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GEOTECHNICAL REPORT

for

PROPOSED
NEW RESIDENTIAL DEVELOPMENT

at

6 MITCHELL ROAD, PALM BEACH

Prepared For

Roger Bain

Project No: 2018-145
March 2024

Document Revision Record

Issue No	Date	Details of Revisions
0	9th November, 2018	Preliminary assessment issue
1	14th August 2020	Development Application issue
2	13 March 2024	Re-Issue with updated drawings

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for____

Name of Applicant

Address of site ___ 6 Mitchell Road, Palm Beach

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

I, ***__Troy Crozier__________*** *on behalf of* ***___Crozier Geotechnical Consultants*** ______

on this the __13 March 2024_____ 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 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
- [x] 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 I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- [ ] have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- [ ] have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Proposed New Residential Development at 6 Mitchell Road, Pam Beach

Report Date: 13 March 2024 **Project No.:** 2018-145

Author: K. Nicholson / T. Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Survey by DP Surveying, reference: 3162, Dated: 11th September 2018
Architectural Design by Housed, Drawing: DA0, DA00 to DA04, DA08 to DA10, DA13 to DA15 and DA21 Date: 6/2/2024.
Geotechnical Review-Landslide Risk Assessment, No.6 Mitchell Road, Palm Beach, Davies Geotechnical Consulting Engineers, Reference: 21-023.A, Dated 1 July 2022.

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

Signature ....

Name ...**Troy Crozier**...............................

Chartered Professional Status...**RPGeo (AIG)** ....

Membership No. ...**10197**..............................

Company... **Crozier Geotechnical Consultants**

AUSTRALIAN INSTITUTE OF GEOSCIENTISTS

TROY CROZIER 10,197

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 _______ 6 Mitchell 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: Proposed New Residential Development at 6 Mitchell Road, Pam Beach
Report Date: 13 March 2024 **Project No.:** 2018-145
Author: K. Nicholson / T. Crozier
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted __11/09/2018_____ (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 ......11/09/2018...........................
- ■ 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 ...**Troy Crozier**..

Chartered Professional Status...**RPGeo (AIG)** ....

Membership No. ...**10197**..

Company... **Crozier Geotechnical Consultants**

REGISTERED PROFESSIONAL GEOSCIENTIST
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TABLE OF CONTENTS

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Date: 13 March 2024

Project No: 2018-145

GEOTECHNICAL REPORT FOR PROPOSED NEW RESIDENTIAL DEVELOPMENT 6 MITCHELL ROAD, PALM BEACH

1. INTRODUCTION:

This report details the results of a geotechnical investigation and assessment carried out for a proposed residential development at No. 6 Mitchell Road, Palm Beach, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Dr Stephen Lesiuk on behalf of Roger Bain.

It is understood that the proposed works involve the demolition of the existing site structure, and the construction of a new dwelling. The proposed dwelling consists of a four-storey structure with two lower living levels, a smaller third level for services and an upper garage structure, connected via a southern elevator and stairwell. The proposed development is to extend from R.L. 74.5m to R.L. 61.3m, with bulk excavations required to an anticipated 3.0m depth. Exposed sandstone bedrock is evident throughout the site, with southern regions of the site featuring large overhanging sections of exposed cliffs.

The site is located within the H1 (highest category) landslip hazard zone as identified within the Geotechnical Hazard Mapping (Geotechnical Risk Management Policy for Pittwater – 2009).

The investigation and reporting were undertaken as per the Tender: P18-265, Dated: 17th August 2018.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Senior Engineering Geologist.
b) Drilling of five boreholes using hand tools along with nine Dynamic Cone Penetrometer (DCP) Tests to investigate the subsurface geology, depth to bedrock and identification of ground water conditions.

The following plans and drawings were supplied for the work:

- Survey Plan: DP Surveying, Ref 3162, Dated: 11th September 2018.
- Architectural Design by Housed, Drawing: DA0, DA00 to DA04, DA08 to DA10, DA13 to DA15 and DA21 Date: 6/2/2024.

2. PROPOSED DEVELOPMENT

The proposed development involves the demolition of the existing structure and the construction of a new four storey dwelling, with a detached garage and rear suspended swimming pool. The existing bridge driveway is to be retained with a single storey garage structure to be constructed adjacent to the top of the driveway at R.L. 71.50m. Landscape works are proposed for regions of the site above this garage structure, including renewal of the existing retaining wall and balustrade at the base of the adjacent public reserve – 'The Bible Garden'.

The four-storey development includes two lower living levels which form the house structure with a partly out of ground swimming pool extending from the north of the structure. This swimming pool is anticipated to be suspended via piers. A small storage level is located below/adjacent to the existing suspended driveway whilst a garage is located upslope at the southern site boundary. An elevator and stairs will connect all four levels of the proposed development adjacent to the existing cliff line in the south-east corner of the block. Excavation for the access to the house structure will be required to an anticipated depth of ≤3.0m, as proposed works appear to intersect the base of the sandstone cliff line at the east end, however some additional excavation/ trimming of the cliff also appears required. Bulk excavation to 3.0m depth appears required for the upper garage structure.

3. SITE FEATURES:

3.1. Description:

The site forms a battle-axe shaped block located on the low north side of Mitchell Road. The site has north, east and west boundaries of approximately 25.8m, 17.0m and 41.8m respectively. The front south boundary is approximately 28.7m and provides street access to the site via a driveway running adjacent to a public reserve, "The Bible Garden" as referenced from the provided survey plan.

An aerial photograph of the site and its surrounds is provided below (Photograph 1), as sourced from NSW Government Six Map spatial data system.

Photograph 1: Aerial photo of site and surrounds

The site dwelling comprises a two-storey metal and concrete block structure constructed under a suspended concrete driveway which provides access to No. 15 Florida Road to the north-east of the site. Two general views of the site are shown in Photograph 2 and Photograph 3.

Photograph 2: View of the front of the site, looking north.

Photograph 3: View of the rear of site, looking west from the driveway directly above dwelling.

3.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet (9130) indicates that the site is located near the boundary between the Hawkesbury Sandstone (Rh) and Upper Narrabeen Group rocks (Rnn). Hawkesbury Sandstone which is of Triassic Age typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite and commonly forms a capping to the ridges in this area. Newport Formation rocks (Upper Narrabeen Group) are slightly older and found lower in the stratigraphy than the Hawkesbury Sandstone. They comprise interbedded laminite, shale and quartz to lithic quartz sandstone and pink clay pellet sandstone.

4. FIELD WORK:

4.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 11th September 2018 by a Senior Engineering Geologist. It included a photographic record of site conditions as well as a geological/geomorphological mapping of the site and adjacent land with examination of soil slopes, rock outcrops, existing structures and neighbouring properties. It also included the drilling of five boreholes (BH1 to BH5) using a hand auger to investigate sub-surface geology in the lower lawn terrace area. A hand auger was used as access to the majority of the site for a conventional drilling rig was unavailable.

DCP testing was carried out from ground surface adjacent to the boreholes and at a further four locations in accordance with AS1289.6.3.2 – 1997, "Determination of the penetration resistance of a soil – 9kg Dynamic Cone Penetrometer" to estimate near surface soil conditions and confirm depths to bedrock.

Explanatory notes are included in Appendix: 1. Mapping information and DCP test locations are shown on Figure: 1, along with detailed Borehole log sheets and Dynamic Penetrometer Test Sheet in Appendix: 2. A geological model/section is provided as Figure: 2 and 3, Appendix: 2. Borehole locations have been omitted from Figure: 1 for clarity however they were drilled in similar locations as the corresponding DCP tests.

4.2. Field Observations:

The site is situated on the low north side of Mitchell Road, within steep north dipping topography. It is currently occupied by a two-storey metal and concrete block residential structure that is formed below a suspended concrete driveway. Access to the site is via a driveway that runs from the low side of Mitchell Road down the west side of a public reserve located up slope from the site, known as 'Palm Beach Bible Garden'. The driveway then turns east and becomes suspended where it passes down a cliff outcrop before continuing into the neighbouring property to the northeast (No.15 Florida Road), at upper house level.

The exposed cliff line strikes east-west across the site near its upper south boundary with the existing house formed below the cliff within a step in the cliff alignment.

The existing site building comprises a metal and concrete block structure that appears to be in satisfactory condition with some minor cracking observed at the base of the rear wall, see Photograph 4. The cause of the cracking observed is unknown, however it may be due to settlement of the underlying dry stack rock wall.

Photograph 4: Cracking observed in the lower section of the rear wall.

A set of steel stairs provide access down the southern cliff face to the south side of the house, at the upper floor level, with a secondary staircase comprising sandstone pavers then providing access around the east side of the house to the rear north side of site, where the borehole and DCP tests were conducted. The sandstone paved stairs do not display any obvious signs of cracking or distress.

The rear of the site comprises a near-level lawn, retained by a wall of approximately 1.50m in height that appears founded off an outcrop of sandstone, however inspection of the condition of this structure was not feasible due to site conditions. Beyond the wall, to the north, exists steep to very steep terrain covered with dense vegetation.

The neighbouring property to the east, No.7 Mitchell Road, comprises a multi-storey rendered residential house that appears less than 20 years old and in good condition. The property is located above the cliff line to the south of the driveway within No.15 Florida Road, with extensive outcrops at its rear extending down to the cliff crest. Within the rear north-west corner of this property the cliff line contains a large overhang structure formed by differential weathering of a lower weaker unit within the cliff geology. This overhang is shown in Photographs 6 and 7.

The neighbouring property to the south 'Palm Beach Bible Garden' has a rear lawn terrace supported above the site by a dry stack sandstone rock retaining wall of up to 1.50m in height formed off the crest of a low (1.50m) sandstone bedrock outcrop/cliff. Signs of distress were not observed within the retaining wall or within the underlying bedrock outcrop, however the walls long term stability is likely limited by its construction style. The remainder of the property is formed as terraced gardens and appeared stable.

The neighbouring properties to the west of the site, No. 5 Mitchell Road and No. 19 Florida Road, contain residential dwellings greater than 10.0m from the common boundary. Both dwellings appear to be in satisfactory condition. The ground surface level within these properties is similar to the site at the boundary with extensive sandstone outcrops within similar topography to the site.

The neighbouring property to the north-east, No.15 Florida Road, comprises a rendered and stone clad residence located on the low north side of the access driveway. The property is positioned within similar steep north dipping topography to the site with the lower level of the house formed into an excavation of up to 3.0m depth in the slope which is covered in shotcrete. Upslope from the house are sloping gardens below the suspended access driveway that extend to the base of the cliff line.

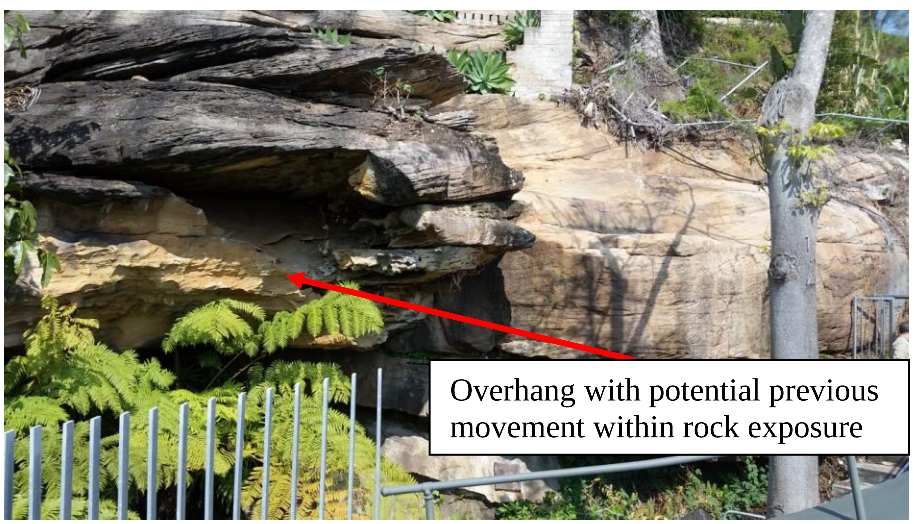
The neighbouring property to the north of the site, No. 17 Florida Road was not inspected due to access conditions, however the property appears to contain a residential house with a rear garden which contains an additional structure.

The neighbouring properties and structures were inspected from the site or road reserves therefore details are limited.

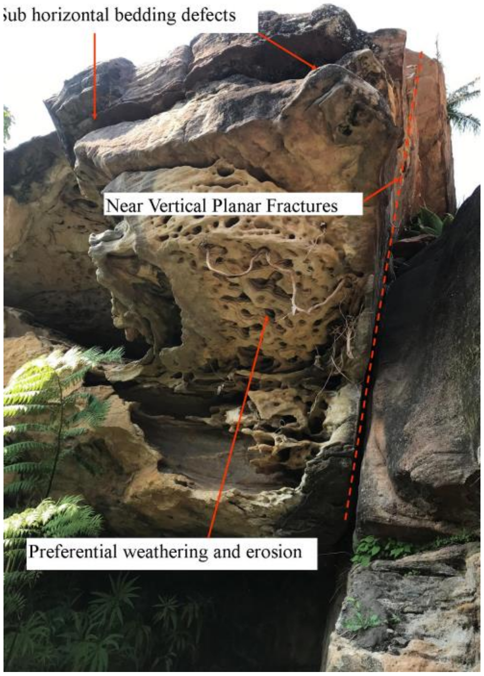
The existing dwelling is accessed via a set of stairs on the south side of the access driveway. A bedrock exposure forms a cliff to the south of the stairs which trends east-west and is formed via a continuous, planar sub-vertical joint defect. The cliff exposes low to medium strength sandstone bedrock and is convex at its crest rising up into the neighbouring properties to the south. Potential signs of previous surface slope movement were observed above the cliff crest including rotating trees and failing fence structures (see Photograph 5) however it was difficult to identify a mechanism for this distress and it may be related to surface creep rather than a deep-seated stability issue.

Photograph 5: View of sandstone outcrops above cliff, looking east.

Potential localised instability was observed in the cliff crest adjacent to the south-east corner of the site, near the base of the access stairs leading to the site house and lower level of the neighbouring property to the north east (No.15 Florida Road). It appears weathering and undercutting of a section of the existing exposed cliff line within No.7 Mitchell Road has resulted in localized rock detachment (See Photograph 6 and Photograph 7) along with a significant overhang. Whilst the dimensions of the overhang indicate it is stable at present further inspection is required from this neighbouring property.



Photograph 6: View of overhanging sandstone outcrops in No. 7, looking south.



Photograph 7: Horizontal bedding defects, near vertical fractures within the south of the site.

Photograph 8: Overhang/undercutting within the site.

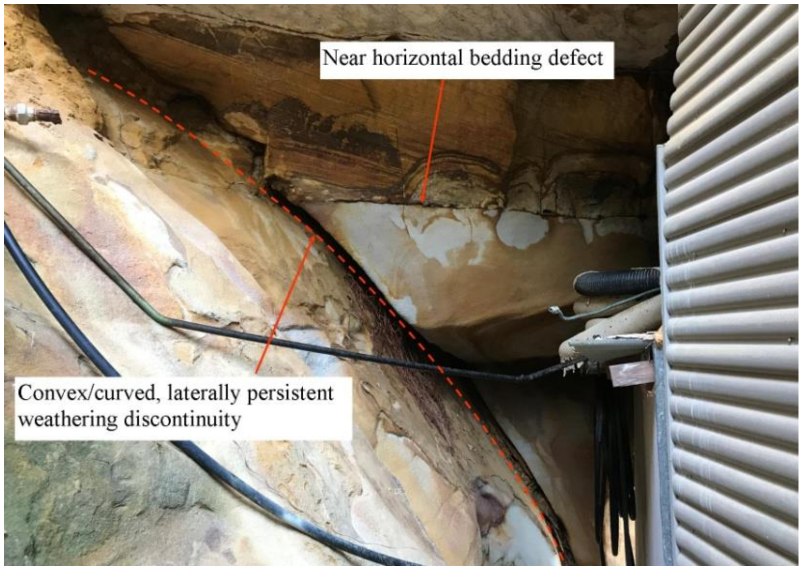
Within the area to the west of the existing site structure, concave undercutting was observed as indicated in Photograph 8. It appears that preferential weathering of the rock mass is occurring and resulting in the concave features indicated in Photograph 8. This has resulted in an overhang in the upper sandstone unit that extends over the existing site house, (Photograph 9).

Photograph 9: Defects within bedrock and overhang/undercutting at south-west corner of existing house.

Areas of exposed bedrock which appeared susceptible to erosion were also observed to the south of the site structure and accumulation of eroded sandstone was observed at the toe of the exposure (Photograph 10).

Photograph 10: Accumulation of eroded sandstone to the south of the site structure

To the south of the site structure, a convex defect was observed in the cliff which appeared to be laterally persistent and trended generally west/east (Photograph 11) through to the sites western side boundary through the lower portion of the cliff exposure. Groundwater was also observed on this defect plane further to the west and within the site. This defect has resulted in separation of the rock to the west of the house at the base of the cliff whilst sub-parallel defects through the units above have also separated those sections (as per Photograph 9).



Photograph 11: convex defects to the rear of the existing site structure.

Photograph 12: Weak zones within bedrock

Bedding defects were also observed within otherwise competent sandstone with weaker seams/partings of clay as a result of less competent rock material also encountered, see Photograph: 12.

4.3. Subsurface Investigation:

The boreholes (BH1-BH5) were drilled using a hand auger and refusal was encountered at all locations at a maximum depth of 0.38m (BH3B) within fill.

DCP tests were carried out from the ground surface adjacent to the boreholes and at additional locations due to the auger ineffectiveness and refused on what has been interpreted as bedrock at between depths of 0.35m to 1.75m.

Based on the borehole logs and DCP test results, the sub-surface conditions at the project site can be classified as follows:

- **TOPSOIL/FILL –** this layer was encountered at all test locations to a maximum depth 0.38m (BH3B), however this layer is anticipated to exist to a maximum depth 1.75m (DCP2a) below the existing ground surface. It comprised mostly fine to medium grained silty sand with gravel and probable cobbles which resulted in auger refusal.
- **SANDSTONE BEDROCK –** Based on DCP test results and observed outcrops throughout the site, sandstone bedrock of at least low strength was interpreted to vary from 0.35m (DCP2) to 1.75m (DCP2a) below the existing ground surface.

A free standing ground water table or significant water seepage were not identified within any of the boreholes. No signs of ground water were observed after the retrieval of the DCP rods.

5. COMMENTS:

5.1. Geotechnical Assessment:

The site investigation identified that the site is located in steep sloping topography dominated by cliff lines and rock outcrops. There were no indications of recent/previous instability and the assessment did not confirm any impeding instability however several rock overhangs do require further assessment.

The DCP's/boreholes undertaken at the rear of the site indicate what has been interpreted as insitu sandstone bedrock at depths between 0.35m and 1.75m below the existing lawn within the north of the site. The DCP testing indicated that the bedrock surface is apparently dipping broadly south to north at 20-25°.

Inspection of sandstone outcrops within the site and adjacent properties indicated that the bedrock is likely to range from low to medium strength with localised clay partings. Defects within the bedrock comprised near horizontal bedding defects, post depositional sub-vertical weathering defects/joints and convex joints along with near vertical fractures. In addition, undercutting through erosion was also observed.

The proposed works involve the demolition of the existing residential house structure with the existing bridge driveway to be retained and a new four storey dwelling is to be constructed. Excavation will be required to an anticipated 3.0m depth for the proposed access/lift to the house structure with minor cliff face trimming also required. Minor excavation for the third-floor level and moderate excavation to potentially 3.0m depth for the garage structure also appear required.

It is anticipated that minor fill soils and then sandstone bedrock will be intersected during excavation. According to DCP test results and interpretation of the site geology, the rock profile at the base of the main structure appears to incline north to south, within the zone of proposed development. As a result, excavation depth will increase to approximately 3.0m towards the southern wall of the proposed main structure, likely requiring greater depths of rock excavation.

As addressed, outcropping sandstone bedrock is prevalent throughout the site, thus it would be prudent to situate all footings on sandstone bedrock of low to medium strength. All footings for each structure including the main structure formed at R.L. 61.3m, the garage structure formed at R.L. 71.5m and the overhanging rear swimming pool should be founded within similar load bearing material (sandstone bedrock of low to medium strength) to reduce differential settlement risk.

Several significant overhangs and potential destabilising defects were identified in the mapping:

> The overhang within No.7 Mitchell Road appears globally stable at present though detailed mapping is not possible without approval of the neighbouring property owner. Based on the location of the overhang and its apparent direction of travel due to failure it is considered a hazard to the site. The scale of the overhang indicates that the risk of instability may need to be mitigated through construction of a support structure, though this would require construction within the neighbouring property. As such discussion with the neighbouring property owner is required.
>
> Weathering will continue to increase the overhang dimensions and will result in detachment of the blocks adjacent to the boundary, on the underside of the overhang as shown in Photograph: 7. Whilst relatively small these blocks are expected to create a hazard for the site.
>
> The overhang and curved defect adjacent to the west end of the existing site house also requires additional inspection and it appears that it will require stability measures due to the proposed house excavation. The proposed excavation for the new house structure appears to create a potential for undermining of the lower block of sandstone that is supporting the overlying rock units and overhang. This area should be geotechnically re-inspected following demolition of the existing house and prior to any excavation or construction as this will provide for better inspection and support installation.

Additional cored boreholes to investigate the bedrock underlying the main part of the site would allow confirmation of numerous aspects and reduce risk related to the development. Coring will indicate the strength of the sandstone and the bearing potential of the bedrock within different zones of proposed construction and confirm the presence of defects in the bedrock below the new development.

Investigation of the slope to the north of the proposed works and above No.17 Florida Road was limited due to site access conditions. It is recommended that inspection of the geotechnical conditions above No.17 Florida Road be ascertained as part of (or prior to) application of the Construction Certificate. It is envisaged that the geotechnical inspection/assessment of the slope will require that the vegetation is cleared and that assessment of the presence of boulders/detached bedrock determined by either roped access or drone photography/footage.

It is considered that the following key issues will need to be addressed prior to confirmation of final design within the site.

- Strength of bedrock underlying the existing lawn;
- Presence, type and orientation of defects within the rock mass in the lower portion of the site;
- Proposed excavation methodology;
- Alternate footing types;
- Possible required stabilisation works

The recommendations and conclusions in this report are based on a preliminary investigation utilising only surface observations and hand drilling tools. This test equipment provides limited data from small, isolated test points across the entire site with limited penetration into rock, therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations.

5.2 Site Specific Risk Assessment:

Based on our site investigation and review of the proposed works we have identified the following credible geological/geotechnical hazards which need to be considered in relation to the existing site and the proposed works. The hazards are:

A. Landslip (rock fall <2m^3) from weathered and detached sections of rock below overhang in No. 7.
B. Landslip (rockslide/topple 20m^3) due to rotation of entire overhang in No. 7.
C. Landslip (debris slide <3m^3) due to collapse of rock walls in upslope portion of site including at boundary with ‘Bible Garden’.
D. Landslip (rockslide/topple 20m^3) due to rotation and movement of overhang and rock above convex joint defect at west end of site.
E. Boulder Roll resulting from loosened blocks due to vibration during excavation.

A qualitative assessment of risk to life and property related to this hazard is presented in Table A and B, Appendix: 3, and is based on methods outlined in Appendix: C of the Australian Geomechanics Society

(AGS) Guidelines for Landslide Risk Management 2007. AGS terms and their descriptions are provided in Appendix: 4.

- Hazard A was estimated to have a **Risk to Life** of **1.33 x 10^{-6}** for a single person, while the **Risk to Property** was considered to be **'Low'**.
- Hazard B was estimated to have a **Risk to Life** of up to **1.20 x 10^{-4}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**. This hazard was considered for no further geotechnical assessment of the cliff line, overhang conditions and without installation of a support system. Where detailed inspection identifies adequate existing stability and/or a support system is implemented to prevent instability, the Likelihood of failure reduces to 'Rare' and risk levels to <**1.20 x 10^{-6}** and '**Low'**.
- Hazard C was estimated to have a **Risk to Life** of up to **4.22 x 10^{-6}** for a single person, while the **Risk to Property** was considered to be **'Moderate'**. This hazard was considered for leaving the existing rock retaining walls in place, however a new retention system is proposed, therefore the Likelihood of failure reduces to 'Rare' and risk levels to <**4.22 x 10^{-8}** and **'Very Low'**.
- Hazard D was estimated to have a **Risk to Life** of up to **6.00 x 10^{-4}** for a single person, while the **Risk to Property** was considered to be **'Very High'**. However, installation of engineered support systems reduces the Likelihood of failure to 'Rare' and risk levels to <**6.00 x 10^{-7}** and '**Low'**.
- Hazard E was estimated to have a **Risk to Life** of up to **1.56 x 10-5** for a single person, while **the Risk to Property** was considered to be '**Moderate'**. It should be noted that due to current access conditions and lack of knowledge concerning the slope to the north of the proposed development, the risks assessed should be considered as estimates and will require further delineation in accordance with Section 4.2 of this report.

Provided the recommendations of this report are implemented including geotechnical inspection and installation of engineered support as required the likelihood of any failure becomes 'Rare' and as such the consequences and risk reduces further and will be within 'Acceptable' levels when assessed against the criteria of the AGS. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

5.3 Preliminary Design & Construction Recommendations:

Preliminary Design and Construction recommendations are tabulated below:

5.3.1. New Footings: Subject to Additional Geotechnical Investigation	
Site Classification as per AS2870 – 2011 for new footing design	Class ‘A’ for footings founded within bedrock
Type of Footing	Shallow pad/strip where excavation into bedrock along south side of building, Piers extending into bedrock to ensure adequate lateral resistance to down slope movement to north or where bedrock surface well below development.
Sub-grade material and Maximum Allowable Bearing Capacity	- LS Bedrock: 1000kPa - MS Bedrock: 2000kPa
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	B_e – Rock site (provided entire new structure founded to bedrock).
Remarks: All permanent structure footings should be founded within bedrock of similar strength to prevent differential settlement unless designed for by the structural engineer. It will be necessary to confirm competent bedrock extends to well below the zone of influence of any proposed footing. Preliminary loads are based on the assumption that either unfavourable defects do not exist below founding depth or, if present, have been stabilised prior.	

5.3.2. Excavation		
Depth of Excavation	Up to 3.0m depth	
Distance of Excavation to Neighbouring Properties/structures	On boundary with Bible Garden, >5.0m from all other boundaries or structures	
Type of Material to be Excavated	Fill and sandstone bedrock	
Guidelines for <u>un-surcharged</u> batter slopes for general information are tabulated below:		
Material	Safe Batter Slope (H:V)*	
	Short Term/Temporary	Long Term/Permanent
Natural soils and extremely low strength bedrock	1.25:1	2:1
Very Low to low strength bedrock	0.5:1	1:1
Low to Medium strength, defect free bedrock	Vertical	Vertical

Remarks: Seepage through the soils can reduce the stability of batter slopes and invoke the need to implement additional support measures. Where safe batter slopes are not implemented the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions. Geotechnical inspection of batters will be required at regular intervals to assess their stability, especially for permanent batters. The presence of defects within fractured rock may require a significant reduction to the maximum batter slopes provided.		
Equipment for Excavation	Fill soils	Excavator with Bucket
Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	5mm/s at all adjacent buildings and north-east corner of No. 7 (overhang)	
Vibration Calibration Tests Required	Pending equipment proposed for use	
Full time vibration Monitoring Required	Pending vibration calibration testing	
Dilapidation Surveys Requirement	Only to No. 15 and common driveway to prevent spurious claims for damage	
Remarks: Water ingress into exposed excavations can result in erosion and stability concerns in both sandy and clayey soils. Drainage measures will need to be in place during excavation works to divert any surface flow away from the excavation crest and any batter slope, whilst any groundwater seepage must be controlled within the excavation and prevented from ponding or saturating slopes/batters. Groundwater is expected along defects within the cliff line and excavation therefore a drainage trench/cavity is recommended to the rear of any excavation into bedrock to prevent dampness in the finished development.		

5.3.3. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		Seepage through defects in the rock mass were observed within the site.
Excavation likely to intersect	Water Table	No
	Seepage	Minor (<0.50L/min), within fill soils at bedrock surface or along defects in the bedrock
Site Location and Topography		Low north side of the road, within steeply north dipping topography
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		Due to the presence of highly impermeable bedrock the property is not suitable for onsite absorption disposal system.

	The site may be suitable for a dispersion system utilising an Onsite Detention System (OSD) and a level spreader designed by a suitably qualified Hydraulic Engineer. This would require an engineered retention system at the rea, to replace the existing stone retaining wall for the lawn terrace.
Remarks: Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer.	

5.4. Conditions Relating to Design and Construction Monitoring:

To allow certification as part of construction, building and post-construction activity for this project, it will be necessary for Crozier Geotechnical Consultants to:

1. Review and approve the structural design drawings, including the retaining structure design and construction methodology, for compliance with the recommendations of this report prior Construction Certificate.
2. Conduct all inspections and assessments as per the recommendations of this report
3. Inspect all new footings to confirm compliance to design assumptions with respect to allowable bearing pressure and stability prior to the placement of steel or concrete.
4. Inspect completed works to ensure no new landslip hazards have been created by site works and that all required stabilisation and drainage measures are in place.

The client and builder should make themselves familiar with the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants cannot provide certification for the Occupation Certificate if it has not been called to site to undertake the required inspections.

5.5. Design Life of Structure:

We have interpreted the design life requirements specified within Councils Risk Management Policy to refer to structural elements designed to support the house etc, the adjacent slope, control stormwater and maintain the risk of instability within acceptable limits. Specific structures and features that may affect the maintenance and stability of the site in relation to the proposed and existing development are considered to comprise:

- stormwater and subsoil drainage systems,
- retaining walls and soil slope erosion and instability,
- maintenance of trees/vegetation on this and adjacent properties.

Man-made features should be designed and maintained for a design life consistent with surrounding structures (as per AS2870 – 2011 (100 years)). It will be necessary for the structural and geotechnical engineers to incorporate appropriate design and inspection procedures during the construction period. Additionally, the property owner should adopt and implement a maintenance and inspection program.

If this maintenance and inspection schedule are not maintained the design life of the property cannot be attained. A recommended program is given in Table: C in Appendix: 3 and should also include the following guidelines.

- The conditions on the block don't 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
- The property is maintained in good order and in accordance with the guidelines set out in;
    - a) CSIRO sheet BTF 18
    - b) Australian Geomechanics "Landslide Risk Management" Volume 42, March 2007.
    - c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component.

It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site.

Also, individual Government Departments will maintain public utilities in the form of power lines, water and sewer mains to ensure they don't leak and increase either the local groundwater level or landslide potential.

6.0 CONCLUSION:

The investigation identified that the site is dominated by rock outcrops and cliff lines within steeply sloping topography. In general soil depths over bedrock were shallow.

Several geotechnical hazards were identified, and all require further assessment and potential installation of support systems to reduce risk levels. This is critical for several of the hazards, though further inspection may prove that risk levels are lower than those estimated.

It is recommended to undertake cored boreholes within the site to allow assessment of bedrock quality and defects below the main building structure.

The entire site and surrounding slopes have been assessed as per the Geotechnical Risk Management Policy for Pittwater 2009 and the Australian Geomechanics – Landslide Risk management Guidelines 2007. Several hazards were assessed to have "unacceptable" risk levels at present, though that is due to lack of information. Provided the recommendations of this report including further inspection and installation of support systems as determined necessary occurs then the site will achieve the 'Acceptable' risk management criteria of Councils policy for the design life of the new development, taken as 100 years. Therefore, the project is considered suitable for the site provided the recommendations of this report are implemented.

In accordance with the above we attach a signed copy of Council's Form 1 and 1a of their Geotechnical Risk Management Policy and no further geotechnical assessment or reporting is considered necessary at this stage for the proposed new works.

Prepared by:	Reviewed by:
Kieron Nicholson	Troy Crozier
Senior Engineering Geologist	Principal Engineering Geologist
	MAIG. RPGeo; 10197

7. REFERENCES:

1. Australian Geomechanics Society 2007, "Landslide Risk Assessment and Management", Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, "The preparation of maps and plans in terms of engineering geology" Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. E. Hoek & J.W. Bray 1981, "Rock Slope Engineering" By The Institution of Mining and Metallurgy, London.
4. C. W. Fetter 1995, "Applied Hydrology" by Prentice Hall. V. Gardiner & R. Dackombe 1983, "Geomorphological Field Manual" by George Allen & Unwin
5. Pells et. al. Design loadings for foundations on shale and sandstone in the Sydney region. Australian Geomechanics Society Journal, 1978.
6. Australian Standard AS 2870 – 2011, Residential Slabs and Footings

Appendix 1

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Brookvale NSW 2100 Email: info@croziergeotech.com.au
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination.
The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT "N" Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

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

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

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from 'feel' and rate of penetration.

Rotary Mud Drilling – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -

Q_c (MPa) = (0.4 to 0.6) N blows (blows per 300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -

$Q_c = (12 \text{ to } 18)\, C_u$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Borehole Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm " " " " "	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

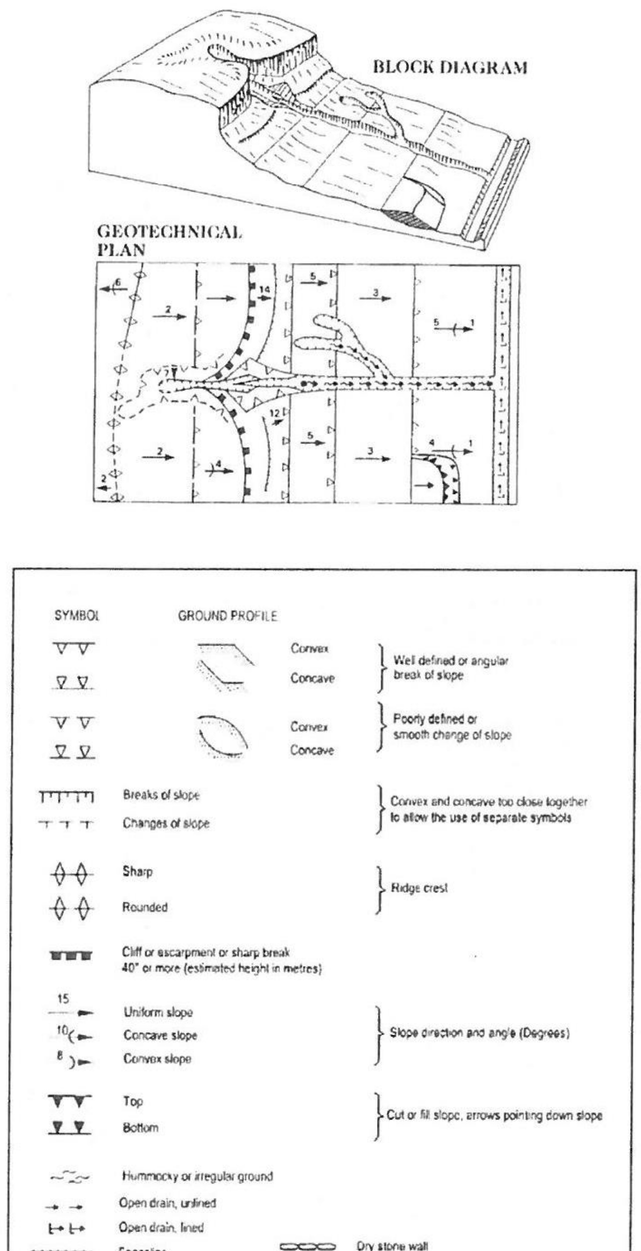
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

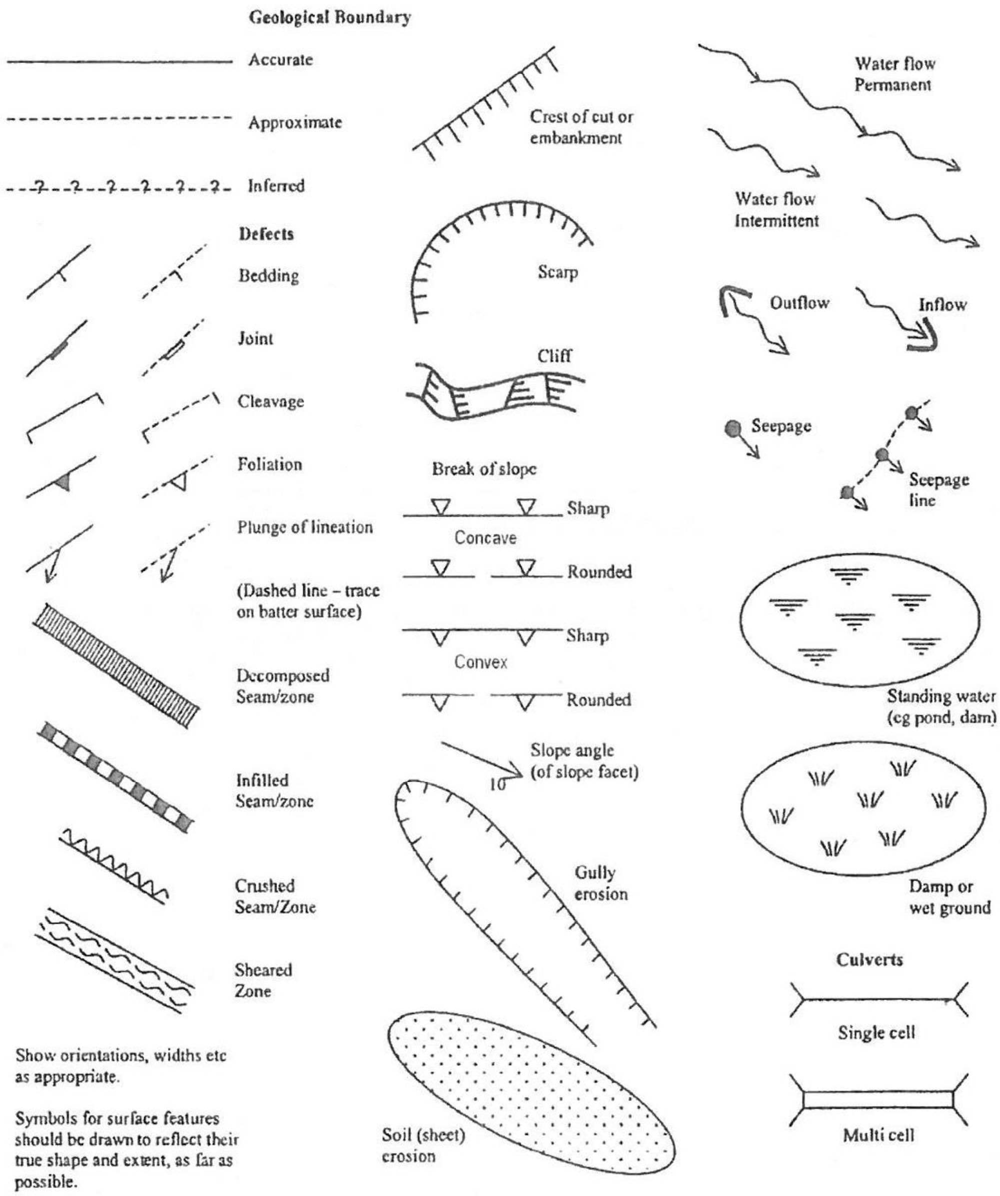
Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



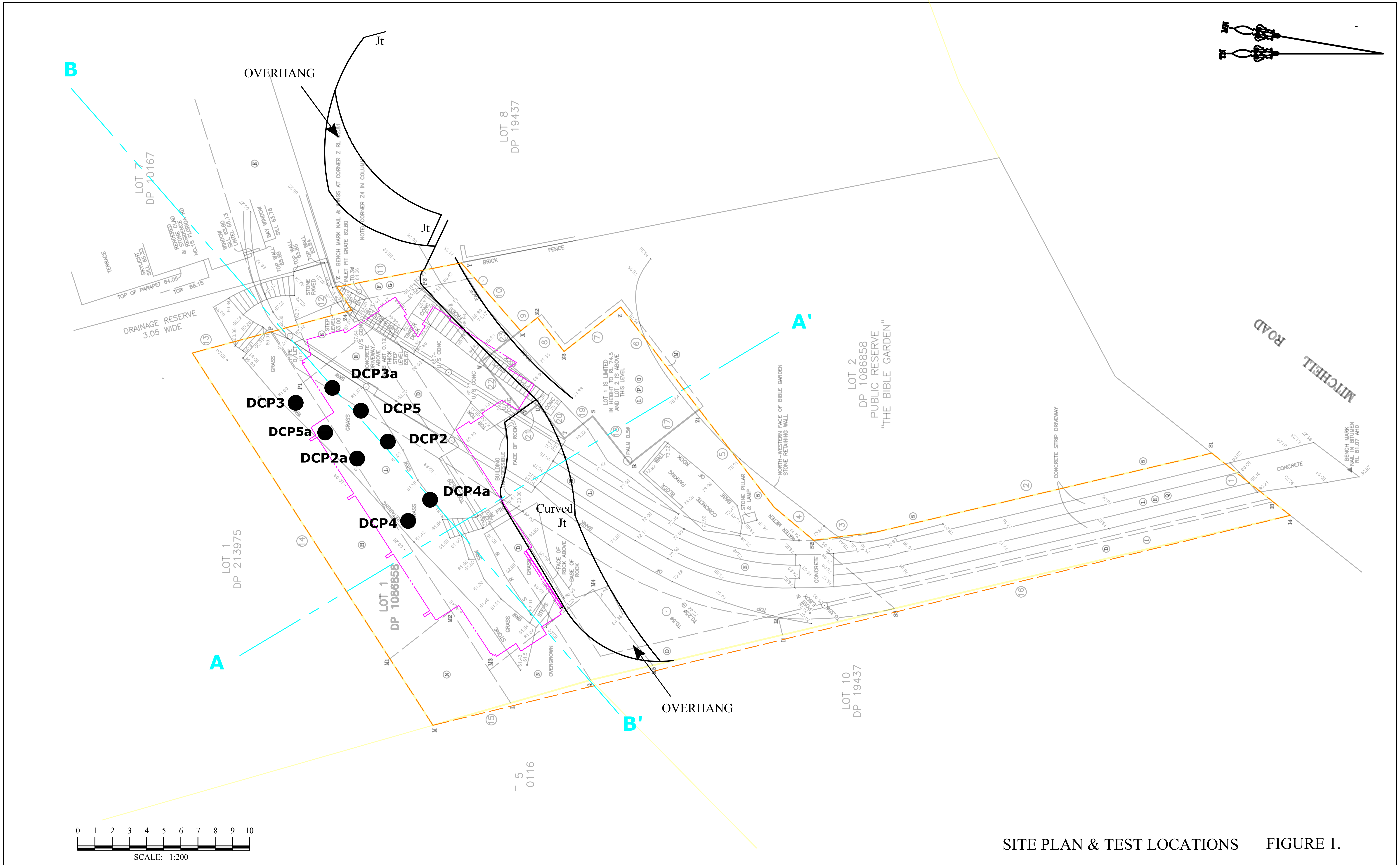
Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

Appendix 2



SITE PLAN & TEST LOCATIONS FIGURE 1.

CROZIER GEOTECHNICAL CONSULTANTS

Crozier Geotechnical
Unit 12, 42-46 Wattle Road
Brookvale NSW 2100

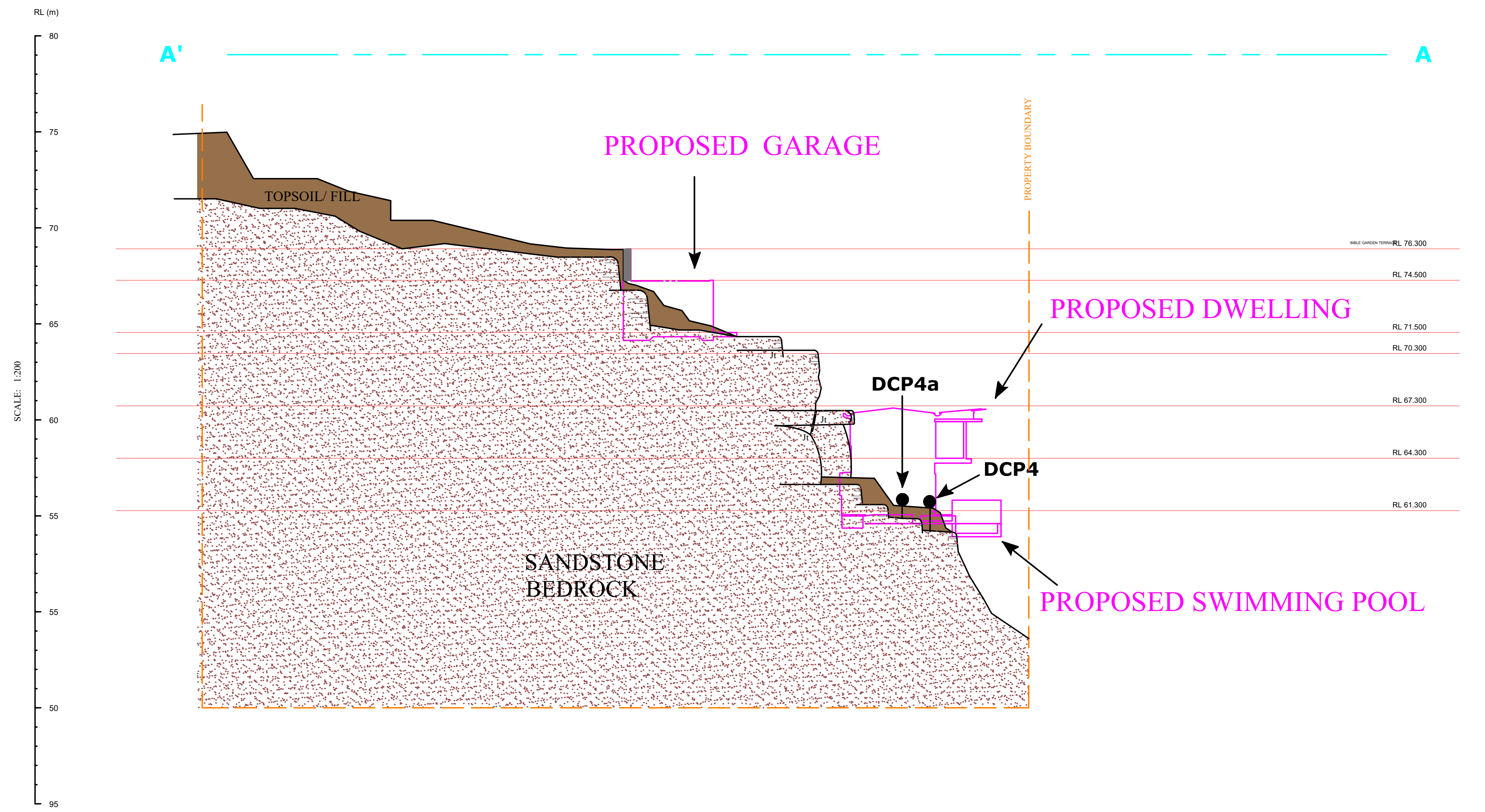
ABN: 96 113 453 624
Phone: (02) 9939 1882
Fax: (02) 9939 1883

Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

A — A'	CROSS-SECTION REFERENCE LINE	●	DYNAMIC PENETROMETER TEST	APPROXIMATE CLIFF LINE	PROPOSED DEVELOPMENT
B — B'	CROSS-SECTION REFERENCE LINE			APPROXIMATE OVERHANG	PROPERTY BOUNDARY

SCALE: 1:200 @ A3 DRAWING: FIGURE 2 DATE: 18/08/2020	PREPARED FOR: Roger Bain
APPROVED BY: TMC DRAWN BY: JC PROJECT: 2018-142	ADDRESS: 6 Mitchell Road, Palm Beach, N.S.W



VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

NB. FOR LOCATION OF SECTION A-A', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL FIGURE 2.

CROZIER GEOTECHNICAL CONSULTANTS

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LEGEND

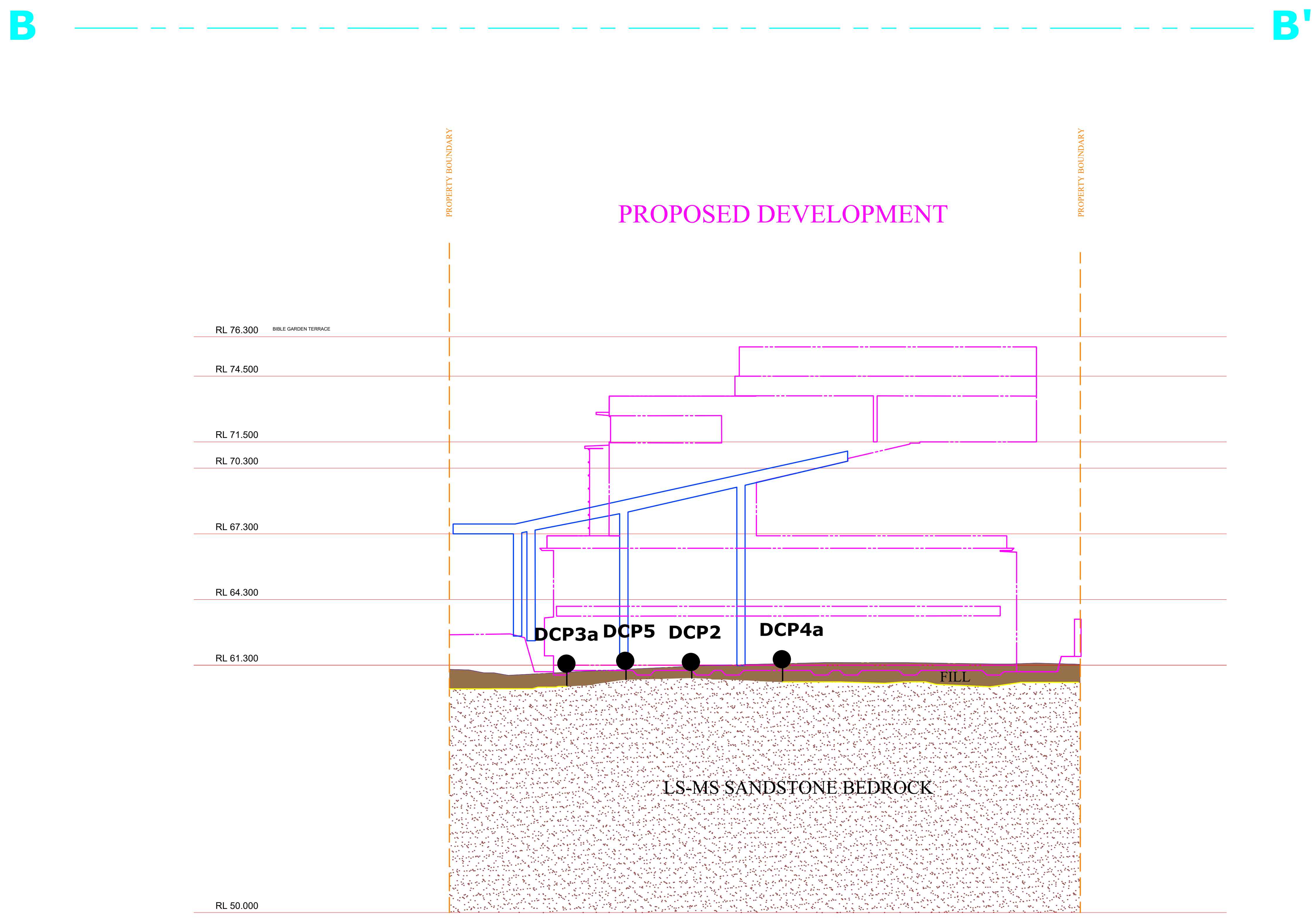
- ● DYNAMIC PENETROMETER TEST
- PROPERTY BOUNDARY
- PROPOSED STRUCTURE
- A'—A CROSS-SECTION REFERENCE LINE
- TOPSOIL/ FILL
- SANDSTONE BEDROCK

SCALE: 1:200 @ A3
DRAWING: FIGURE 2
DATE: 18/08/2020

PREPARED FOR:
Roger Bain

APPROVED BY: TMC
DRAWN BY: JC
PROJECT: 2018-142

ADDRESS:
6 Mitchell Road, Palm Beach, N.S.W



0 1 2 3 4 5 6 7 8 9 10

SCALE: 1:200

VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

NB. FOR LOCATION OF SECTION B-B', PLEASE REFER TO FIGURE 1. SITE PLAN AND TEST LOCATIONS

GEOLOGICAL MODEL FIGURE 3.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical | ABN: 96 113 453 624
Unit 12, 42-46 Wattle Road | Phone: (02) 9939 1882
Brookvale NSW 2100 | Fax: (02) 9939 1883

Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

- DCP — DYNAMIC CONE PENETROMETER
- PROPOSED STRUCTURES
- EXISTING STRUCTURES
- PROPERTY BOUNDARY
- CROSS-SECTION REFERENCE LINE
- PROBABLE ROCK PROFILE
- SOIL/FILL
- SANDSTONE BEDROCK

SCALE:	1:200 @ A3
DRAWING:	FIGURE 3
DATE:	14/08/2020
APPROVED BY:	TMC
DRAWN BY:	JC
PROJECT:	2018-145

PREPARED FOR:
Roger Bain

ADDRESS:
96 Mitchell Road, Palm Beach, N.S.W

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 1

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.					
0.20	Hand Auger refusal at 0.20m on boulder/cobbles.					
1.00						
2.00						

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

Crozier Geotechnical Consultants

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 1A

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
0.20	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.					
	Hand Auger refusal at 0.20m on boulder/cobbles.					
1.00						
2.00						

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

Crozier Geotechnical Consultants

BOREHOLE LOG

CLIENT: Roger Bain | **DATE:** 11.09.18 | **BORE No.:** 1B

PROJECT: Demoltion and construction | **PROJECT No.:** 2018-145 | **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach | **SURFACE LEVEL:** RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.					
0.25	Hand Auger refusal at 0.25m on boulder/cobbles.					
1.00						
2.00						

RIG: N/A | DRILLER: AC | LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: | CHECKED:

Crozier Geotechnical Consultants

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 2

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
0.20	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.				
	Hand Auger refusal at 0.20m on boulder/cobbles/gravels.				
1.00					
2.00					

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Roger Bain
DATE: 11.09.18
BORE No.: 2A

PROJECT: Demoltion and construction
PROJECT No.: 2018-145
SHEET: 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach
SURFACE LEVEL: RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.				
0.18	Hand Auger discontinued at 0.18m due to suspected Asbestos (sample taken).				
1.00					
2.00					

RIG: N/A
DRILLER: AC
LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS:

CHECKED:

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 2B

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
	TOPSOIL/FILL - Light/Dark brown, fine to medium grained, moist silty sand.					
0.24	Hand Auger refusal at 0.24m on boulder/cobbles/gravels.					
1.00						
2.00						

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 3

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.4m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
0.15	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.				
	Hand Auger refusal at 0.15m on boulder/cobbles/gravels.				
1.00					
2.00					

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 3A

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.4m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
0.10	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.				
	Hand Auger refusal at 0.10m on boulder/cobbles/gravels.				
1.00					
2.00					

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

BOREHOLE LOG

CLIENT: Roger Bain **DATE:** 11.09.18 **BORE No.:** 3B

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145 **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach **SURFACE LEVEL:** RL ≈ 61.4m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand with gravels and glass fragments.				
0.38	Hand Auger refusal at 0.375m on boulder/cobbles/gravels.				
1.00					
2.00					

RIG: N/A DRILLER: AC LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: CHECKED:

Crozier Geotechnical Consultants

BOREHOLE LOG

CLIENT: Roger Bain | **DATE:** 11.09.18 | **BORE No.:** 4

PROJECT: Demoltion and construction | **PROJECT No.:** 2018-145 | **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach | **SURFACE LEVEL:** RL ≈ 61.6m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
	TOPSOIL/FILL - Dark brown, fine to medium grained, moist silty sand.				
0.22	Hand Auger refusal at 0.22m on boulder/cobbles/gravels.				
1.00					
2.00					

RIG: N/A | DRILLER: AC | LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS: | CHECKED:

Crozier Geotechnical Consultants

BOREHOLE LOG

CLIENT: Roger Bain | **DATE:** 11.09.18 | **BORE No.:** 5

PROJECT: Demoltion and construction | **PROJECT No.:** 2018-145 | **SHEET:** 1 of 1

LOCATION: 6 Mitchell Rd, Palm Beach | **SURFACE LEVEL:** RL ≈ 61.6m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
	TOPSOIL/FILL - Light/Dark brown, fine to medium grained, moist silty sand with gravels.					
0.35	Hand Auger refusal at 0.35m on boulder/cobbles/gravels.					
1.00						
2.00						

RIG: N/A | DRILLER: AC | LOGGED: CL

METHOD: Hand Auger

GROUND WATER OBSERVATIONS: Not encountered

REMARKS:

CHECKED:

DYNAMIC PENETROMETER TEST SHEET

CLIENT: Roger Bain **DATE:** 11.09.18

PROJECT: Demoltion and construction **PROJECT No.:** 2018-145

LOCATION: 6 Mitchell Rd, Palm Beach **SHEET:** 1 of 1

	Test Location								
Depth (m)	1	2	2a	3	3a	4	4a	5	5a
0.00 - 0.15	2	1	1	1	2	2	2	2	3
0.15 - 0.30	9	9	7	4	10	9	3	2	3
0.30 - 0.45	14	17	11	1	8	7	3	10	5
0.45 - 0.60	13	(B) @ 0.35m	6	2	17	4	3	7	10
0.60 - 0.75	9		6	2	16	3	5	(B) @ 0.47m	14
0.75 - 0.90	14		7	5	(B) @ 0.65m	5	(B) @ 0.65m		12
0.90 - 1.05	(B) @ 0.87m		12	3		7			10
1.05 - 1.20			8	12		15			5
1.20 - 1.35			9	6		6			(B) @ 1.20m
1.35 - 1.50			6	(B) @ 1.22m		(B) @ 1.25m			
1.50 - 1.65			5						
1.65 - 1.80			14						
1.80 - 1.95			(B) @ 1.75m						
1.95 - 2.10									
2.10 - 2.25									
2.25 - 2.40									
2.40 - 2.55									
2.55 - 2.70									
2.70 - 2.85									
2.85 - 3.00									

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

(B) Test hammer bouncing upon refusal on solid object

-- No test undertaken at this level due to prior excavation of soils

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Appendix 3

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood of Slide	Spatial Impact of Slide		Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (rock fall $<2m^3$) from detached rock fragments in overhang within No. 7		Sections of rock are partly detached and extensivley weathered	a) House 5m from base of cliff, 1% impacted		a) Person in house 16hrs/day avge.	a) Almost certain to not evacuate	a) Person in building, minor damage only	
			Almost Certain	**Prob. of Impact**	**Impacted**				
		a) Site House	0.1	0.20	0.01	0.6667	1	0.01	**1.33E-06**
B	Landslip (rock slide/topple $20m^3$) due to collapse of entire overhang within No. 7		Overhang appears stable at present, though further inspection required within neighbouring property	a) House 5m down slope, 20% impacted		a) Person in house 16hrs/day avge.	a) Almost certain to not evacuate	a) Person in building, crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Site House	0.001	0.90	0.20	0.6667	1	1.00	**1.20E-04**
C	Landslip (debris slide $<3m^3$) due to collapse of rock retaining walls during excavation adjacent to Bible Garden property		Excavation proposed adjacent to boundary and existing rock walls, walls in reasonable condition at present and up to 1.50m in height	a) Garage adjacent to walls, 50% impacted b) Access driveway 5m across slope, 1% impacted c) Lawn terrace at crest of wall, 10% impacted		a) Person in garage 1hrs/day avge. b) Person on driveway 0.5hr/day avge. c) Person in terrace 3hr/day avge	a) Possible to not evacuate b) Possible to not evacuate c) Likely to not evacuate	a) Person in building, minor damage only b) Person in car or open space, unlikely buried c) Person in open space, possible buried	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Proposed garage	0.001	0.90	0.50	0.0417	0.5	0.01	**9.38E-08**
		b) Access driveway	0.001	0.20	0.01	0.0208	0.5	0.05	**1.04E-09**
		c) Bible Garden lawn terrace	0.001	0.90	0.10	0.1250	0.75	0.50	**4.22E-06**
D	Landslip (rock slide/topple $20m^3$) from undermining or failure of overhang and detached blocks at west end, above convex defect due to excavation for house		Rock excavations up to 3.0m depth below cliff base and location where convex defect intersects slope	a) House within 2.0m of cliff face, 20% impacted b) House is >25m down steep slope, 5% impacted c) House is >20m down steep slope, 10% impacted		a) Person in house 16hrs/day avge. b) Person in house 16hrs/day avge. c) Person in house 16hrs/day avge.	a) Almost certain to not evacuate b) Almost certain to not evacuate c) Almost certain to not evacuate	a) Person in building, impact b) Person in building, impact c) Person in building, impact	
			Likely	**Prob. of Impact**	**Impacted**				
		a) Site House	0.01	0.90	0.20	0.6667	1	0.50	**6.00E-04**
		b) House No. 17 Florida Rd	0.01	0.20	0.05	0.6667	1	0.50	**3.33E-05**
		c) House No. 19 Florida Rd	0.01	0.25	0.10	0.6667	1	0.50	**8.33E-05**
E	A. Boulder Roll resulting from loosened blocks due to vibration during excavation.		a) Possible boulders on slope obscured by vegetation	a) Garden below steep slope, likely impact small area of garden.		a) Person in garden 5hrs/day avge.	a) Almost certain to not evacuate	a) Person in open space, possibly crushed	
			Possible	**Prob. of Impact**	**Impacted**				
		a) Garden 17 Florida Road	0.001	0.75	0.10	0.2083	1	1.00	**1.56E-05**

* hazards considered in current condition and/or without remedial/stabilisation measures or poor support systems
* likelihood of occurrence for design life of 100 years
* Spatial Impact - Probaility of Impact refers to slide impacting structure/area expressed as a % (i.e. 1.00 = 100% probability of slide impacting area if slide occurs).
Impacted refers to expected % of area/structure damaged if slide impacts (i.e. small, slow earth slide will damage small portion of house structure such as 1 bedroom (5%), where as large boulder roll may damage/destroy >50%)
* neighbouring houses considered for impact of slide to bedroom unless specified, due to high occupancy and lower potential for evacuation.
* considered for person most at risk, where multiple people occupy area then increased risk levels
* for excavation induced landslip then considered for adjacent premises/buildings founded off shallow footings, unless indicated
* evacuation scale from Almost Certain to not evacuate (1.0), Likely (0.75), Possible (0.5), Unlikely (0.25), Rare to not evacuate (0.01). Based on likelihood of person knowing of landslide and completely evacuating area prior to landslide impact.
* vulnerability assessed using Appendix F - AGS Practice Note Guidelines for Landslide Risk Management 2007

TABLE : B

Landslide risk assessment for Risk to Property

HAZARD	Description	Impacting	Likelihood		Consequences		Risk to Property
A	Landslip (rock fall $<2m^3$) from detached rock fragments in overhang within No. 7	a) Site House	Almost Certain	Event is expected to occur over design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Moderate
B	Landslip (rock slide/topple $20m^3$) from undermining or failure of overhang and detached blocks at west end, above convex defect due to excavation for house	a) Site House	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
C	Landslip (debris slide $<3m^3$) due to collapse of rock retaining walls during excavation adjacent to Bible Garden property	a) Proposed garage	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate
		b) Access driveway	Unlikely	The event might occur under very adverse circumstances over the design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Very Low
		c) Bible Garden lawn terrace	Unlikely	The event might occur under very adverse circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Low
D	Landslip (rock slide/topple $20m^3$) from undermining or failure of overhang and detached blocks at west end, above convex defect due to excavation for house	a) Site House	Almost Certain	Event is expected to occur over design life.	Major	Extensive damage to most of site/structures with significant stabilising to support site or MEDIUM damage to neighbouring properties.	Very High
		b) House No. 17 Florida Rd	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
		c) House No. 19 Florida Rd	Possible	The event could occur under adverse conditions over the design life.	Medium	Moderate damage to some of structure or significant part of site, requires large stabilising works or MINOR damage to neighbouring property.	Moderate
E	A. Boulder Roll resulting from loosened blocks due to vibration during excavation.	a) House No.17 Florida Road	Possible	The event could occur under adverse conditions over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Moderate

* hazards considered in current condition, without remedial/stabilisation measures and during construction works.

* qualitative expression of likelihood incorporates both frequency analysis estimate and spatial impact probability estimate as per AGS guidelines.

* qualitative measures of consequences to property assessed per Appendix C in AGS Guidelines for Landslide Risk Management.

* Indicative cost of damage expressed as cost of site development with respect to consequence values: Catastrophic : 200%, Major: 60%, Medium: 20%, Minor: 5%, Insignificant: 0.5%.

TABLE: 2

Recommended Maintenance and Inspection Program

Structure	Maintenance/ Inspection Item	Frequency
Stormwater drains.	Owner to inspect to ensure that the open drains, and pipes are free of debris & sediment build-up. Clear surface grates and litter. Owner to check and flush retaining wall drainage pipes/systems	Every year or following each major rainfall event. Every 10 years or where variation to retention system identified (i.e. damp)
Retaining Walls. or remedial measures	Owner to inspect walls for deveation from as constructed condition and repair/replace.	Every two years or following major rainfall event.
Large Trees on or adjacent to site	Arborist to check condition of trees and remove as required. Where tree within steep slopes (>18°) or adjacent to structures requires geotechincal inspection prior to removal	Every five years
Slope Stability	Geotechnical Engineering Consultant to check on site stability and maintenance Anchors and slope stabilising measures	Five years after construction is completed. Every 15 years

N.B. Provided the above shedule is maintained the design life of the property should conform with Councils Risk Management Policy.

Appendix 4

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.

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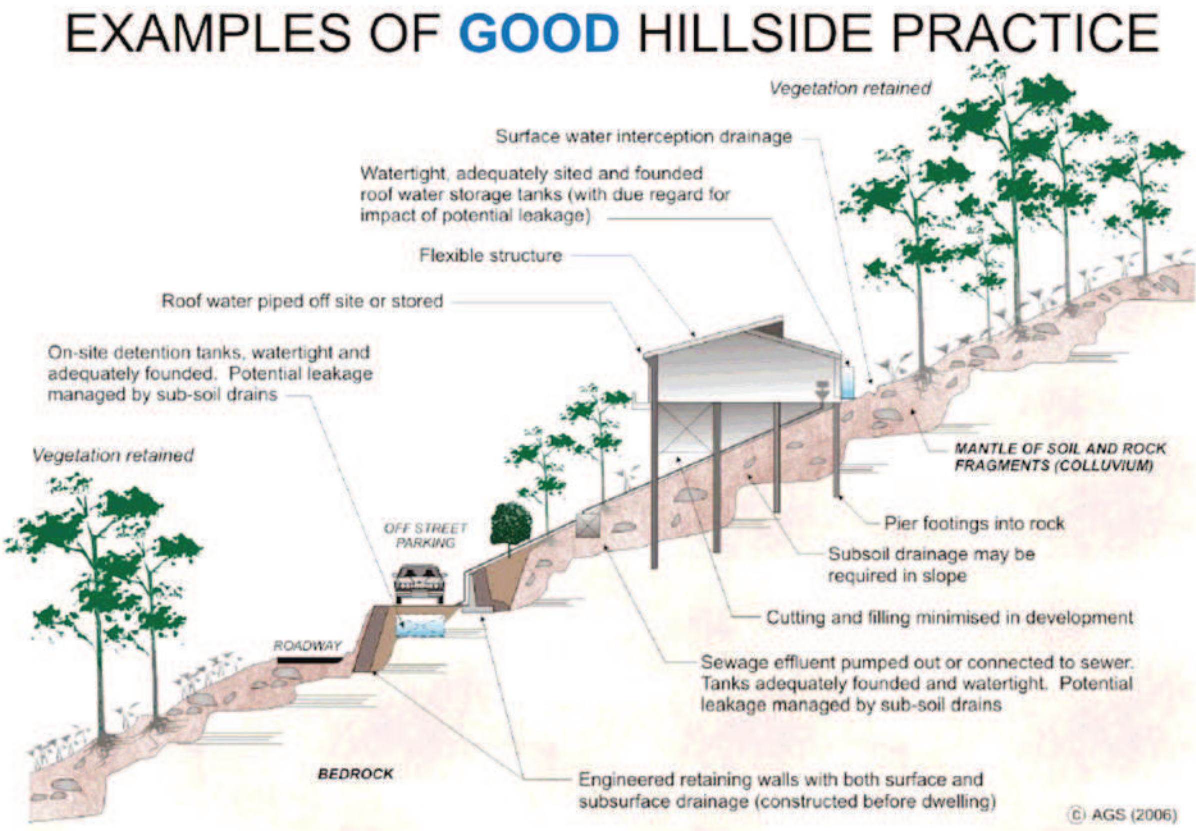
Appendix 5

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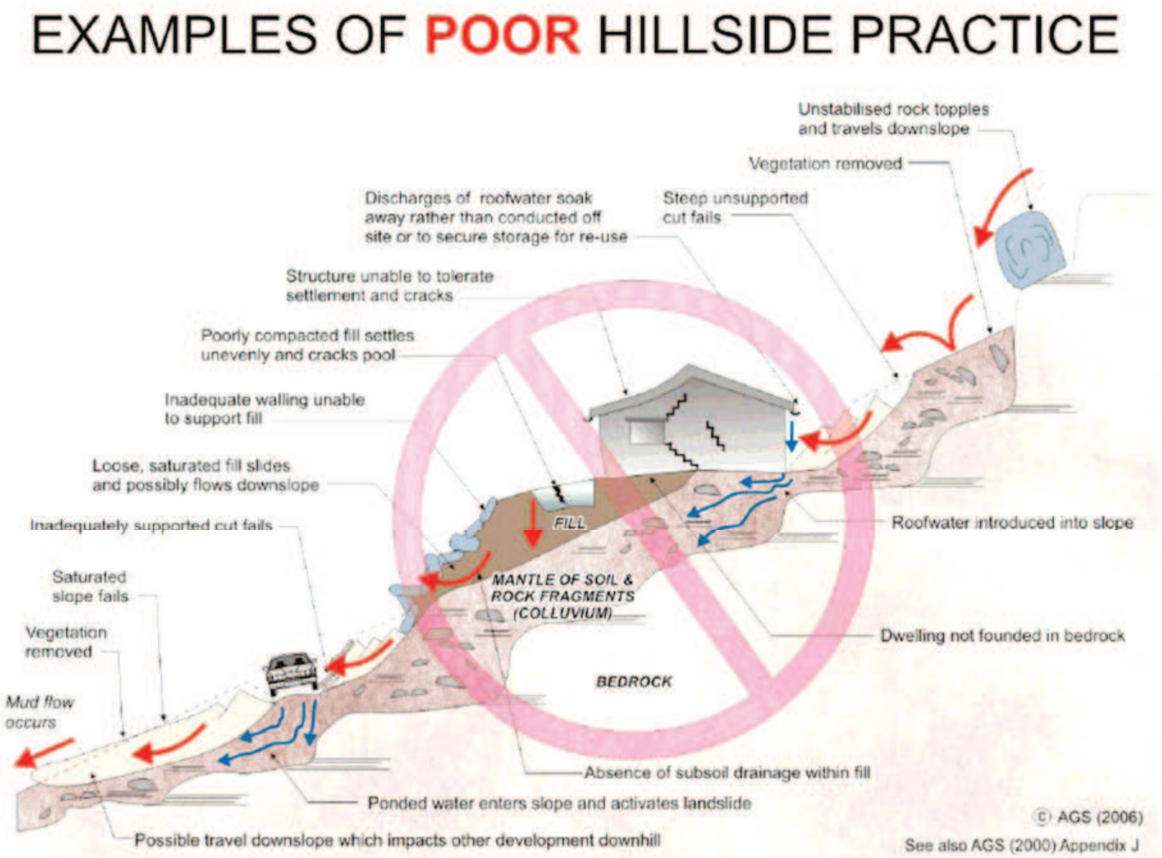
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles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