.5:1
Sandy and clayey soils	1.5:1	2:1
Sandstone (extremely low strength)	1:1	1.5:1
Sandstone / Siltstone (very low)	0.5:1	0.75:1 *
Sandstone / Siltstone (low strength)	0.15:1	0.25:1 *
Sandstone / Siltstone (medium or higher strength)**	Vertical *	Vertical *

* Dependent upon jointing and the absence of unfavourably oriented joints – subject to inspection by a Geotechnical Engineer.
** Unlikely to be encountered within the depth of excavation.

6.3 Retaining Structures

Where space limitations preclude the battering of either cut or filled slopes, it will be necessary to provide support to the cut or filled embankments using an appropriate "engineer designed" retaining wall system. Retaining walls will be required for the double garage and at the rear of the pool area with reinforced concrete block walls being a cost-effective option for the double garage. It is very unlikely that vertical cuts in the clayey soils and weathered very low strength bedrock will remain stable for enough time to allow construction of blockwork retaining walls and as such temporary stabilisation measures such as reinforced shotcrete facing will be required prior to construction of permanent retaining walls for the garage construction. Excavation and retention at the rear of the pool area will need to be done in stages as it is unlikely that pier drilling equipment will be able to access the area and a soldier pile wall is thus not a viable retention option. The excavation will need to be carried out in 1m - 1.5m drops and a soil nail and reinforced shotcrete wall constructed progressively. This wall will need to be tied into a reinforced concrete footing constructed at the toe of the wall.

Lateral earth pressures for a cantilevered wall, or a wall restrained by a single row of ground anchors may be calculated using the following triangular earth pressure distribution:

$H_z = K \gamma z$

Where: H_z = horizontal pressure at depth, z
γ = unit weight of soil (20 kN/m^3) or rock (22 kN/m^3)
K = lateral earth pressure coefficient

Pressures acting on retaining walls can be calculated based on the parameters listed in Table 6 for the materials likely to be retained.

Table 6 - Design Parameters for Retaining Structures

Material	Unit Weight (kN/m³)	Friction Angle Long Term (Drained)	Cohesion (Drained) (kPa)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
				Active (K_a)	At Rest (K_o)	
Residual clayey soils and well compacted clayey filling	20	ϕ' = 25°	c'=5	0.35	0.5	2.0
Silty Sands (Loose)	18	ϕ' = 30°	c'=0	0.35	0.5	3.0
Extremely low strength rock	22	ϕ' = 30°	c'=10	0.25	0.4	200 kPa
Very low and low strength rock (jointed)	22	ϕ' = 35°	c'=20	0.20	0.3	400 kPa
Low strength rock	22	ϕ' = 38°	c'=50	0.1		2000 kPa
Medium strength rock	22	ϕ' = 40°	c'=250	0.0**		4000 kPa
High Strength Rock	24	ϕ' = 40°	c'=500	0.0**		6000 kPa

* Ultimate design values

** 0.1 if highly fractured

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

6.4 Foundations

The results of the fieldwork indicate that weathered bedrock is at relatively shallow depth below the existing ground surface levels and will likely be exposed after excavation for construction of the double garage and pool. As such, the use of pad/strip footings or possibly shallow piers, founding in the weathered sandstone bedrock would be appropriate for the double garage and swimming pool, with the foundations dimensioned based on founding in at least very low strength sandstone, with an allowable bearing pressure (for serviceability) of 800kPa, increasing to 1500kPa, if founded in low strength sandstone. Settlement is expected to be less than 1% of the footing width for footings founded in sandstone bedrock.

A geotechnical engineer should inspect and verify the founding strata for any new footings at the time of construction. Some additional information on performance and maintenance of footings for residential developments is given in CSIRO BTF 18 which is enclosed in Appendix G.

6.5 Slope Protection Measures

The existing slope above the existing building was observed to be well vegetated with structured garden beds. These garden beds are considered to be an adequate erosion control measure as long they are not disturbed in the future. Any vegetation disturbed during the proposed works must be replanted following completion of excavation and any remediation works.

6.6 Site Drainage

In order to maintain an acceptable level of risk of landslide it is crucial to control site drainage from both upslope areas and on the site itself. It is recommended that the existing stormwater drainage system be checked for the proposed development. If the strata overlying bedrock is allowed to become saturated due to inadequate drainage or a broken service pipe, then the risk of slip or erosion would be significantly increased.

6.7 Design Life of Structure

We have interpreted the design life requirements specified within Councils Geotechnical Risk Management Policy to refer to structural elements designed to support the proposed garage, swimming pool and the adjacent slope, control stormwater and maintain the risk of instability within acceptable limits.

Specific structures that may affect the maintenance and stability of the site in relation to the proposed development are considered to comprise:

- Retaining structures to support embankments/terraces adjacent to the garage and pool area,
- Stormwater and subsoil drainage systems,
- Maintenance of trees on this and adjacent properties.

These features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 1966 (70 years)) In order to attain a design life of 100 years as required by the Councils Geotechnical Risk Management Policy, it will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period and the property owner adopt and implement a maintenance and inspection program. A recommended program is given below and includes those in Table A enclosed in Appendix H.

- The site is inspected 12 months after the development is complete to verify that there have been no changes to the site stability by both the Structural Engineer and Geotechnical Consultant (at the same time, same day).
- The conditions on the site do not change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site, and the property is maintained in good order and in accordance with the guidelines set out in;
    a) CSIRO BTF 18 (see Appendix G) and,
    b) The Australian Geomechanics article “Geotechnical Risk Associated with Hillside Development” Number10, December 1985.

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to a relevant professional (e.g. structural engineer or geotechnical engineer).

6.8 Geotechnical Verification

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

7.0 Conditions Relating to Monitoring of Design and Construction

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

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

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

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

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

8.0 Limitations

This report has been prepared for the Client, Wyer & Co Pty Ltd, based on a walkover site inspection, and limited geotechnical testing at locations indicated to address the requirements of the proposed residential development at 888 Barrenjoey Road, Palm Beach NSW.

The geotechnical assessment and recommendations provided in this report are based on experience with previous geotechnical investigations and construction review of similar developments in similar geological conditions, and have been prepared with the benefit of hand drilled boreholes. To confirm the assessed soil and rock properties in this report, further investigation would be required such as coring and strength testing of rock and should be carried out if the scale of the development warrants, or if any of the properties are critical to the design, construction or performance of the development. Alliance cannot accept responsibility if the advice provided in this report is used for other sites or for preparing structural drawings.

Should you need any further information or to discuss this report, please contact the undersigned.

Written by

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Principal Geotechnical Engineer

Reviewed by

Mark Green
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APEC IntPE (Aus) CGeol FGS JP
Principal Geotechnical Engineer

Photo 1 – View of site from Barrenjoey Road, looking north east.

Photo 2 – View of location of proposed garage, looking east.

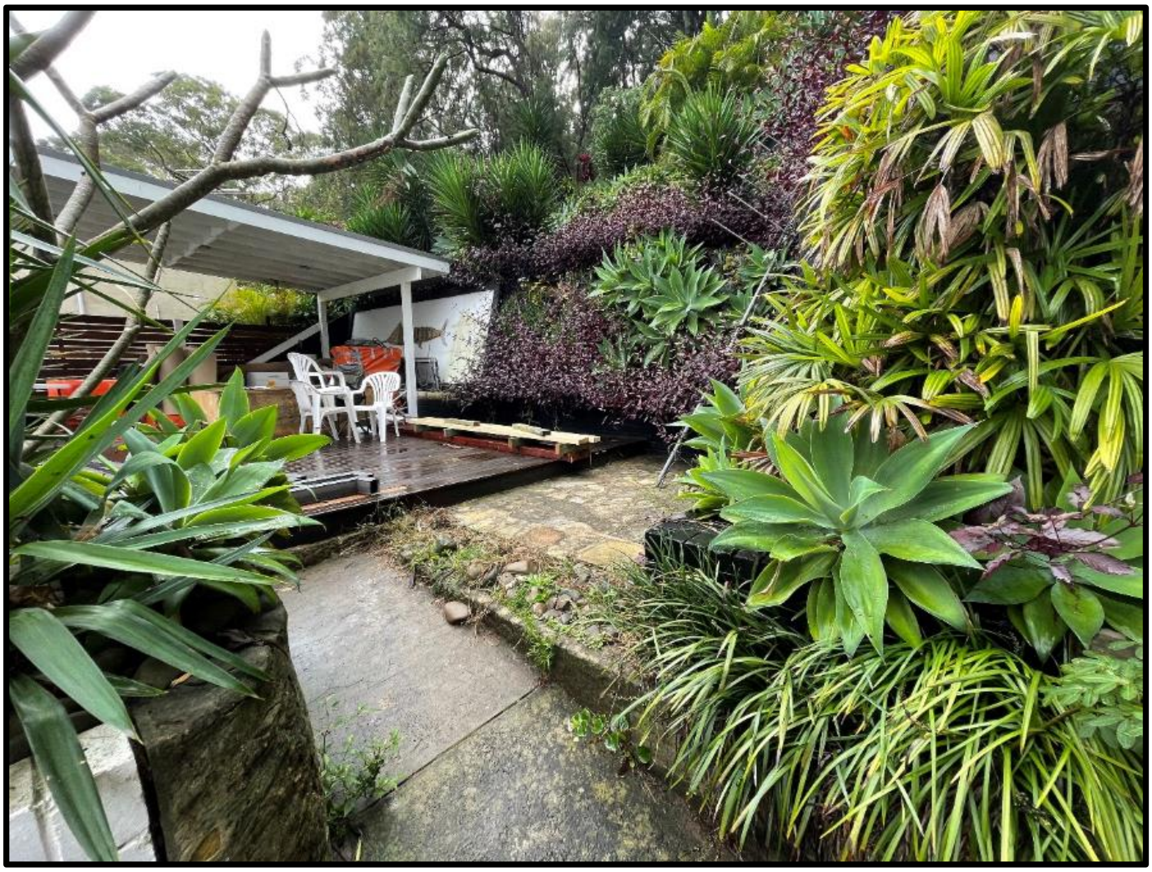


Photo 3 – View of location of proposed swimming pool, looking north-north-east.

Photo 4 - View of location of proposed swimming pool, looking north-south-east.

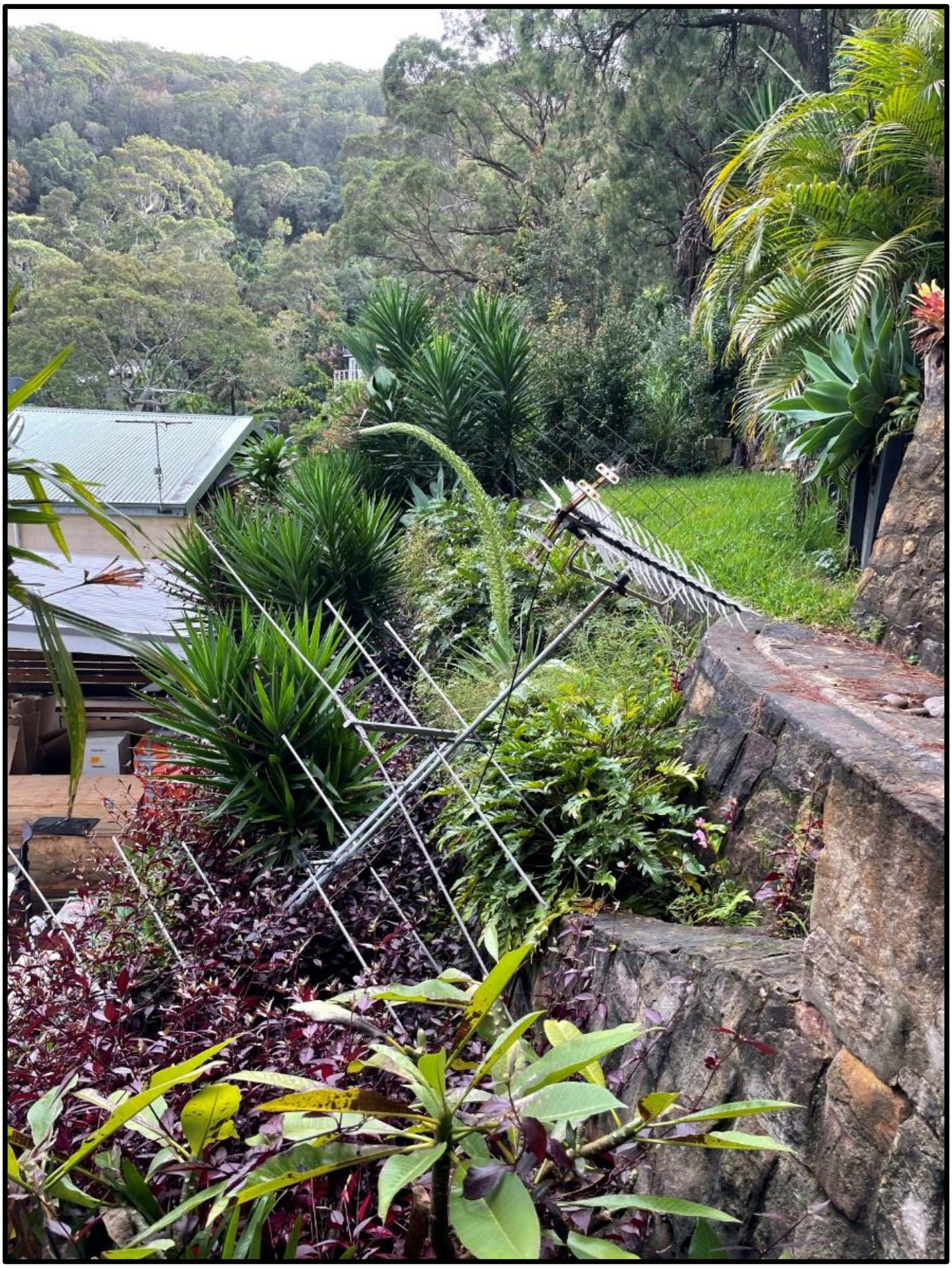


Photo 5 – View of terraced gardens and lawn area upslope from proposed pool location.

Photo 6 – View of concrete drain traversing north/south across rear section of site.

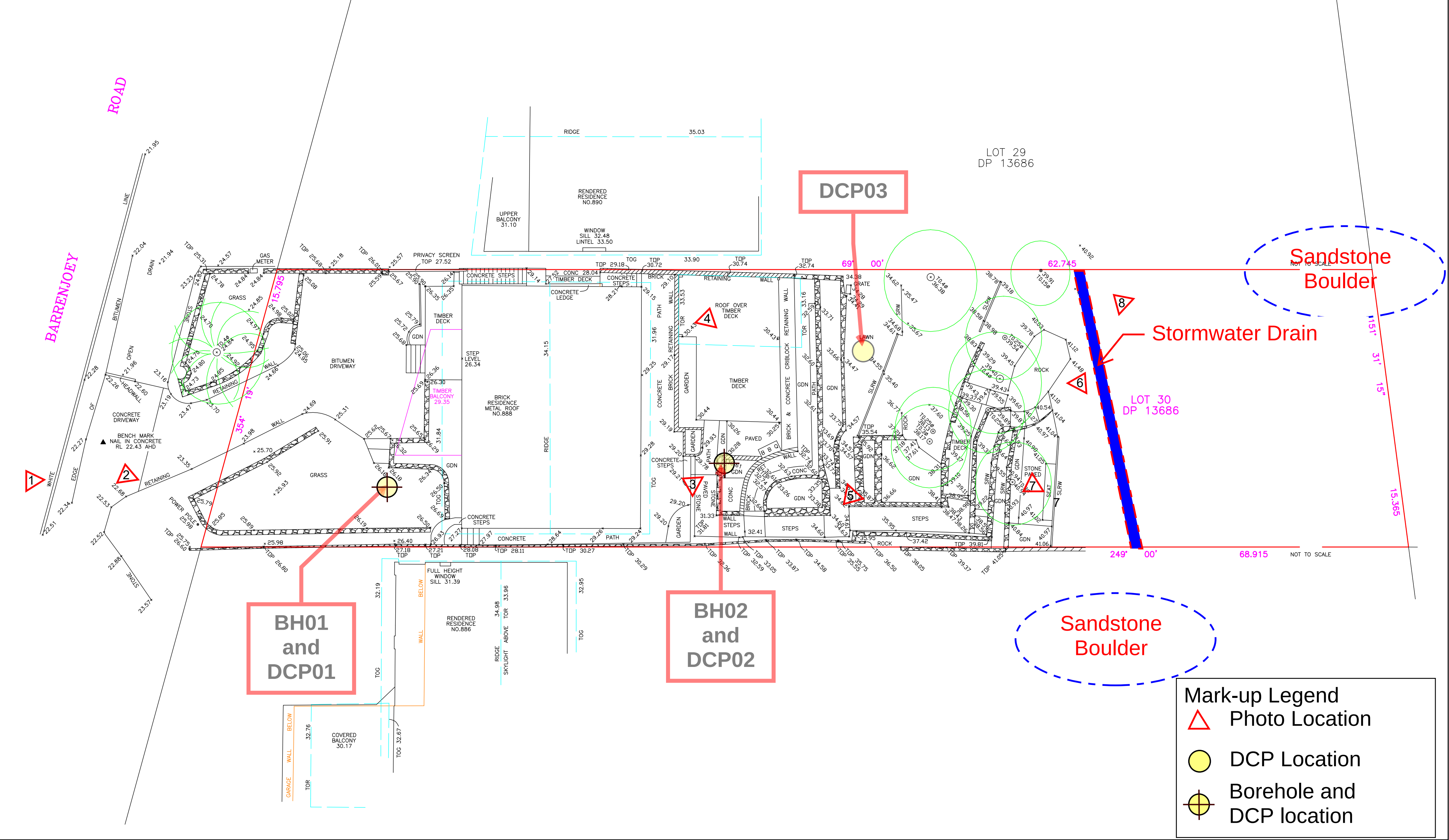
Photo 7 – Large sandstone boulder/outcrop in rear section of site on W side of concrete drain.

Photo 8 – Very large sandstone boulder/outcrop near north-eastern corner of site.

Photo 9 – View of typical sandstone rock wall with minor cracking.

APPENDIX B – Investigation Location Plan

* Site Plan not to Scale *



Geotechnical Site Investigation Plan

alliance	Client Name:	Wyer & Co Pty Ltd	Figure / Drawing Number:	12949-GR-1-A
	Project Name:	Proposed Residential Development	Figure / Drawing Date:	11/05/2021
	Project Location:	888 Barrenjoey Road, Palm Beach, NSW	Report Number:	12949-GR-1-1

APPENDIX C – Borehole Logs and Explanatory Notes

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Borehole Log

Alliance Geotechnical Pty Ltd
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BH No: BH01
Sheet: 1 of 1
Job No: 12949

Client: Wyer & Co
Project: Proposed Residential Development
Location: 888 Barren Joey Road, Palm Beach

Started: 7/05/2021
Finished: 7/05/2021
Borehole Size 50 mm

Rig Type: Mechanical Soil Sampler **Hole Location:** Refer to drawing 12949-GR-1-A **Driller:** MS **Logged:** MS
RL Surface: 26.2m **Contractor:** Alliance **Bearing:** --- **Checked:** LT

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
HA		26.0	0.0–0.7		--	FILL: CLAY, low to medium plasticity, brown mixed pale grey and orange, with silt, sand and fine to medium sandstone gravel. (Appears moderately compacted)		MC ~ PL	--	FILL
		25.5	0.7–0.9		--	FILL: CLAY, medium to high plasticity, pale grey mottled red.				
			0.9–1.2		--	REMNANT TOPSOIL: Silty SAND, fine to mediun grained, dark grey, with clay, trace organics.		M		REMNANT TOPSOIL
		25.0 / 24.5	1.2–2.0		--	Silty SAND, fine grained, dark grey, trace fine to medium sandstone gravel. 1.8m: With fine to medium sandstone gravel.			MD	SLOPEWASH/COLLUVIUM
		24.0	2.0			2.0m: Hand Auger refusal on sandstone boulder. Borehole BH01 terminated at 2m				

RL scale (m): 26.0, 25.5, 25.0, 24.5, 24.0, 23.5, 23.0, 22.5, 22.0, 21.5
Depth scale (m): 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0

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Borehole Log

Alliance Geotechnical Pty Ltd
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BH No: BH02
Sheet: 1 of 1
Job No: 12949

Client: Wyer & Co
Project: Proposed Residential Development
Location: 888 Barren Joey Road, Palm Beach
Started: 7/05/2021
Finished: 7/05/2021
Borehole Size 50 mm

Rig Type: Mechanical Soil Sampler **Hole Location:** Refer to drawing 12949-GR-1-A **Driller:** MS **Logged:** MS
RL Surface: 30.0m **Contractor:** Alliance **Bearing:** --- **Checked:** LT

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
HA					--	FILL/TOPSOIL: Clayey SAND, fine to medium grained, dark grey, with organics.		W	--	FILL
		29.5	0.5		--	FILL: Sandy CLAY, medium plasticity, brown-grey, fine to coarse sand, with fine to coarse sandstone gravel and cobbles. (Appears well compacted)		MC ~ PL		
		29.0	1.0		CI - CH	Silty CLAY, medium to high plasticity, brown mottled red with fine to medium sand and sandstone gravel.			St	RESIDUAL
		28.5	1.5		--	SANDSTONE: extremely low strength, extremely weathered, orange grey, fine to medium grained sandstone.		MC <~ PL	--	EXTREMELY WEATHERED BEDROCK
						Borehole BH02 terminated at 1.5m				
		28.0	2.0							
		27.5	2.5							
		27.0	3.0							
		26.5	3.5							
		26.0	4.0							
		25.5	4.5							
		25.0	5.0							

Explanatory Notes
Drill & Excavation Logs

General

Information obtained from site investigations is recorded on log sheets. Soils and very low strength rock are commonly drilled using a combination of solid-flight augers with a Tungsten-Carbide (TC) bit. Descriptions of these materials presented on the "Borehole Log" are based on a combination of regular sampling and in-situ testing. Rock coring techniques commences once material is encountered that cannot be penetrated using a combination of solid-flight augers and Tungsten-carbide bit. The "Cored Borehole Log" presents data from drilling where a core barrel has been used to recover material - commonly rock.

The "Excavation - Geological Log" presents data and drawings from exposures of soil and rock resulting from excavation of pits or trenches.

The heading of the log sheets contains information on Project Identification, Hole or Test Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material description and structure presented as a series of columns in relation to depth below the ground surface which is plotted on the left side of the log sheet. The scale is presented in the depth column as metres below ground level.

As far as is practicable the data contained on the log sheets is factual. Some interpretation is included in the identification of material boundaries in areas of partial sampling, the location of areas of core loss, description and classification of material, estimation of strength and identification of drilling induced fractures, and geological unit. Material description and classifications are based on Australian Standard Geotechnical Site Investigations: AS 1726 - 2017 with some modifications as defined below.

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

Drilling

Drilling, Casing and Excavating

Drilling methods deployed are abbreviated as follows

AS	Auger Screwing
ADV	Auger Drilling with V-Bit
ADT	Auger Drilling with TC Bit
BH	Backhoe
E	Excavator
HA	Hand Auger
HQ	HQ core barrel (~63.5 mm diameter core) *
HMLC	HMLC core barrel (~63.5 mm diameter core) *
NMLC	NMLC core barrel (~51.9 mm diameter core) *
NQ	NQ core barrel (~47.6 mm diameter core) *
RR	Rock Roller
WB	Wash-bore drilling

* Core diameters are approximate and vary due to the strength of material being drilled.

Drilling Fluid/Water

The drilling fluid used is identified and loss of return to the surface estimated as a percentage. It is introduced to assist with the drill process, in particular, when core drilling. The introduction of drill fluid/water does not allow for accurate identification of water seepages.

Drilling Penetration/Drill Depth

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

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

Groundwater Levels

Date of measurement is shown.

▼	Standing water level measured in completed borehole
▽	Level taken during or immediately after drilling
►—	Groundwater inflow water level

Samples/Tests

Samples collected and testing undertaken are abbreviated as follows

ES	Environmental Sample
DS	Disturbed Sample
BS	Bulk Sample
U50	Undisturbed (50 mm diameter)
C	Core Sample
SPT	Standard Penetration Test
N	Result of SPT (*sample taken)
VS	Vane Shear Test
IMP	Borehole Impression Device
PBT	Plate Bearing Test
PZ	Piezometer Installation
HP	Hand Penetrometer Test
HB	Hammer Bouncing

Excavation Logs

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

Material Description – Soil

Material Description - In accordance with AS 1726-2017

Classification Symbol - In accordance with the Unified Classification System (AS 1726-2017).

Abbreviation	Typical Names
GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures.
SW	Well graded sands, gravelly sands, little or no fines.
SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
SM	Silty sand, sand-silt mixtures.
SC	Clayey sands, sand-clay mixtures.
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
OL	Organic silts and organic silty clays of low plasticity. *
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts.
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts. *
Pt	Peat and other highly organic soils. *

* Additional details may be provided in accordance with the Von Post classification system (1922).

Organic Soils - Identification using laboratory testing:

Material	Organic Content - % of dry mass
Inorganic	<2
Organic Soil	<2 ≤ 25
Peat	> 25

Organic Soils - Descriptive terms for the degree of decomposition of peat:

Term	Decomposition	Remains	Squeeze
Fibrous	Little or none	Clearly recognizable	Only water No solid
Pseudo-fibrous	Moderate	Mixture of fibrous and amorphous	Turbid water < 50% solids
Amorphous	Full	Not recognizable	Paste > 50% solids

Particle Characteristics– Definitions are as follows:

Fraction	Component (& subdivision)		Size (mm)
Oversize	Boulders		> 200
	Cobbles		> 63 ≤ 200
Coarse grained soils	Gravel	Coarse	> 19 ≤ 63
		Medium	> 6.7 ≤ 19
		Fine	> 2.36 ≤ 6.7
	Sand	Coarse	> 0.6 ≤ 2.36
		Medium	> 0.2 ≤ 0.6
		Fine	> 0.075 ≤ 0.21
Fine grained soils	Silt		0.002 ≤ 0.075
	Clay		< 0.002

Secondary and minor soil components

In coarse grained soils – The proportions of secondary and minor components are generally estimated from a visual and tactile assessment of the soils. Descriptions for secondary and minor soil components in coarse grained soils are as follows.

Designation of components	Percentage fines	Terminology (as applicable)	Percentage accessory coarse fraction	Terminology (as applicable)
Minor	≤ 5	Trace clay / silt	≤ 5	Trace sand / gravel
	> 5 ≤12	With clay / silt	> 5 ≤12	With sand / gravel
Secondary	> 12	Silty or clayey	> 30	Sandy or gravelly

Descriptions for secondary and minor soil components in fine grained soils are as follows.

Designation of components	Percentage coarse grained soils	Terminology (as applicable)
Minor	≤ 5	Trace sand / gravel / silt / clay
	> 5 ≤12	With sand / gravel / silt / clay
Secondary	> 30	Sandy / gravelly / silty / clayey

Plasticity Terms – Definitions for fine grained soils are as follows:

Descriptive Term	Range of Liquid Limit for silt	Range of Liquid Limit for clay
Low Plasticity	≤ 50	≤ 35
Medium Plasticity	N/A	> 35 ≤50
High Plasticity	> 50%	> 50

Particle Characteristics

Particle shape and angularity are estimated from a visual assessment of coarse-grained soil particle characteristics. Terminology used includes the following:

Particle shape – spherical, platy, elongated,

Particle angularity –angular, sub-angular, sub-rounded, rounded.

Moisture Condition – Abbreviations are as follows:

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

Moisture content of fine-grained soils is based on judgement of the soils moisture content relative to the plastic and liquid limit as follows:

MC < PL	Moist, dry of plastic limit
MC ≈ PL	Moist, near plastic limit
MC > PL	Moist, wet of plastic limit
MC ≈ LL	Wet, near liquid limit
MC > LL	Wet of liquid limit

Consistency - of cohesive soils in accordance with AS 1726-2017, Table 11 are abbreviated as follows:

Consistency Term	Abbreviation	Indicative Undrained Shear Strength Range (kPa)
Very Soft	**VS**	< 12
Soft	**S**	12 ≤ 25
Firm	**F**	25 ≤ 50
Stiff	**St**	50 ≤ 100
Very Stiff	**VSt**	100 ≤ 200
Hard	**H**	≥ 200
Friable	**Fr**	-

Density Index (%) of granular soils is estimated or is based on SPT results. Abbreviations are as follows:

Description	Abbreviation	Relative Density	SPT N
Very Loose	VL	< 15%	0 - 4
Loose	L	15 - 35%	4 - 10
Medium Dense	MD	35 - 65%	10 - 30
Dense	D	65 - 85%	30 - 50
Very Dense	VD	> 85%	> 50

Structures - Fissuring and other defects are described in accordance with AS 1726-2017 using the terminology for rock defects

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

Material Description - Rock

Material Description

Descriptions of rock for geotechnics and engineering geology in civil engineering

Identification of rock type, composition and texture based on visual features in accordance with AS 1726-2017.

Rock Naming – Where possible conventional geological names are used within the logs. Engineering properties cannot be inferred directly from the rock names in the table, but the use of a particular name provides an indicative range of characteristics to the reader. Lithological identification of rock is provided to appreciate the geology of an area, to correlate geological profiles seen in boreholes or to distinguish boulders from bedrock.

Grain Size – Grain size is done in accordance with AS1726-2017 as follows:

Coarse grained	Mainly 0.6 to 2 mm
Medium grained	0.2 – 0.6 mm
Fine grained	0.06 – 0.2 mm

Colour – Rock colour is described in the moist condition.

Texture and Fabric - Frequently used terms include:

Sedimentary Rock	Metamorphic Rock	Igneous
Bedded	Cleaved	Massive
Interbedded	Foliated	Flow banded
Laminated	Schistose	Folded
Folded	Banded	Lineated
Massive	Lineated	Porphyritic
Graded	Gneissose	Crystalline
Cross-bedded	Folded	Amorphous

Bedding and Laminated – AS 1726 – 2017 bedding and laminated rock descriptions are provided below with additional detail from BS EN ISO 14689-1 as guidance.

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

Features, inclusions and minor components – Features, inclusions and minor components within the rock material shall be described where those features could be significant such as gas bubbles, mineral veins, carbonaceous material, salts, swelling minerals, mineral inclusions, ironstone or carbonate bands, cross-stratification or minerals the readily oxidise upon atmospheric exposure.

Moisture content – Where possible descriptions are made by the feel and appearance of the rock using one according to following terms:

Dry	Looks and feels dry.
Moist	Feels cool, darkened in colour, but no water is visible on the surface
Wet	Feels cool, darkened in colour, water film or droplets visible on the surface

The moisture content of rock cored with water may not be representative of its in-situ condition.

Durability – Descriptions of the materials durability such as tendency to develop cracks, break into smaller pieces or disintegrate upon exposure to air or in contact with water are provided where observed.

Rock Material Strength – The strength of the rock material is based on uniaxial compressive strength (UCS). The following terms are used:

Rock Strength Class	Abbreviation	UCS (MPa)	Point Load Strength Index, $I_{s(50)}$ (MPa)
Very Low	VL	> 0.6 ≤ 2	> 0.03 ≤ 0.1
Low	L	> 2 ≤ 6	> 0.1 ≤ 0.3
Medium	M	> 6 ≤ 20	> 0.3 ≤ 1
High	H	> 20 ≤ 60	> 1 ≤ 3
Very High	VH	> 60 ≤ 200	> 3 ≤ 10
Extremely High	EH	> 200	> 10

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

D	Diametral Point Load Test
A	Axial Point Load Test

Where the estimated strength log covers more than one range it indicates the rock strength varies between the limits shown. Point Load Strength Index test results are presented as $I_{s\ (50)}$ values in MPa.

Weathering - Weathering classification assists in identification but does not imply engineering properties. Descriptions are as follows:

Term (Abbreviation)	Description
Fresh (FR)	No signs of mineral decomposition or colour change.
Slightly Weathered (SW)	partly stained or discoloured. Not or little change to strength from fresh rock.
Moderately Weathered (MW)	material is completely discoloured, little or no change of strength from fresh rock.
Highly Weathered (HW)	material is completely discoloured, significant decrease in strength from fresh rock.
Extremely Weathered (EW)	Material has soil properties. Mass structure, material texture and fabric of original rock are still visible.
Residual Soil (RS)	Material has soil properties. Mass structure and material texture and fabric of original rock not visible, but the soil has not been significantly transported.

Alteration – Physical and chemical changes of the rock material due to geological processes by fluids at depth at pressures and temperatures above atmospheric conditions. Unlike weathering, alteration shows no relationship to topography and may occur at any depth. When altered materials are recognized, the following terms are used:

Term		Abbreviation		Definition
Extremely Altered		XA		Material has soil properties. Structure, texture and fabric of original rock are still visible. The rock name is replaced with the name of the parent material, e.g. Extremely Altered basalt. Soil descriptive terms are used.
Highly Altered	Distinctly altered	HA	DA	The whole of the rock material is discoloured. Rock strength is changed by alteration. Some primary minerals are altered to clay minerals. Porosity may be higher or lower due to loss of minerals or precipitation of secondary minerals in pores.
Moderately Altered	Distinctly altered	MA	DA	The whole of the rock material is discoloured Little or no change of strength from fresh rock. The term 'Distinctly Altered' is used where it is not practicable to distinguish between 'Highly Altered' and 'Moderately Altered'. Distinctly Altered is defined as follows: The rock may be highly discoloured; Porosity may be higher due to mineral loss; or may be lower due to precipitation of secondary minerals in pores; and Some change of rock strength.
Slightly Altered		SA		Rock is slightly discoloured Little or no change of strength from fresh rock.

Alteration is only described in the context of the project where it has relevance to the civil and structural design.

Defect Descriptions

General and Detailed Descriptions – Defect descriptions are provided to suit project requirements. Generalized descriptions are used for some projects where it is unnecessary to describe each individual defect in a rock mass, or where multiple similar defects are present which are too numerous to log individually. The part of the rock mass to which this applies is delineated.

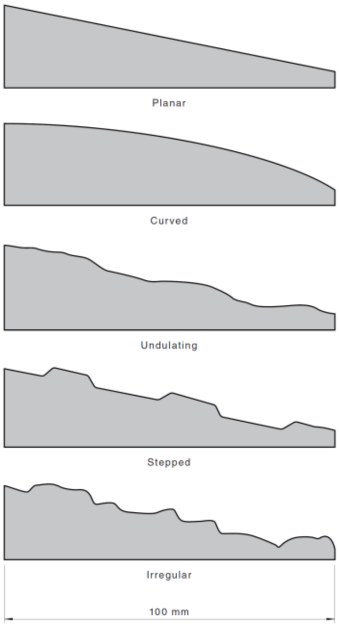
Detailed descriptions are given of defects judged to be particularly significant in the context of the project. For example, crushed seams in an apparently unstable slope. As a minimum, general descriptions outlining the number of defect sets within the rock mass and their broad characteristics are provided where it is possible to do so.

Defect Type – Defect abbreviations are as follows:

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

Defect Orientation – The dip and dip direction are recorded as a two-digit and three-digit number separated by a slash, e.g. 50/240 only when orientated core are collected and there is not core loss that could obscure core orientation. If alternative measurements are made, such as dip and strike or dip direction relative to magnetic north this shall be documented.

Surface Shape –At the medium scale of observation, description of the roughness of the surface shall be enhanced by description of the shape of the defect surface using the following terms, as illustrated below:



Defect Coatings and Seam Composition – Coatings are described using the following terms:

(a) *Clean* No visible coating.
(b) *Stained* No visible coating but surfaces are discoloured.
(c) *Veneer* A visible coating of soil or mineral, too thin to measure; may be patchy.
(d) *Coating* A visible coating up to 1 mm thick. Soil in-fill greater than 1 mm shall be described using defect terms (e.g. infilled seam). Defects greater than 1 mm aperture containing rock material great described as a vein.

Defect Spacing, Length, Openness and Thickness –described directly in millimetres and metres. In general descriptions, half order of magnitude categories are used, e.g. joint spacing typically 100 mm to 300 mm, sheared zones 1 m to 3 m thick.

Depending on project requirements and the scale of observation, spacing may be described as the mean spacing within a set of defects, or as the spacing between all defects within the rock mass. Where spacing is measured within a specific set of defects, measurements shall be made perpendicular to the defect set.

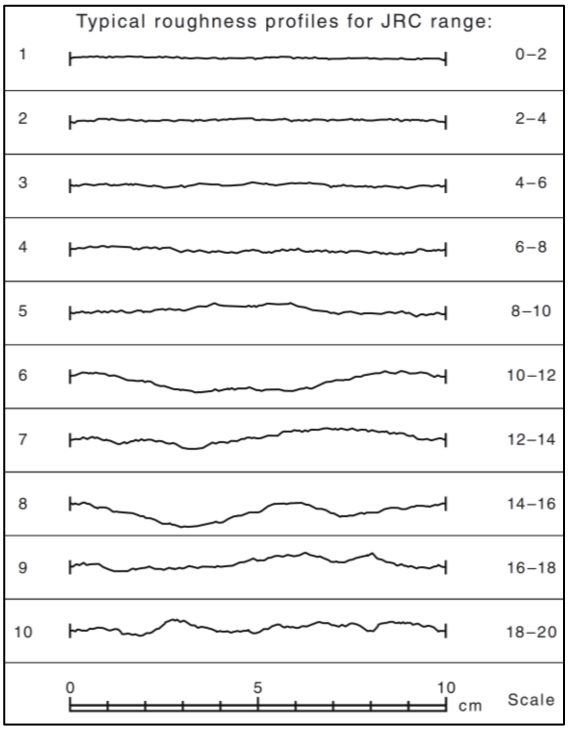
Defect spacing and length (sometimes called persistence), shall be described directly inmillimetres and metres.

Stratigraphic Unit - Geological maps related to the project are used for the designation of lithological formation name and, where possible geological unit name, e.g. Bringelly Shale, Potts Hill Sandstone Member.

Defect Roughness and Shape – Defect surface roughness is described as follows:

Very rough	Many large surface irregularities with amplitude generally more than 1 mm.
Rough	Many small surface irregularities with amplitude generally less than 1 mm.
Smooth	Smooth to touch. Few or no surface irregularities.
Polished	Shiny smooth surface
Slickensided	Grooved or striated surface, usually polished.

Where applicable Joint Roughness Range (JRC) is provided as follows:



Joint roughness profiles and corresponding JRC range based on Barton, N and Choubey, V. The Shear Strength of Rock Joints in Theory and Practice. *Rock Mechanics.* Vol. 10 (1977), pp. 1–54.

Where possible the mineralogy of the coating is identified.

Defect Infilling - abbreviated as follows:

CA	Calcite	KT	Chlorite
CN	Clean	MS	Secondary Mineral
Cy	Clay	MU	Unidentified Mineral
CS	Crushed Seam	Qz	Quartz
Fe	Iron Oxide	X	Carbonaceous

Parameters Related to Core Drilling

Total Core Recovery – T

Defect Spacing or Fracture Index – T

Rock Quality Designation – Y

Core Loss – Core loss occurs when material is lost during the drilling process It is shown at the bottom of the run unless otherwise indicated where core loss is known.

APPENDIX D – Dynamic Cone Penetrometer Testing Results

alliance

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Dynamic Cone Penetrometer (DCP) Test Report

Client	Wyer &Co Pty Ltd	**Report Number**	12949-GR-1-1
Project Name	Proposed Residential Development	**Project Number**	12949
Project Location	888 Barrenjoey Road Palm Beach	**Date Tested**	7 May 2021
Test Method	AS 1289.6.3.2		

Test Number	**DCP-01**	**DCP-02**	**DCP-03**		
Test Locations	Refer to Drawing 11949-GR-1-A				
Surface Material	Filling - Clay	Filling - Clay	Topsoil Filling		
Surface Conditions	Dry to Moist	Dry to Moist	Dry to Moist		
Approximated RL (m AHD)	26.2	30.0	34.5		
0.00 – 0.15	2	2	1		
0.15 – 0.30	2	10	1		
0.30 – 0.45	3	7	2		
0.45 – 0.60	3	9	3		
0.60 – 0.75	3	17	2		
0.75 – 0.90	2	12	4		
0.90 – 1.05	3	6	4		
1.05 – 1.20	2	4	3		
1.20 – 1.35	3	13	5		
1.35 – 1.50	5	9	12		
1.50 – 1.65	3	7	15/75mm Refusal		
1.65 – 1.80	5	4			
1.80 – 1.95	4	5			
1.95 – 2.10	5	6			
2.10 – 2.25	4	8			
2.25 – 2.40	15/120mm Refusal	16			
2.40 – 2.55					
2.55 – 2.70					

Notes: This test report is intended to be read in conjunction with the geotechnical report by Alliance Geotechnical (ref: GR12949-1-1).

APPENDIX E – AGS Risk Terms and Risk Analysis Tables

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

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

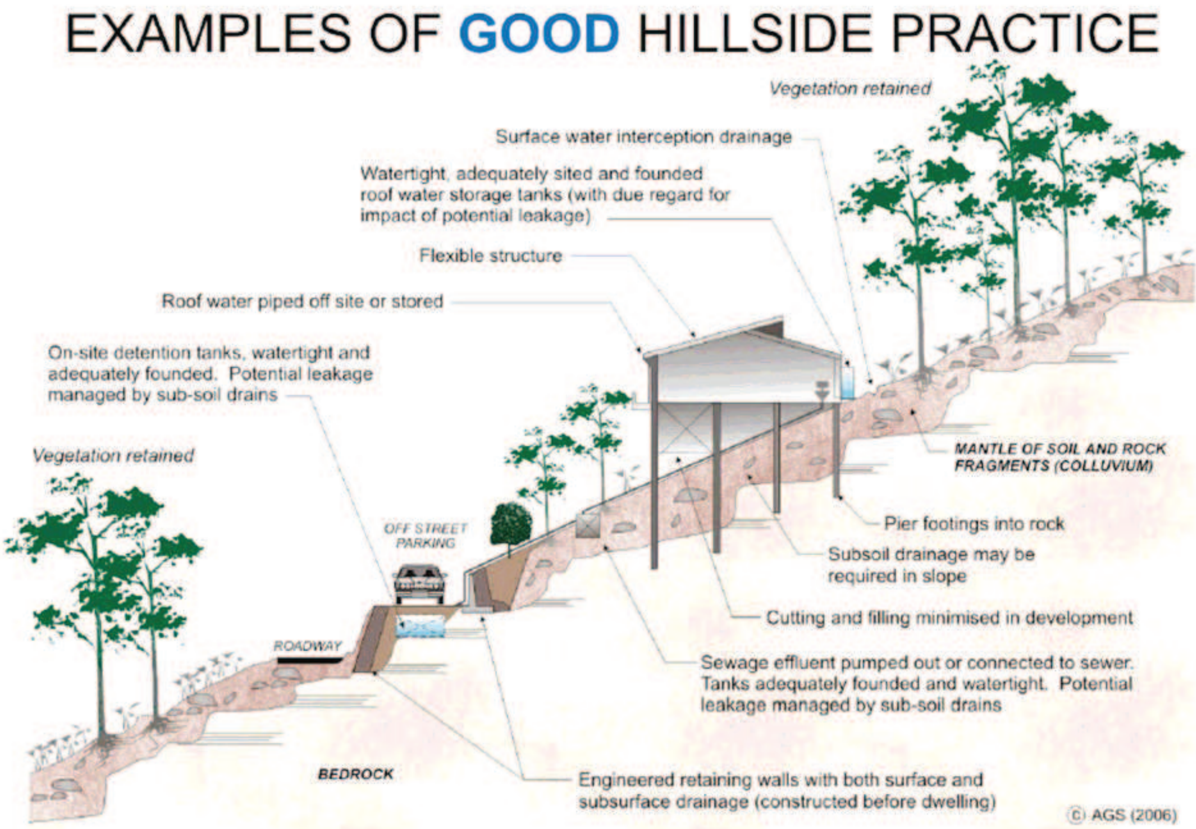
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
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.

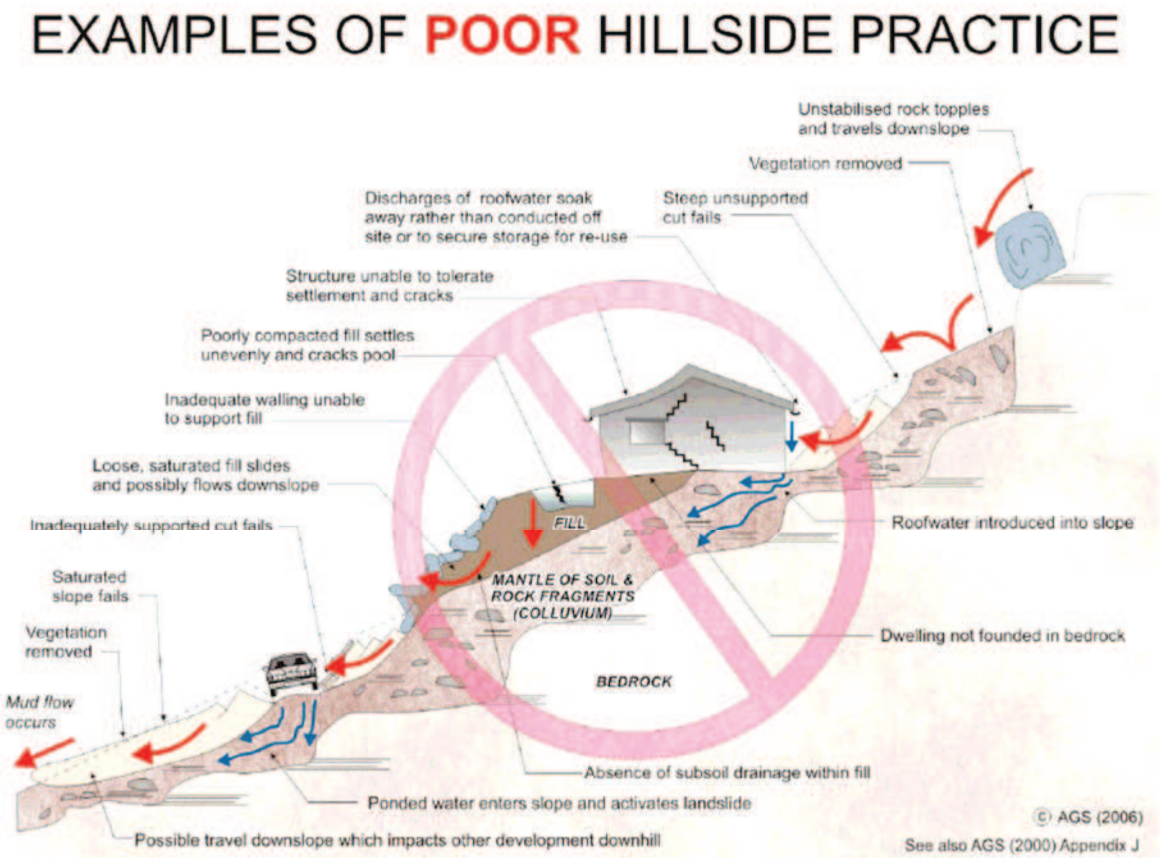
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

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
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
OFF STREET PARKING
ROADWAY
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
Mud flow occurs
BEDROCK
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
© AGS (2006)
See also AGS (2000) Appendix J

APPENDIX G – CSIRO BTF 18

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.

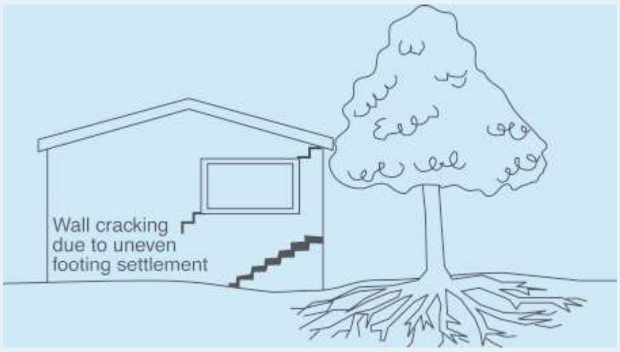
Seasonal swelling/shrinkage in clay

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.

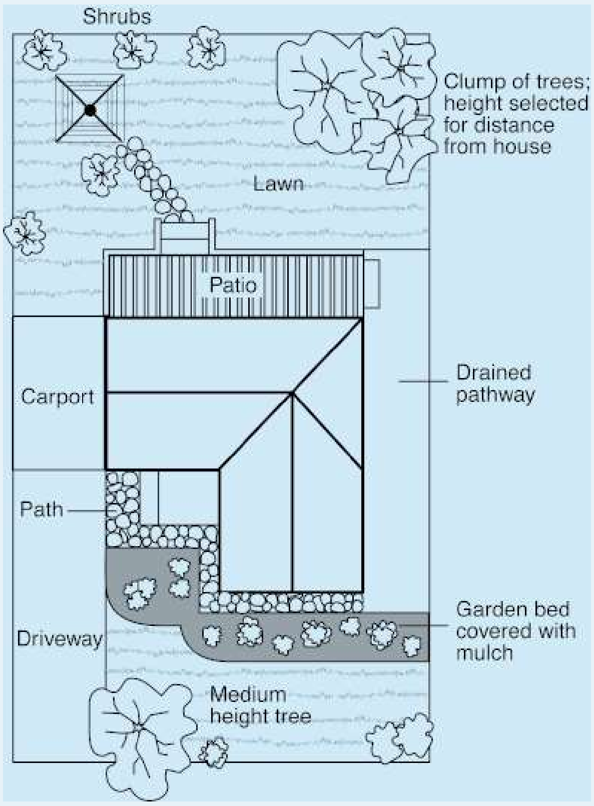
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

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

Distributed by

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APPENDIX H – Table A Maintenance and Inspection Program

TABLE A – RECOMMENDED MAINTENANCE AND INSPECTION PROGRAM

Structure	Maintenance / Inspection Item	Frequency
Stormwater Drains	Owner to inspect to ensure that the drains and pipes are free of debris and sediment build-up. Clear roof gutters, surface grates and drainage pits.	Every year or following every major rainfall event.
Retaining Walls	Owner to inspect walls for deviation from as constructed condition.	Every two years or following a major rainfall event.
Swimming Pool	Owner to inspect for leaks from pool, pumps and filters.	Every 3 months
Large Trees on site	Arborist to check the condition of trees to ensure stability.	Every five years or after a major storm event.
Slope stability	Hydraulics (stormwater) & geotechnical consultants to check site stability at the same time and provide report.	One year after construction is completed.

APPENDIX I – Northern Beaches Council (Pittwater) Forms 1 and 1a

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for____

Name of Applicant

Address of site **888 Barrenjoey Road Palm Beach**

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

I, **LACHLAN TAYLOR** *on behalf of* **Alliance Geotechnical Pty Ltd**
(Insert Name) (Trading or Company Name)

on this the 11 May 2021 certify that I am a geotechnical engineer ~~or engineering geologist or coastal engineer~~ as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

■ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: **12949-GR-1-1 Report on Geotechnical Investigation 888 Barrenjoey Road Palm Beach**

Report Date: **18 May 2021**
:
Author: **Lachlan Taylor**

Author's Company/Organisation: **Alliance Geotechnical Pty Ltd**

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

DP Surveying Survey Plan Ref 2385 dated 19 February 2021
Wyer & Co Pty Ltd development application drawings, Job No. 20.052, Drawing No. DA_1.0, DA_5.0, DA_5.1, DA_7.0, DA_7.1 and DA_7.2 all dated 4 May 2021

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

Signature … LTaylor …………………………..

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

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

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

Company…**Alliance Geotechnical Pty Ltd**

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

Development Application for____
Name of Applicant
Address of site _**888 Barrenjoey Road Palm Beach**___

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

Geotechnical Report Details:

Report Title: **12949-GR-1-1 Report on Geotechnical Investigation 888 Barrenjoey Road Palm Beach**
Report Date: **18 May 2021**
Author: **Lachlan Taylor**
Author's Company/Organisation: Alliance Geotechnical Pty Ltd

Please mark appropriate box

- ■ Comprehensive site mapping conducted ___________ (date)
- ■ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
- ■ Subsurface investigation required
  - ☐ No Justification …………………………………………………...
  - ■ Yes Date conducted **7 May 2021**

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

  - ■ Above the site
  - ■ On the site
  - ■ Below the site
  - ■ Beside the site

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

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

Signature …… ……………………………………………………..

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

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

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

Company… **Alliance Geotechnical Pty Ltd**