ASCENT

GEOTECHNICAL CONSULTING

Geotechnical Assessment

Project: New Boatshed
121 Florence Terrace, Scotland Island NSW.

Prepared for:
Scott & Carrie Towers
c/- Stephen Crosby & Associates
PO Box 204
Church Point, NSW 2105

REF: AG 19236
20th December, 2019

AG 19236
20th December, 2019

Geotechnical Assessment

For **New Boat Shed** at

121 Florence Terrace, Scotland Island NSW

Document Status			Approved for Issue	
Version	**Author**	**Reviewer**	**Signature**	**Date**
1	Ben Morgan	Karen Allan		20/12/2019
Document Distribution				
Version	**Copies**	**Format**	**To**	**Date**
1	1	PDF	Scott & Carrie Towers	20/12/2019
1	1	PDF	Stephen Crosby – Stephen Crosby & Associates Pty Ltd	20/12/2019

Limitations

This report has been prepared Scott & Carrie Towers c/- Stephen Crosby – Stephen Crosby & Associates Pty Ltd, in accordance with Ascent Geotechnical Consulting's (Ascent) Fee Proposal dated 16th December, 2019.

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

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

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

Ascent Geotechnical Consulting Pty Ltd
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1 Overview

1.1 Background

This report presents the findings of a geotechnical assessment carried out at 121 Florence Terrace, Scotland Island (the "Site") by Ascent Geotechnical Consulting (Ascent). This assessment has been prepared to meet Northern Beaches Council lodgement requirements for Development Application (DA).

1.2 Proposed Development

Details of the proposed development are outlined in architectural plans prepared by Stephen Crosby & Associates, Project No. 2128, Drawing Number DA03, dated September 2019: -

The proposed works comprise the following:

- Demolition of existing boatshed and timber deck,
- Construction of new boat shed, slip-way, skid-ramp and retaining walls,
- The proposed development will take place on an approximately combined 884.80m^2 residential block being Lot 58 in D.P. 12749 & Lot LIC 597101.

1.3 Relevant Instruments

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

- Northern Beaches Council – Pittwater Local Environment Plan (PLEP) 2014 & Pittwater Development Control Plan (PDCP) 2013.
- Appendix 5 (to Pittwater P21) Geotechnical Risk Management Policy for Pittwater – 2009.
- Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007).
- Australian Standard 1726:2017 Geotechnical Site Investigations.
- Australian Standard 2870:2011 Residential Slabs and Footings.
- Australian Standard 1289.6.3.2:1997 Methods of Testing Soils for Engineering Purposes.
- Australian Standard 3798:2007 Guidelines on earthworks for commercial and residential developments.

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2 Site Description

2.1 Summary

A summary of site conditions identified at the time of our inspection is provided in the table below (Table 1.).

Table 1: Summary of site conditions.

Parameter	Description
Site Visit	Morgan Spreadbury-Key - Ascent Geotechnical – 16/12/2019
Site Address	121 Florence Terrace, Scotland Island NSW – Lot 58 in D.P. 12749 & Lot LIC 597101.
Site Area m^2 (approx.)	Combined 884.8.0m^2 (By Title)
Existing development	Single storey wood & fibro clad residence, tile roof. Detached wood & fibro clad boatshed, tile roof.
Aspect	South-east
Average gradient	~20-25 degrees
Vegetation	Dense medium to large native trees and shrubs across site.
Retaining Structures	Existing boatshed is surrounded by a large concrete slab, retained by mortared and stack rock sandstone seawalls, ~1.0m in height. Small, stable sandstone stack rock retaining wall along entry stairway.
Neighbouring environment	Residentially developed to the north and south. Florence Terrace and native bushland to the north-west. Pittwater to the south-east.

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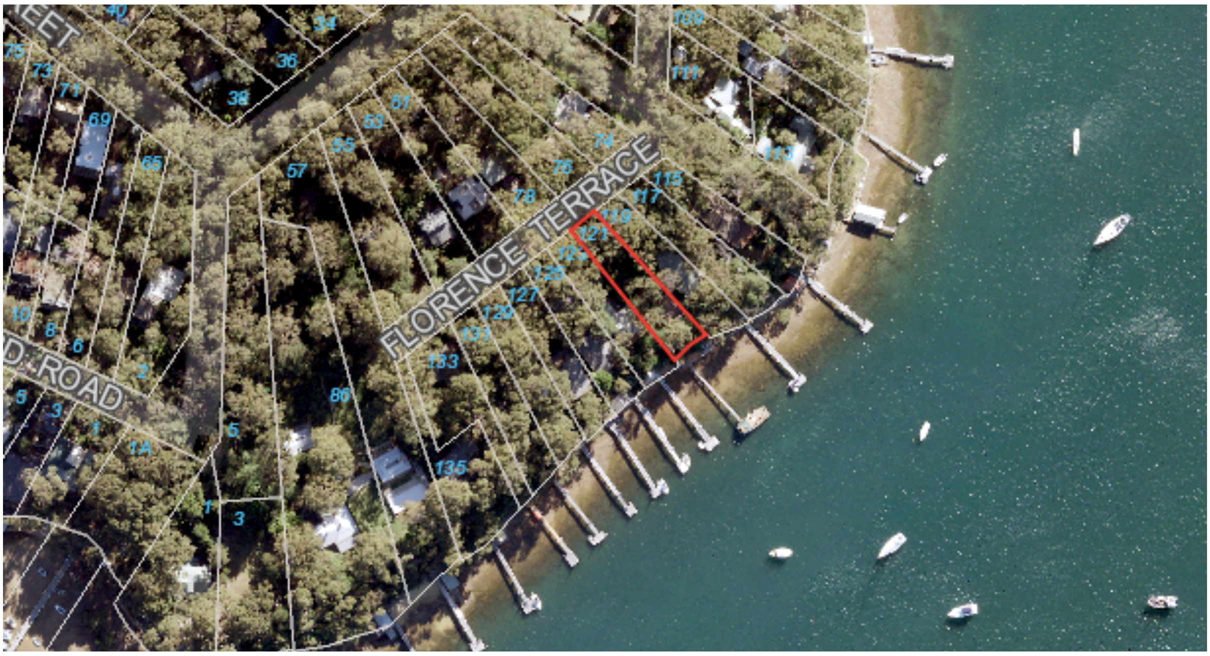

Image 1: Site location – 121 Florence Terrace, Scotland Island - Red Polygon (© NBC Mapping)

2.2 Geology and Geological Interpretation

The Sydney 1:100,000 Geological Sheet 9130 (NSW Dept. Mineral Resources, 1983) indicates that the site is underlain by the Newport Formation of the upper Narrabeen Group (Rnn). The Newport Formation geology is comprised of interbedded laminite, shale and quartz, to lithic-quartz sandstones which are similar in composition to the overlying Hawkesbury Sandstones. The Narrabeen Group bedrock was exposed below the mean high-water mark, directly in front of the existing seawalls. Various small to medium sized detached floaters are scattered across the block.

The soil profile consists of fill (O & A Horizons) and sandy/silty clays (B Horizon) overlying weathered bedrock (C Horizon). Based on our observations and the results of testing onsite, we would expect competent weathered shale bedrock to be found between 200 – 350m from current surface levels across the site of the proposed boatshed.

NOTE: The local geology is comprised predominantly of shale, with variable plasticity clays overlying. Sandstone floaters or large detached joint blocks are often present in the soil profile. The Newport Formation bedrock usually mirrors the general topography of the block, but can be found in benched terraces. Subsequently ground conditions on site may alter significantly across short distances. This variability should be anticipated and accounted for in the design and construction of any new foundations.

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2.3 Fieldwork

A site investigation was undertaken on the 16th December, 2019, which included a limited geotechnically focused visual assessment of the property and its surrounds, geotechnical mapping, photographic record and limited subsurface investigation.

Two Dynamic Cone Penetrometer (DCP) tests were conducted to determine the relative density of the subgrade, and the depth to weathered rock (if encountered). These tests were conducted to the Australian Standard for ground testing: AS 1289.6.3.2 – 1997. Possible locations of testing were constrained by the existing boatshed, concrete slab and abundant floaters reducing exposure of the natural ground line. The location of these tests is shown on the site plan provided and summary of the test results is presented below, with full details in the engineering logs presented in the appendix section of this report:

Table 2: Summary DCP test results.

TEST	DCP 1	DCP 2
SUMMARY	Refusal @ 0.35m bouncing on inferred weathered bedrock or large floaters. Fine white impact dust on dry tip.	Refusal @ 0.20m bouncing on inferred weathered bedrock or large floaters. Fine white impact dust on dry tip.

Hand Auger Testing

Due to the lack of exposed natural ground line, hard surfaces and existing structures as well as the know geological conditions of the site, and the likely presence of fill, Hand Auger Borehole testing was not deemed necessary for the completion of our Geotechnical Assessment.

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

3 Geotechnical Assessment

3.1 Site Classification

Due to likely presence of shallow uncontrolled fill on site, the site is classified as **"P"** in accordance with AS 2870:2011.

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3.2 Ground Water

Due to the close proximity to the shoreline, the of the area of the proposed works may be influenced from groundwater variations resultant from normal tidal fluctuations.

Normal ground water seepage is expected to move downslope through the soil profile along the interface with underling bedrock, or any impervious horizons in the profile such as clays.

3.3 Surface Water

Overland or surface flows entering the site from the adjoining areas were not identified at the time of our inspection, however normal overland runoff could enter the site from above during heavy or extended rainfall.

3.4 Slope Stability

A landslide hazard assessment of the existing slope has been undertaken in accordance with the Australian Geomechanics Society Landslide Risk Management Concepts and Guidelines, 2007.

- No evidence of significant soil creep, tension cracks or other indicators of slope instability were identified at the time of our visual assessment.
- The access pathway between the existing boatshed and the existing dwelling, is bordered by steep banks of rubbly colluvium soils, loose vegetation and medium to large sandstone floaters. One medium sized sandstone floater displays minor undermining of the silty/sandy soil. We would suggest this floater be removed from the soil profile, or adequate support for the underlying soil materials be installed to mitigate further undermining.
- The property is classified '**Geotechnical Hazard H1**' in Northern Beaches Council PLEP Geotechnical Hazard Map (PLEP Geotechnical Hazard Map **Image 2** below).

Image 2: 121 Florence Terrace, Scotland Island – Red polygon (© PLEP 2014)

3.5 Geotechnical Hazards and Risk Analysis

The slope across the subject site has an average gradient of ~20-25 degrees. The soil profile is interpreted to comprised of fill/rubbly colluvium, and sandy/silty clay overlying weathered bedrock, confirmed by ground testing. The likelihood of the slope failing is assessed as '**UNLIKELY**', the consequences of such a failure are assessed as '**MINOR**'. The risk to property is '**LOW**'. The existing conditions and proposed development are considered to constitute an '**ACCEPTABLE**' risk to life and a '**LOW**' risk to property provided that the recommendations outlined in **Section 3.6** are adhered to.

3.6 Recommendations

The proposed development is considered to be suitable for the site. No significant geotechnical hazards will result from the completion of the proposed development provided the recommendations presented in Table 3 are adhered to.

Table 3: Geotechnical Recommendations.

Recommendation	Description
Soil Excavation	Soil excavation will be required for the construction of appropriate footings for the proposed boatshed and associated works. It is anticipated that these excavations will encounter fill, and silty/sandy clays before weathered bedrock, most likely shale, is encountered. The soil materials should be readily excavated with a bucket excavator, auger attachment or using hand tools. Provided the loose soils and fill overlying weathered rock are battered back to a minimum of 45 degrees, they should remain stable without support for a short period until permanent support is in place. If permanent batters are proposed, the unsupported batter must not be steeper in gradient than 35 degrees, and should be supported by geotextile fabric, pinned to the slope and planted with soil binding vegetation.
Rock Excavation	All excavation recommendations as outlined below should be read in conjunction with Safe Work Australia's *'Excavation Work – Code of Practice'*, published March, 2015.

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	It is essential that any excavation through rock that cannot be readily achieved with a bucket excavator, ripper or similar, should be carried out initially using a rock saw to minimise the vibration impact and disturbance on the adjoining properties, and adjacent structures. Any rock breaking must be carried out only after the rock has been sawed and in short bursts (2-5 seconds) to prevent the vibration amplifying. The break in the rock from the saw must be between the rock to be broken and the closest adjoining structure. Hand operated pneumatic picks may be used without restriction. All excavated material is to be removed from the site in accordance with current Office of Environment and Heritage (OEH) regulations.
Vibrations	The Australian Standard AS2670.2-1990 "Evaluation of human exposure to whole-body vibrations – continuous and shock induced vibrations in buildings (1-80 Hz)" suggests a day time limit of 5 mm/s component PPV for human comfort is acceptable. We would suggest allowable vibration limits be set at 5mm/s PPV, and monitoring devices installed at the footing level of any adjacent structures. It is expected that rock hammers with an approximate weight of 400-600kg will be adequate to operate within these tolerances. It may be necessary to move to smaller rock hammers or to rotary grinders or rock saws if vibrations limits cannot be met. Manufacturers of the plant should be consulted regarding peak vibration output. The propagation of vibrations can be mitigated by pulsing the use of rock hammers, i.e. short bursts, utilising line sawing along boundaries.
Excavation Support	Where required, vertical or sub-vertical cuts through at least low strength bedrock should stand unsupported until permanent supporting structures are installed. Provided the appropriate batter angles, mentioned above, are achieved, and any exposed soil batter is covered to prevent excessive infiltration or evaporation of moisture, no significant excavation support should be required. It is anticipated that steel reinforcement and concrete should be introduced to the required footing excavations in a relatively short period of time after completion of excavation. Temporary support may be necessary depending upon the material encountered in the

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	cuts, the likelihood of heavy rain and the length of period before permanent support is installed. Pier excavations should be covered to mitigate the risks of cave in. Moderate to large sized detached sandstone blocks are present within the bordering embankments of the access pathways between the existing boatshed and residence, in close proximity and uphill of the proposed new boatshed and associated works. Where possible the removal of any detached boulder/blocks before commencement of excavation works would be advantageous. Where removal of boulders/blocks is not possible, or deeply embedded boulders are encountered in the wall of the excavation, these may require over excavation and underpinning or rock bolting to ensure no movement is possible that might result in collapse, or detrimental point loads being applied to retaining systems.
Sediment and Erosion Control	Appropriate design and construction methods shall be required during site works to minimise erosion and provide sediment control. In particular, any stockpiled soil will require erosion control measures, such as siltation fencing and barriers, to be designed by others.
Footings	All pad, strip or piered footings should be founded on and socketed a minimum of 300mm into the underlying weathered bedrock. For fully cleaned footings, the allowable bearing pressure is **600 kPa**. Higher bearing capacities may be achieved with the addition of skin friction in unlined bored piers, dependant on their depth. **Note:** The local geology is comprised of highly variable interbedded clays, shales and sandstones, with abundant detached joint blocks and sandstone floaters in the upper profile. Subsequently ground conditions on site may alter significantly across short distances. This variability should be anticipated and accounted for in the design and construction of any new foundations. **We recommend that Ascent be contacted immediately if conditions onsite are outside of those expected.**
Retaining Structures	Any retaining structures to be constructed as part of the site works are to be backfilled with suitable free-draining materials wrapped in a non-woven geotextile fabric (i.e Bidim A34 or similar), to prevent the clogging of the drainage with sediment.

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Fills	Any fill that may be required is to comprise local sand, clay and weathered rock. Existing organic topsoil is to be cleared in preparation for the introduction of fill. Any new fill material is to be placed in layers not more than 250 mm thick and compacted to not less than 95% of Standard Optimum Dry Density at plus or minus 2% of Standard Optimum Moisture Content. All new fill placement is to be carried out in accordance with AS 3798 – 2007 – Guidelines on earthworks for commercial and residential developments.
Stormwater Disposal	Any stormwater collected from hard surfaces is to be collected and piped to an appropriately designed stormwater system for the block through any storage tanks or on-site detention that may be required by the regulating authorities, and preferably discharged to Pittwater, via non-erosive level spreader systems or similar.
Inspections	It is essential that the foundation materials of all footing excavations be inspected and approved before steel reinforcement and concrete is placed. We would recommend that Ascent be called to inspect footings early in the excavation phase, to ensure an appropriate foundation material has been achieved, and to avoid costly over, or under excavation.
Conditions Relating to Design and Construction Monitoring	To comply with Council conditions and enable the completion of Forms 2B and 3 as required in Councils Geotechnical Risk Management Policy, it will be necessary, at the following stage for Ascent to; **Form 2B** – Pre-Construction Certificate. Review and certify the geotechnical content of all structural designs. **Form 3** – Ascent has inspected and certified all new footings and bulk excavations to confirm compliance to design with respect to allowable bearing pressure and stability. Final inspection of site, post construction. **Note*** failure to arrange Ascent to carry out the necessary foundation material/footings inspections, prior to steel reinforcement and concrete being placed, will preclude our ability to issue the Form 3.

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

For and on behalf of, **Ascent Geotechnical Consulting Pty Ltd,**

Ben Morgan BSc Geol.	**Karen Allan** CPEng MIEAust
Engineering Geologist	Senior Civil/Geotechnical Engineer

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4 References

NSW Department of Mineral Resources (1983), Sydney Australia 1: 100,000 Geological Series Sheet 9130.

Australian Geomechanics Society (March 2007), *Landslide Risk Management*, Australian Geomechanics 42 (1).

Australian Standard 1726:2017 Geotechnical Site Investigations.

Australian Standard 2870:2011 Residential Slabs and Footings.

Australian Standard 1289.6.3.2:1997 Methods of Testing Soils for Engineering Purposes.

Australian Standard 3798:2007 Guidelines for earthworks for commercial and residential developments.

Horton Coastal Engineering Advice on 307 Whale Beach Road, Palm Beach, dated 12th of June, 2019.

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GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1 – To be submitted with Development Application

Development Application for SCOTT & CARRIE TOWERS
Name of Applicant

Address of site 121 FLORENCE TERRACE, SCOTLAND ISLAND NSW

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

I, KAREN ALLAN (insert name) *on behalf of* Ascent Geotechnical Consulting P/L (Trading or Company Name)

on this the 20/12/2019 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.

Please mark appropriate box

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

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

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

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

☐ Have examined the site and the proposed development/alteration is separate form and 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

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

Geotechnical Report Details:

Report Title: Geotechnical Assessment Report for New Boatshed at 121 Florence Terrace, Scotland Island NSW.
Report Date: 20/12/2019

Author : Ben Morgan / Karen Allan

Author's Company/Organisation : Ascent Geotechnical Consulting Pty Ltd

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

Architectural plans prepared by Stephen Crosby and Associates, Project No. 2128, Drawing No. DA03, dated September, 2019

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 Northern Beaches 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 [signature]

Name Karen Allan

Chartered Professional Status MIE Aust CPEng NER

Membership No. 793020

Company Ascent Geotechnical Consulting Pty Ltd

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

Development Application for **SCOTT & CARRIE TOWERS**
Name of Applicant

Address of site **121 FLORENCE TERRACE, SCOTLAND ISLAND NSW**

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: Geotechnical Assessment Report for Proposed New Boatshed at 121 Florence Terrace, Scotland Island NSW

Report Date: 20/12/2019

Author: Ben Morgan / Karen Allan

Author's Company/Organisation: Ascent Geotechnical Consulting PTY LTD

Please mark appropriate box

☒ Comprehensive site mapping conducted 16/12/2019
(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 16/12/2019

☒ 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 KAllan

Name Karen Allan

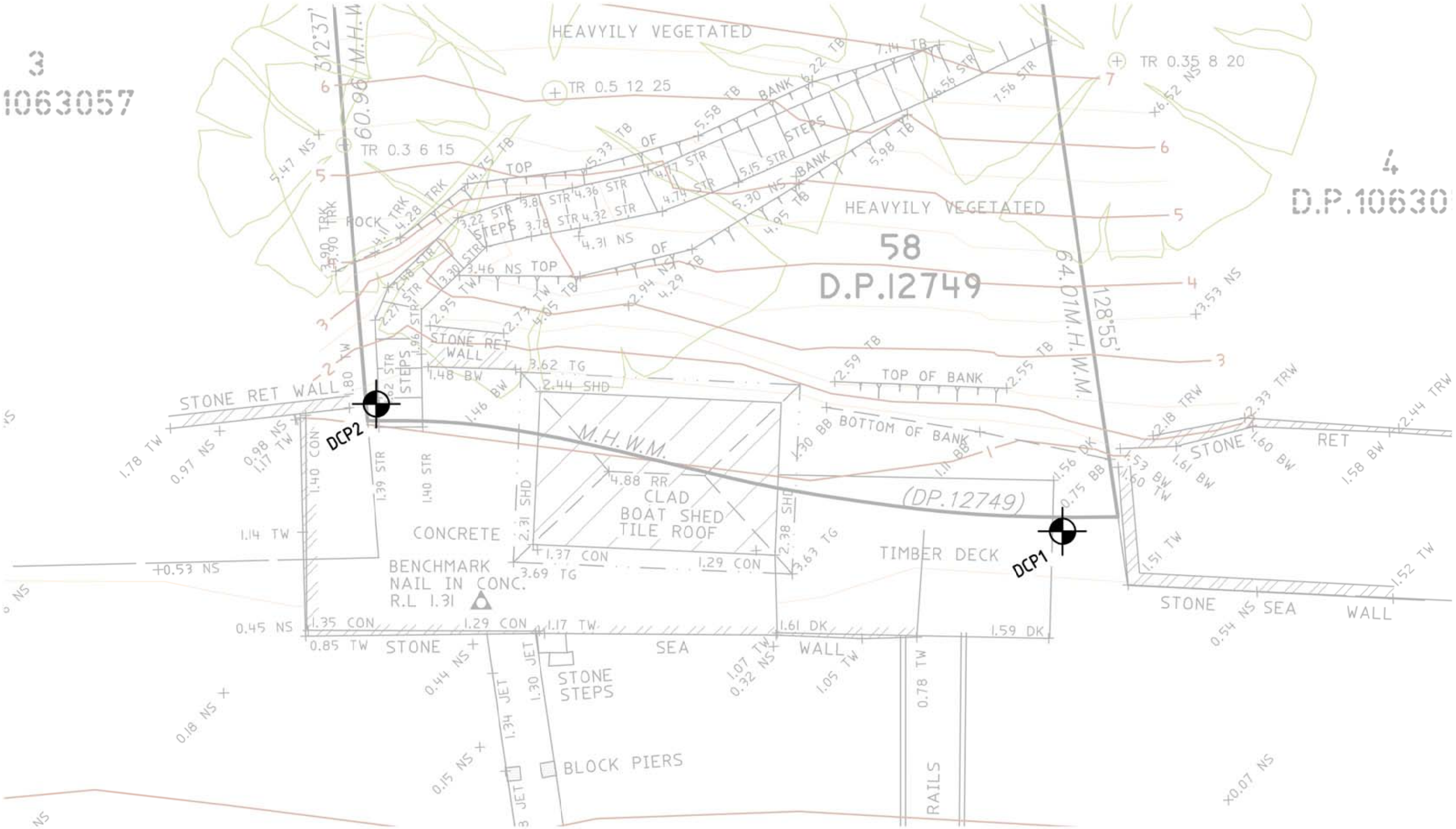
Chartered Professional Status MIE Aust CPEng

Membership No. 793020

Company Ascent Geotechnical Consulting Pty Ltd

LEGEND

DCP LOCATIONS



SITE PLAN/GROUND TEST LOCATIONS

SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	19.12.19	PRELIMINARY ISSUE	VT	BM

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CLIENT:
SCOTT & CARRIE TOWERS

SITE PLAN/GROUND TEST LOCATIONS AT 121 FLORENCE TERRACE SCOTLAND ISLAND NSW

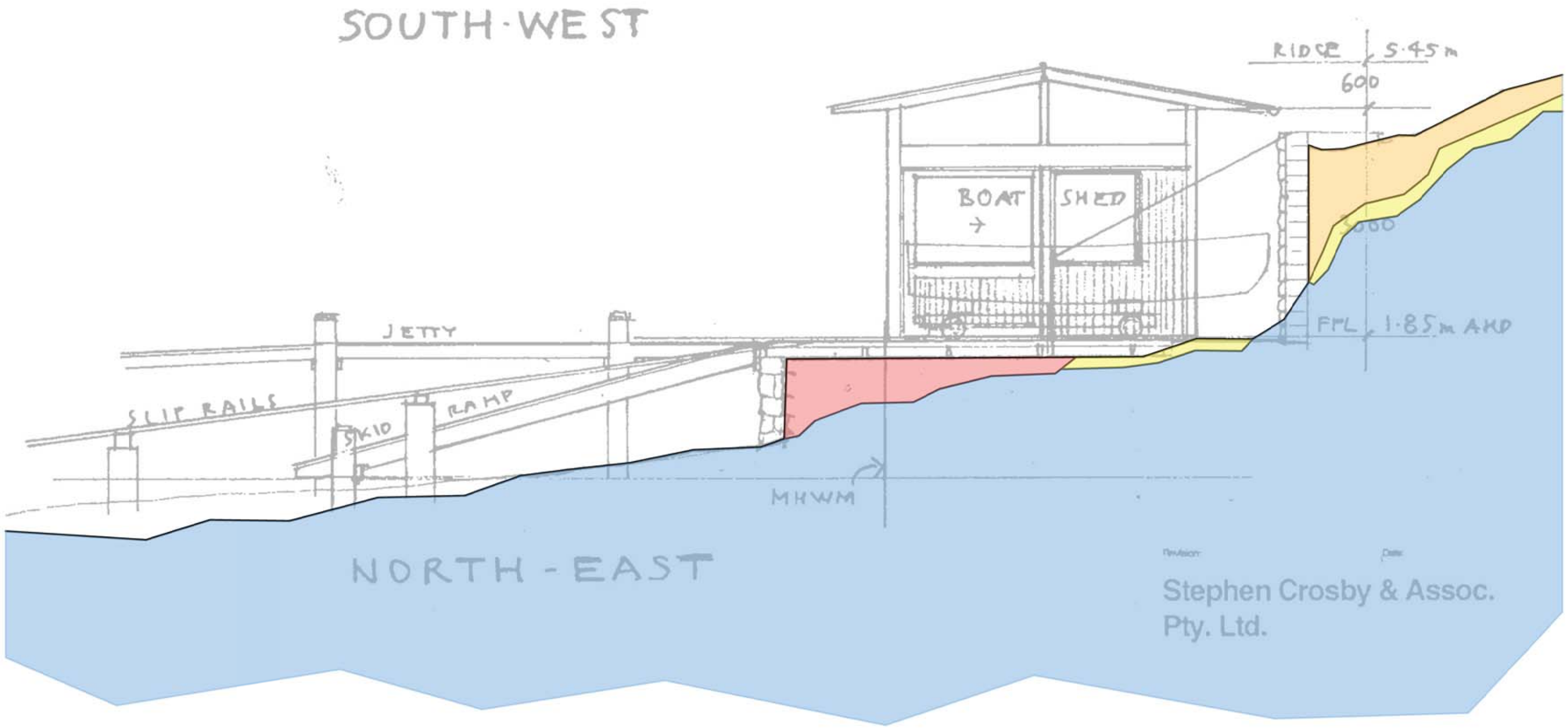
DATE: 19/12/2019

SCALE: AS SHOWN @ A3

DRAWING TITLE: SITE PLAN

DRAWING NO: AG 19236- S1

INTERPRETED SUBSURFACE SECTION ONLY.
ACTUAL GROUND CONDITIONS MAY VARY.



LEGEND

- FILL
- COLLUVIUM SOILS
- CLAYS
- NEWPORT FORMATION GEOLOGY

INFERRED GEOLOGICAL SECTION
SCALE NTS

REV	DATE	REVISION DESCRIPTION	REV BY	CHCKD
A	19.12.19	PRELIMINARY ISSUE	VT	BM

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CLIENT: SCOTT & CARRIE TOWERS

INFERRED GEOLOGICAL SECTION AT 121 FLORENCE TERRACE SCOTLAND ISLAND NSW

DATE: 19/12/2019
SCALE: AS SHOWN @ A3
DRAWING TITLE: ELEVATION
DRAWING NO: AG 19236- S2

ASCENT GEOTECHNICAL CONSULTING

Po Box 37, Manly, NSW 1655, Australia
Tel: 0448 255 537
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Dynamic Cone Penetration Test Report

Client:	Scott & Carrie Towers	Job No:	AG 19236
Project:	New Boatshed	Date:	16/12/19
Location:	121 Florence Terrace, Scotland Island NSW	Operator:	MSK
Test Procedure:	AS 1289.6.3.2 – 1997		

Test Data

Test No: DCP 1		Test No: DCP 2		Test No:		Test No:		Test No:	
Test Location: Refer to Site Plan		Test Location: Refer to Site Plan		Test Location:		Test Location:		Test Location:	
RL:		RL:		RL:		RL:		RL:	
Soil Classification: A		Soil Classification: A		Soil Classification:		Soil Classification:		Soil Classification:	
Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0 - 0.3	10	0.0 - 0.3	10 Rs						
0.3 - 0.6	5 Rs	0.3 - 0.6							
0.6 - 0.9		0.6 - 0.9							
0.9 - 1.2		0.9 - 1.2							
1.2 - 1.5		1.2 - 1.5							
1.5 - 1.8		1.5 - 1.8							
1.8 - 2.1		1.8 - 2.1							
2.1 - 2.4		2.1 - 2.4							
2.4 - 2.7		2.4 - 2.7							
2.7 - 3.0		2.7 - 3.0							
3.0 - 3.3		3.0 - 3.3							
3.3 - 3.6		3.3 - 3.6							
3.6 - 3.9		3.6 - 3.9							
3.9 - 4.2		3.9 - 4.2							
4.2 - 4.5		4.2 - 4.5							
4.5 - 4.8		4.5 - 4.8							
4.8 - 5.1		4.8 - 5.1							
DCP 1: Refusal @ 0.35m Bouncing on bedrock or large floaters. White impact dust on dry tip.		DCP 2: Refusal @ 0.20m Bouncing on bedrock or large floaters. White impact dust on dry tip.							

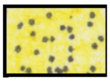
Remarks:	Weight:	9 kg
Available test locations limited by existing structures, hard surfaces and utility locations. No groundwater encountered.	Drop:	510 mm
	Rod Diameter:	16 mm

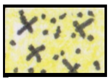
Rs = Solid ring/Hammer bouncing

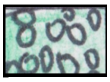
D = Dropped under wieght of Hammer

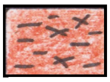
GUIDE TO NOTES, DESCRIPTIONS AND TERMS USED ON ENGINEERING LOGS

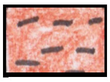
Graphic Symbols Used - Soil Main Component Only

SAND 

SILTY SAND 

GRAVEL 

SILTY CLAY 

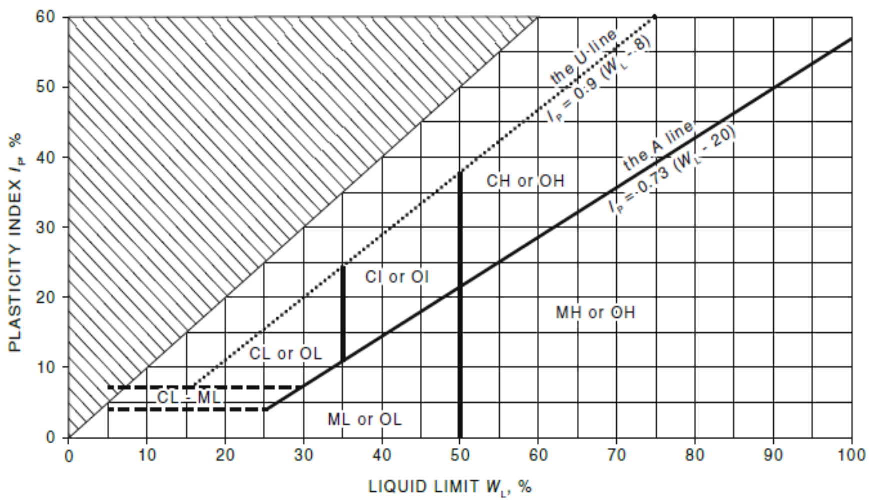
CLAY 

FILL 

Soil Description - Refer to AS1726 (2017) for full details.

Main Components		Particle Size	USCS Symbol	Typical Names
COARSE GRAINED SOILS (more than 65% of material less than 63 mm is larger than 0.075 mm)	BOULDERS			
	COBBLES	200		
	GRAVELS (more than half of material is larger than 2.36 mm size)	63	GW	Well graded gravel and sand mixtures, little or no fines
		19	GP	Poorly graded gravel and sand mixtures, little or no fines
		6.7	GM	Silty gravels, gravel sand and silt mixes
		2.36	GC	Clayey gravels, gravel sand and clay mixes
	SANDS (more than half of material is smaller than 2.36 mm size)	0.6	SW	Sand and gravel Sand mixes, little or no fines
		0.21	SP	Sand and gravel Sand mixes, little or not fines, poorly graded
			SM	Sand and silt mixes
		0.075	SC	Sand and clay mixes
FINE GRAINED SOILS (more than 35% of material less than 63 mm in size is less than 0.075mm)	SILTS & CLAYS (low to medium plasticity		ML	Inorganic silts, very fine sand, rock flour, silty or clayey fine sand, clayey silts with slight plasticity
			CL and CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays and lean clays
			OL	Organic silt
	SILTS & CLAYS (high plasticity)		MH	Inorganic Silt
			CH	Inorganic clays of high plasticity
			OH	Organic silts and clays of medium to high plasticity; organic silt
	ORGANIC SOILS		PT	Peat and other highly organic soils

Laboratory Classification - Refer to AS1726 (2017) for full details.

<table>
<tr><th></th><th>% Passing 0.075 mm</th><th>Plasticity of fine fraction</th><th>$C_u = D_{60}/D_{10}$</th><th>$C_c = D_{30}^2 / D_{10} D_{60}$</th><th>NOTES</th></tr>
<tr><td>GW</td><td>0-5</td><td></td><td>> 4</td><td>Between 1 and 3</td><td rowspan="8">(1) and (2)</td></tr>
<tr><td>GP</td><td>0-5</td><td></td><td colspan="2">Fails to comply with above</td></tr>
<tr><td>GM</td><td>> 12%</td><td>Below "A" line or PI<4</td><td colspan="2">Fines are silty</td></tr>
<tr><td>GC</td><td>> 12%</td><td>Above "A" line or PI > 7</td><td colspan="2">Fines are clayey</td></tr>
<tr><td>SW</td><td>0-5</td><td></td><td>> 6</td><td>Between 1 and 3</td></tr>
<tr><td>SP</td><td>0-5</td><td></td><td colspan="2">Fails to comply with above</td></tr>
<tr><td>SM</td><td>> 12%</td><td>Below "A" line or PI<4</td><td colspan="2">Fines are silty</td></tr>
<tr><td>SC</td><td>> 12%</td><td>Above "A" line or PI > 7</td><td colspan="2">Fines are clayey</td></tr>
<tr><td>ML</td><td colspan="5" rowspan="8">

NOTE: The U line is an approximate upper bound for most natural soils. Data which plot above the U line may represent unusual/problem soil behaviour, or unreliable data and should be considered carefully.

FIGURE 5 MODIFIED CASAGRANDE CHART FOR CLASSIFYING SILTS AND CLAYS ACCORDING TO THEIR BEHAVIOUR

</td></tr>
<tr><td>CL and CI</td></tr>
<tr><td>OL</td></tr>
<tr><td>MH</td></tr>
<tr><td>CH</td></tr>
<tr><td>OH</td></tr>
<tr><td>PT</td></tr>
<tr></tr>
<tr><td colspan="6">NOTES
(1) Identify fines by method for fine grained soils
(2) Borderline classificaiton occcur when percentage of fines is greater than 5% and less than 12% and require the use of SP-SM, GW-GC etc.</td></tr>
</table>

Soil Colour is desribed in its moist condition using black, white, grey, red, brown, orange, yellow, green or blue. Combinations can be used for borderline cases with the stronger colour preceeding the weaker colour. Pale, dark or mottled may be used where necessary. For further details refer to AS1726 (2017) Section 6.1.5

Soil Moisture Condiiton is based on the appearance and feel of the soil as per AS1726 (2017) Section 6.1.7.
Dry (D) - non-cohesive and free-running
Moist (M) - Soil feels cool, darkened in colour, tends to stick together
Wet (W) - Soil feels cool, darkened in colour, tends to sick together and free water

Material Density and Consistency

Consistency - Cohesive Soils

Term	Field Assessment	Symbol	SPT "N" Value	Undrained Shear Stength, su (kPa)	Unconfined Compressive Strength qu, (kPa)
Very Soft	Ooozes between fingers when squeezed	VS	0 - 2	< 12	< 25
Soft	Easily moulded with fingers	S	2 - 4	12 - 25	25 - 50
Firm	Can be moulded by strong pressure of	F	4 - 8	25 - 50	50 - 100
Stiff	Not possible to mould with fingers	St	8 - 15	50 - 100	100 - 200
Very Stiff		VSt	15 - 30	100 - 200	200 - 400
Hard	Can be indented with difficulty by thumb nail	H	> 30	> 200	> 400

Consistency - Non-Cohesive Soils

Term	Symbol	SPT N Value	Field Guide	Density Index (%)
Very Loose	VL	0 - 4	Foot imprints readily	0 - 15
Loose	L	4 - 10	Shovels easily	15 - 35
Medium Dense	MD	10 - 30	Shovelling difficult	35 - 65
Dense	D	30 - 50	Pick required	65 - 85
Very Dense	VD	> 50	Picking difficult	85 - 100

Rock Weathering Guide

Residual Soil		RS	Soil like material developed on extremely weathered rock, the mass structure and substance fabric are no longer evident, the material has not been significantly transported
Extremely Weathered		XW	Material is weathered to such an extent that it has "soil" like properties, but substance fabric and rock structure is still
Highly Weathered	DW	HW	Rock is discoloured, and rock strength significantly changed by weathering.
Moderately Weathered	DW	MW	Rock is discoloured, original rock colour is not recognizaable, but little or no change in strength from fresh rock.
Slightly Weathered		SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh Rock		FR	Rock shows no signs of decomposition or staining.

*DW - Distinctly weathered - Some change in rock strength due to weathering and highly discoloured.

Rock Strength Condition (Intact Rock Strength)

Term	**Symb**	**Is(50)**	**Field Guide to Strength**
Extremely Low	EL	< 0.03	Easily remoulded by hand to a material with soil like
Very Low	VL	0.03 - 0.1	Material crumbles under firm blows wit the sharp end of a pick, can be peeled with a knife but too hard to cut into a triaxial sample by hand. Can break pieces up to 3 cm thick by hand
Low	L	0.1 - 0.3	Easily scored with a knife; indentations 1 mm to 3 mm shown after blows with a pick; has dull sound under hammer. A 50 mm diameter sample may be broken by hand.
Medium	H	0.3 - 1.0	Readily scored with a knife; a 50mm diameter core sample can be broken by hand with difficulty
High	H	1.0 - 3.0	A piece of 50mm diameter cores cannot be broken by hand; rock rings under hammer blow
Very High	VH	3.0 - 10	Hand specimem breaks with pick after more than on blow, rock rings under hammer.
Extremely High	EH	> 10	Specimum requires many blows with pick to break through intact rock; rock rings under hammer.

ASCENT
GEOTECHNICAL CONSULTING

General Notes About This Report

Introduction
These supporting notes have been prepared by Ascent Geotechnical Consultants (AGC) to assist our clients interpret and understand the limitations of this report. Not all sections below are necessarily relevant to this report.

Limitations
Geotechnical reports are based on information gained from limited sub-surface site testing 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 the information on which they rely.

This report has been prepared for this specific project's design proposal. This report should not be relied upon for any other project or if the design proposal of this project changes without the prior knowledge of AGC.

Subsurface Conditions
Subsurface conditions can change with time and can vary significantly between test locations and over very short distances. That actual interface between the materials may be far more gradual or abrupt than interpreted. Therefore, actual conditions in areas not tested may differ from those predicted since no subsurface investigation, no matter how comprehensive, can reveal al subsurface details and anomalies.

Groundwater
Groundwater levels indicated in our subsurface testing are recorded at specific times. The groundwater levels recorded will depend on ground permeability, seepage and environmental variations.

Site inspections
Ascent Geotechnical Consultants will always be please to provide engineering inspection services for aspects of work relating to this report. This may range from standard foundation material inspections for footings, to a full-time engineering presence on site or through one stage of the development. Ascent Geotechnical Consultants are familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

Anomalies
If the ground or groundwater conditions onsite prove to differ from those described in this report we would recommend that Ascent Geotechnical Consulting be contacted as a matter of priority. It is far easier and less costly to address these issues if they are addressed early on in the project.

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

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

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

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

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

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

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

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

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

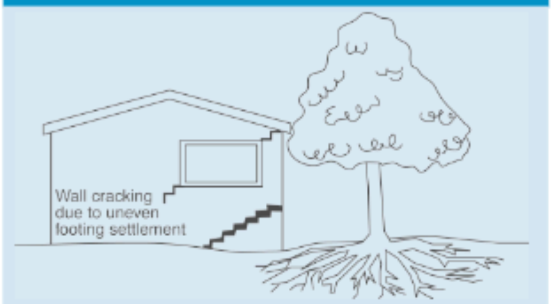
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

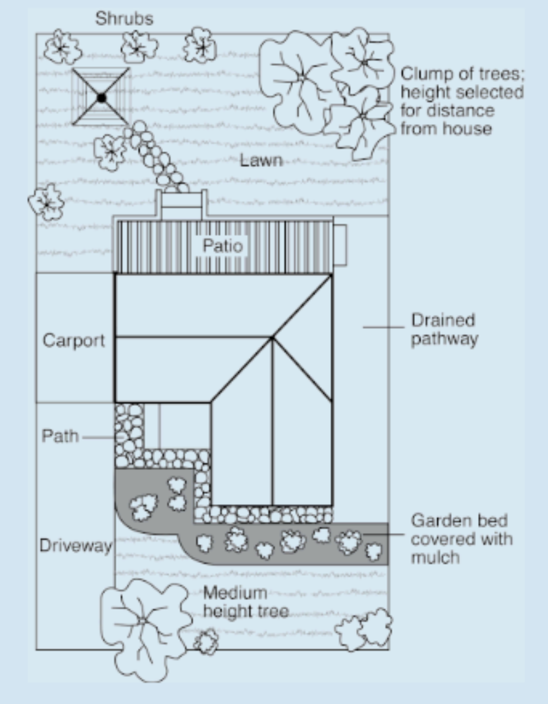
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

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

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

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

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

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

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

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

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

Remediation

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

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

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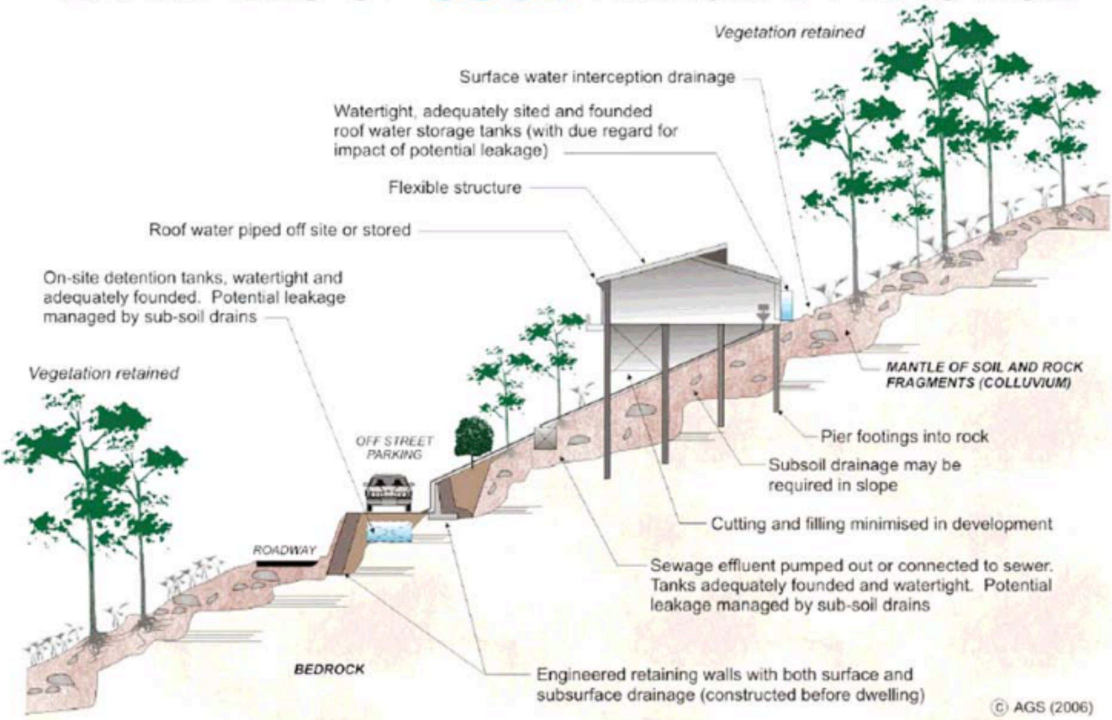
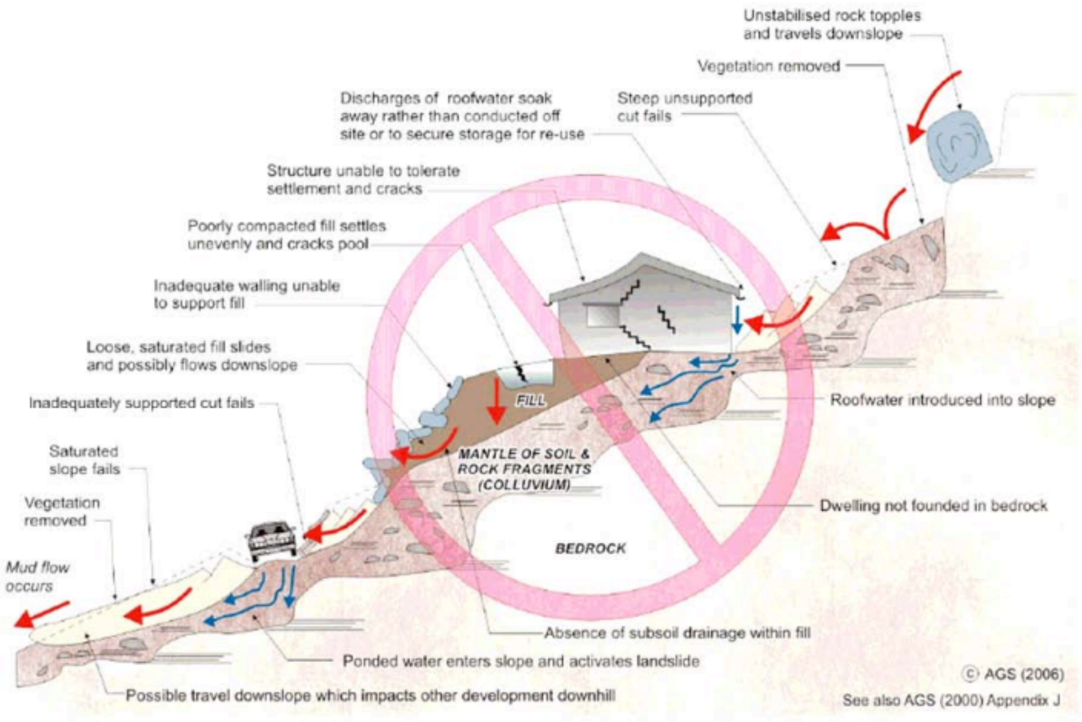
EXAMPLES OF **GOOD** HILLSIDE PRACTICE



EXAMPLES OF **POOR** HILLSIDE PRACTICE



PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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.