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Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

REPORT ON GEOTECHNICAL ASSESSMENT

for

PROPOSED ALTERATIONS AND ADDITIONS

at

26 BUNGOONA AVENUE, ELANORA HEIGHTS

Prepared For

Mr. Charles Hill

Project No.: 2017-230

October, 2017

Document Revision Record

Issue No	Date	Details of Revisions
0	30th October 2017	Original issue

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for Mr and Mrs Cahill c/- Mark Harcum Design Practice

Name of Applicant

Address of site 26 Bungoona Avenue, Elanora Heights

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 30th October 2017 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

☐ 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: Geotechnical Assessment Report for Proposed Alterations and Additions

Report Date: 30th October 2017 **Project No.:** 2017-230

Author: T. Crozier

Author's Company/Organisation: Crozier Geotechnical Consultants

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

Architectural drawings by Mark Harcum Design Practice, Drawing No. SK01 and SK02, Dated: April 2017.

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**

REGISTERED ... GEOTECHNICAL ... AUSTRALIAN INSTITUTE OF GEOSCIENTISTS ... TROY CROZIER 10197

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for Mr and Mrs C Hill c/- Mark Hurcum Design Practice
Name of Applicant
Address of site 26 Bungoona Avenue, Elanora Heights

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 Alterations and Additions
Report Date: 30th October 2017 **Project No.:** 2017-230
Author: T. Crozier
Author's Company/Organisation: Crozier Geotechnical Consultants

Please mark appropriate box

- ■ Comprehensive site mapping conducted 25th October 2017 (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 .....bedrock outcropping and minor development.....
  - ☐ Yes Date conducted .....
- ☐ 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 .....50 years..... 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**

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CROZIER GEOTECHNICAL CONSULTANTS

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GEOTECHNICAL ASSESSMENT REPORT FOR PROPOSED ALTERATIONS & ADDITIONS 26 BUNGOONA AVENUE, ELANORA HEIGHTS, NSW

1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for proposed alterations and additions at 26 Bungoona Avenue, Elanora Heights, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the request of the client Mr. Charles Hill.

The site is situated on the high north side of Bungoona Avenue within moderately south dipping topography near a ridge/plateau crest. The site is currently occupied by a two storey timber and steel residential dwelling situated above a cliff crest with a masonry garage at the front of the house, located at the base of the cliff.

It is understood that the proposed works involve construction of a new lift that will provide access form the garage to the house. The works will be generally above ground surface levels and require minimal excavation for the lift over-run and footings.

Reference to Pittwater Council's LEP 2014 Geotechnical Risk Management Map (GTH_013), the site has been classified as being within the H1 (highest category) landslip hazard zone therefore the site requires a Geotechnical Landslip Risk Assessment to be conducted in support of a Development Application. This report therefore includes a detailed description of the field work, assessment of proposed works, site specific risk assessment where landslip hazards are identified and recommendations for construction to maintain the "Acceptable Risk Management" criteria.

The investigation and reporting were undertaken as per the Tender P17-363, Dated: 8th September 2017.

The investigation comprised:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Principal Engineering Geologist.
b) Review of Ortho Photomaps and Aerial Photography of the site.

The following plans and diagrams were supplied for the work;

- Architectural drawings by Mark Harcum Design Practice, Drawing No. SK01 and SK02, Dated: April 2017.

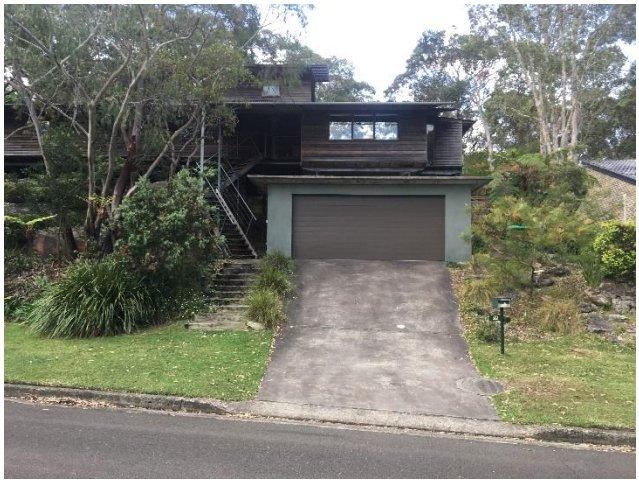
2. SITE FEATURES:

2.1. Description:

The site is located on the high north side of Bungoona Avenue and is within moderately south dipping topography close to the crest of a steep slope that defines the southern edge of a plateau. Reference to the NSW Government Six Map spatial data indicates the site is a square shaped block located on the high north side of Bungoona Avenue with side boundaries of approximately 29.00m in length.

The site contains a masonry garage in the lower south-east corner with gardens to the south containing boulders. A low (<5.0m) cliff strikes across the property at the rear of the garage with a two storey timber and steel house located above the cliff crest and extending over the garage. To the rear of the house is a small deck and gardens with an inground swimming pool in the north-east corner and another high cliff in the north-west corner.

Photos of the front of the site taken form the road reserve is supplied below.



2.2. Geology:

Reference to the Sydney 1: 100,000 Geological Series sheet (9130) indicates that the site is underlain by Hawkesbury Sandstone (Rh) which is of Triassic Age. The rock unit typically comprises medium to coarse grained quartz sandstone with minor lenses of shale and laminite.

Morphological features often associated with the weathering of Hawkesbury Sandstone topography are the formation of near flat ridge tops with steep angular side slopes that consist of sandstone terraces and cliffs in part covered with sandy colluvium. The terraced areas often contain thin sandy clay to clayey sand residual soil profiles with intervening rock (ledge) outcrops. The outline of the cliff areas are often rectilinear in plan view, controlled by large bed thickness and wide spaced near vertical joint patterns. The dominant defect orientation being south-east and north-east. Many cliff areas are undercut by differential weathering along sub-horizontal to gently west dipping bedding defects or weaker sandstone/siltstone/shale horizons. Slopes are often steep (15º to 23°) and are randomly covered by sandstone boulders.

3. FIELD WORK:

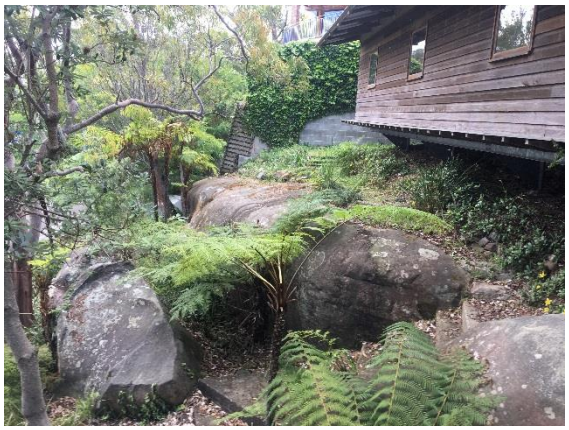
3.1. Methods:

The field investigation comprised a walk over inspection and mapping of the site and adjacent properties on the 25th October 2017 by a Principal Engineering Geologist. It included a photographic record of the site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of rock outcrops, vegetation and existing structures.

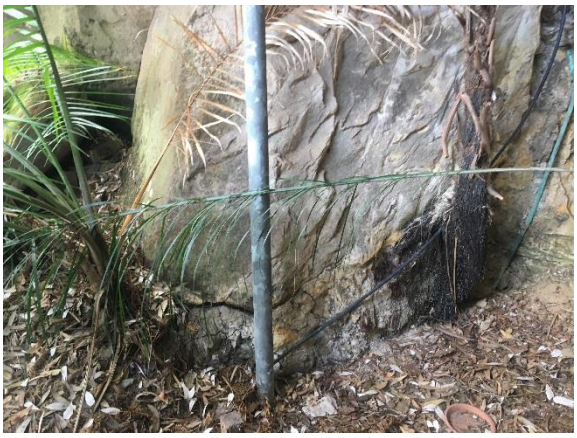
3.2. Field Observations:

Bungoona Avenue is near level where it passes the site and consists of a bitumen pavement with concrete kerb and gutter. A gently south dipping lawn reserve is located between the site boundary and the kerb. There were no indications of excess deterioration, cracking or deformation within the road reserve to indicate any form of slope instability.

The front of the site contains a gently dipping near natural garden with dense vegetation and numerous medium to large size sandstone boulders. These boulders have separated from a 2.00m to 5.00m high sandstone bedrock cliff that strikes across the site from the rear edge of the garage, in a south-west direction, towards the sites south-west corner. A concrete driveway provides access up to a two car masonry garage structure that is formed up to the cliff face in the south-east corner of the site. The soil/garden slopes and boulders generally appear stable in their current position. The garage may have involved some minor excavation for its construction and adjacent to its north-west corner the end of one boulder is exposed along with a clayey sand residual soil below its base, see photos below:



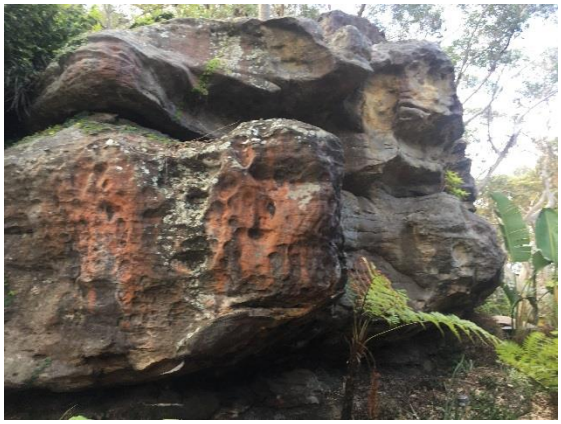
Front yard of site showing bedrock and boulders



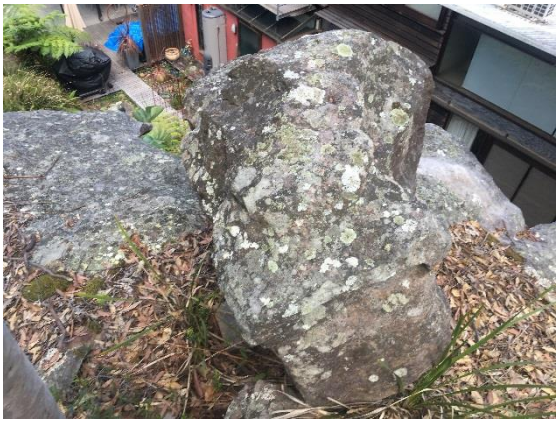
Base of boulder adjacent to garages north-west corner

The existing house is a two storey timber and steel structure that is supported above ground surface via steel columns and beams. The house is a generally timber structure and appears of approximately 40 years of age. The garage, which is a masonry structure may be a more recent addition. The house and garage appear in good conditions with visible signs of excess deterioration, settlement or movement to indicate slope instability.

The backyard contains an inground swimming pool in the rear north-east corner with a sloping bedrock outcrop rising up from the rear of the site to a gently sloping lawn area in the adjacent land. This outcrop which forms a low cliff extends towards the east. Towards the west a low cliff strikes south through the adjacent land and then turns west within the site to form an approximately 5.00m high cliff within the north-west corner of the site. The cliff shows some separation along joint defects and the lower cliff face is undermined by weathering. A small boulder is also located above the cliff crest.



Cliff in rear north-west corner, slight overhang



Small boulders above cliff.

The neighbouring property to the east (No. 24) contains a one and two storey brick residence located on the centre of the block within a near level terrace that is slightly raised above road reserve levels and similar to the garage within the site. The cliff line that passes through the site, to the rear of the garage, appears to curve to the north and was not observed within this property.

The neighbouring property to the west (No. 28) contains a multi-storey residential house located to the north-west of the site house and adjacent to the upper cliff line. This property is located slightly above site levels with a 1.00m high concrete block retaining wall along the common boundary supporting a lawn terrace. A very large (5.00m □6.00m high) timber cribb wall supports this lawn terrace along its southern edge adjacent to the properties front boundary.

The neighbouring buildings and properties were only inspected from within the site or from the road reserve however the visible aspects did not show any significant signs of large scale slope instability or other major geotechnical concerns which would impact the site.

4. COMMENTS:

4.1. Geotechnical Assessment:

The inspection and assessment identified no obvious significant landslip hazards within the site or adjacent properties. The existing residence is approximately 40 years of age with no signs of excess cracking or settlement with bedrock outcropping below the structure. The cliff and boulders at the front of the property all appear stable with the boulders generally buried into the garden slope. The rear cliff line does have an undercut however its scale and the location of any adjacent defects indicate a very low probability of instability. The boulder located above the crest of the cliff also appears stable in its current position. Surface stormwater appears controlled and there were no signs of surface flow or erosion.

It is understood that the proposed works involve construction of a new lift from the garage to the house levels. The works will involve a small isolated excavation to achieve a lift over-run and footings. This excavation will not present a credible landslip hazard due to its scale and location.

The boulder located adjacent to the lift location is long (5.00m) and its stability will not be affected by the excavation due to the separation distances. Should excavation for the lift be widened for any reason then an underpinning of concrete or brick to below excavation level will ensure no movement occurs.

There were no signs of previous landslip instability within the site whilst the proposed works will not create a landslip hazard and the identified hazards within the cliff will not affect the proposed works. Therefore the proposed works are considered separate from and not affected by a geotechnical hazard. As such no further geotechnical investigation or reporting is required as part of this Development Application

4.2. Slope Stability & Risk Assessment:

Based on our site inspection we have identified the following potential geological/geotechnical hazards which need to be considered in relation to the existing site. The hazards are:

A. Landslip (rock fall $20m^3$) from rear cliff line due to erosion of cliff base
B. Landslip (rock fall $2m^3$) boulder from crest of rear cliff line

A qualitative assessment of risk to life and property related to these hazards is presented in Table: A and B, Appendix: 1, 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: 2.

The **Risk to Life** from both hazards was estimated to be up to **5.58×10^{-9}** for persons whilst the **Risk to Property** was considered to be **'Very Low'** in all situations. The hazards were therefore considered to be "Acceptable" when assessed against the criteria of the AGS 2007.

Both hazards are located at the rear of the property and will not affect the proposed development. Therefore the proposed works are considered separate from and not affected by a geotechnical hazard. As such no further geotechnical investigation or reporting is required as part of this Development Application.

4.3. Conditions Relating to Design and Construction Monitoring:

If requested by Council to complete Forms: 2 and 3 as part of construction, building and post-construction certificate requirements of the Councils Geotechnical Risk Management Policy 2009, it will be necessary for Crozier Geotechnical Consultants to:

1. Review and approve the structural drawings for compliance with the recommendations of this report.
2. Inspect the site upon completion of the construction to confirm no changes to slope stability as a result of the works and that the stormwater system has been suitably connected/upgraded.

The client and builder should make themselves familiar with the Councils Geotechnical Policy. Crozier Geotechnical Consultants can <u>not</u> sign Form: 3 of the policy for an occupation certificate if it has not reviewed structural designs and been called to site to undertake any required inspections.

4.4. 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, 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 (50 years)). In order to attain the □Acceptable Risk Management□criteria for a design life of 100 years as required by the Councils Risk Management Policy, it will be necessary for the property owner to adopt and implement a maintenance and inspection program. It is considered that the existing house will have a design life of 50 years from its upgrade following the proposed works.

If a maintenance and inspection schedule are not implemented the design life of the property may not be attained. A recommended program is given in Table: 1 below 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, and 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

Table 1: Recommended Maintenance and Inspection Program

Structure	**Maintenance/ Inspection Item**	**Frequency**
Stormwater drains.	Owner to inspect to ensure that the drains and pipes are free of debris & sediment build-up. Clear surface grates and litter.	Every year or following each major rainfall event
Retaining Walls	Owner to inspect walls for deviation from as constructed condition.	Every two years or following major rainfall event
Large Trees on or adjacent to site	Arbourist to check condition of trees and remove as required	Every five years
Slope Stability	Geotechnical Consultant to check stability of rear cliff overhang	Every ten years

N.B. Provided the above schedule is maintained the design life of the property should conform AS2870 and Councils 100 years stability criteria

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). It is assumed that Pittwater 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 levels or landslide potential.

5. CONCLUSION:

The inspection and assessment identified no obvious significant slope movement, excess surface stormwater flow or seepage, erosion or likely instability within the site or adjacent properties. The entire site and surrounding slopes have been assessed as per the Pittwater Council Geotechnical Risk Management Policy 2009 and achieve the "Acceptable Risk Management" criteria.

The proposed works involve construction of a new lift that will involve a small, shallow and isolated excavation. The proposed works are relatively minor from a geotechnical perspective and should not create any new instability, therefore the proposed works are separate from and not affected by a geotechnical hazard, and no further geotechnical assessment or reporting is required as part of this DA.

It is considered that the site will meet the "Acceptable" risk management criteria for the design life of the development, taken as 50 years, provided the property is maintained as per the recommendations of this report.

Prepared by:

Troy Crozier
Principal Engineering Geologist
MAIG. RPGeo; 10197

Reviewed by:

Shahzada Rizvi
Senior Engineering Geologist

6.0. REFERENCES:

1. Australian Geomechanics Society 2007, "Landslide Risk Assessment and Management", Australian Geomechanics Journal Vol 42, No 1, March 2007.
2. Geotechnical Risk Management Policy for Pittwater, 2009.

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Appendix 1

TABLE : A

Landslide risk assessment for Risk to life

HAZARD	Description	Impacting	Likelihood	Spatial Impact	Occupancy	Evacuation	Vulnerability	Risk to Life
A	Landslip (rock fall 20m³) due to overhang in rear cliff		Cliff contains 2.0m deep undercut at base, no significant destabilising defects and overhanging unit is capable of support	a) Roll into half of garden area, b) May reach edge of house and impact very small portion	a) Person in garden (1hr/month average), b) Person in house 20hrs/day.	a) Likely to not evacuate b) Unlikely to not evacuate	a) Person in open space crushed, b) Person in building no collapse	
			Unlikely					
		a) Garden area downslope	0.00001	0.50	0.0015	0.75	1.00	**5.58E-09**
		b) Site house	0.00001	0.05	0.8333	0.25	0.05	**5.21E-09**
B	Landslip (boulder roll <2m³) from top of rear cliff		Boulder is located back from cliff crest, is irregularly supoprted	a) Roll into small area of garden, b) May reach edge of house and impact very small portion	a) Person in garden (1hr/month average), b) Person in house 20hrs/day.	a) Likely to not evacuate b) Unlikely to not evacuate	a) Person in open space crushed, b) Person in building no collapse	
			Unlikely					
		a) Garden area downslope	0.00001	0.10	0.0015	0.75	1.00	**1.12E-09**
		b) Site house	0.00001	0.01	0.8333	0.25	0.05	**1.04E-09**

* hazards considered in current condition and/or without suitable remedial/stabilisation measures
* likelihood of occurrence for design life of house (considered 100years)
* considered for person most at risk
* considered for adjacent premises/buildings founded via 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)
* 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 20m³) due to overhang in rear cliff	a) Garden area downslope	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
		b) Site house	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Minor	Limited Damage to part of structure or site requires some stabilisation or INSIGNIFICANT damage to neighbouring properties.	Very Low
B	Landslip (boulder roll <2m³) from top of rear cliff	a) Garden area downslope	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
		b) Site house	Rare	The event is conceivable but only under exceptional circumstances over the design life.	Insignificant	Little Damage, no significant stabilising required or no impact to neighbouring properties.	Very Low

* 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%.

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Appendix 2

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.

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.