Crozier Geotechnical Consultants
Unit 12/ 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd
ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au

# REPORT ON GEOTECHNICAL ASSESSMENT

**for**

**PROPOSED ALTERATIONS AND ADDITIONS**
**TO EXISTING MARINE FACILITIES**
**at**

**167 RIVERVIEW ROAD, AVALON BEACH, NSW**

**Prepared For**

**SRSJ Management**

**Project No.: 2021-278.3**
**May 2023**

## Document Revision Record

| Issue No | Date | Details of Revisions |
|---|---|---|
| 0 | 25 May 2023 | Original issue |
| | | |

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

**Development Application for** ________________________________________

Name of Applicant

**Address of site** ___ 167 Riverview Road Avalon Beach, NSW

***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*** *25* May 2023 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:** Report on Geotechnical Investigation for Proposed Alterations and Additions to Existing Domestic Marine Facilities

**Report Date:** 25 May 2023 **Project No.:** 2021-278.3

**Author:** Kieron Nicholson/Troy Crozier

**Author's Company/Organisation:** Crozier Geotechnical Consultants

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

Design Drawings – Australian Ports and Marines, 'Proposed New Jetty, Ramp, Pontoon and Slip Rails', Reference: Loc.1 to Loc.5, dated 26/05/20

Department of Primary Industries Assessment – 'Jetty, ramp, pontoon and two stabilizing piles', Reference C21/486, Dated: 21 August 2021.

Statement of Environmental Effects - Addition and Alteration to Existing Domestic Marine Facilities, 20 March 2023

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**

## GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

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

**Development Application for**______________________________________________

Name of Applicant

**Address of site** ___167 Riverview Road Avalon Beach, 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:** Report on Geotechnical Investigation for Proposed Alterations and Additions to Existing Domestic Marine Facilities

**Report Date:** 25 May 2023 **Project No.:** 2021-278.3

**Author:** Kieron Nicholson/Troy Crozier

**Author's Company/Organisation:** Crozier Geotechnical Consultants

**Please mark appropriate box**

■ Comprehensive site mapping conducted ____11 January 2022___________

☐ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)

☐ Subsurface investigation required

- ■ No Justification Limited Development Scope .......
- ☐ 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 for remnant structure post renovations.
  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**

TROY CROZIER
10197

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Crozier Geotechnical Consultants
Unit 12/ 42-46 Wattle Road
Brookvale NSW 2100
Crozier Geotechnical Consultants a division of PJC Geo - Engineering Pty Ltd
ABN: 96 113 453 624
Phone: (02) 9939 1882
Email: info@croziergeotech.com.au



**GEOTECHNICAL ASSESSMENT FOR PROPOSED**
**ALTERATIONS AND ADDITIONS TO EXISTING DOMESTIC MARINE FACILITIES**
**AT 167 RIVERVIEW ROAD, AVALON BEACH, NSW**

## 1. INTRODUCTION:

This report details the results of a geotechnical assessment carried out for a proposed new jetty, ramp, pontoon and slip rails at 167 Riverview Road, Avalon Beach, NSW. The assessment was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Australian Ports and Marinas on behalf of the client, SRSJ Management. CGC has undertaken previous geotechnical investigation within the site for a separate Development Application. The results of that investigation have been utilized in preparation of this report.

The site is located within the H1 (highest category) landslip hazard zone as identified within Northern Beaches Councils precinct (Geotechnical Risk Management Policy for Pittwater - 2009). To meet the Councils Policy requirements for land classified as H1 a detailed Geotechnical Report which meets the requirements of Paragraph 6.5 of that policy is required for submission with the Development Application. The report must include a landslide risk assessment of the site and proposed works, plans, geological sections and provide recommendations for construction and to ensure stability is maintained for a design life of 100 years. The site is classified as falling within Acid Sulphate Soils (ASS) Risk Zone 1 and 5 therefore assessment of the potential for ASS generation will also need to be addressed as part of the DA submission.

Based on our understanding of the proposed development, the findings of the previous geotechnical investigation undertaken, Council and project requirements, and comprised:

a) A review of the geotechnical inspection and mapping of the site and adjacent properties undertaken by a Senior Engineering Geologist.

The results of the previous report have been included in this report and revised where required and relevant to the proposed development and include a site description, geological setting and geological field observations.

This report provides recommendations for Council use in assessment of the Development Application and includes:

- Site specific AGS Risk Assessment.
- ASS Assessment.
- Assessment of the impacts of the development.
- Measures to protect adjacent properties during construction and following completion of the development.

The following documents have been supplied and relied on for the work:

- Design Drawings – Australian Ports and Marines, 'Proposed New Jetty, Ramp, Pontoon and Slip Rails', Reference: Loc.1 to Loc.5, dated 26/05/20
- Department of Primary Industries Assessment – 'Jetty, ramp, pontoon and two stabilizing piles', Reference C21/486, Dated: 21 August 2021.
- Statement of Environmental Effects - Addition and Alteration to Existing Domestic Marine Facilities, 20 March 2023

### 1.1 Proposed Development:

It is understood that the proposed works involve the construction of a new jetty, ramp, pontoon and slip rails to the south of an existing boatshed. The construction of a single mooring pile to the south of the new jetty is also proposed.

It is further understood that the new jetty will be supported on five piles with the pontoon supported on two wider diameter piles installed to bedrock, and that the method of installation will not require removal of the soil to install, removal of groundwater and bulk excavation will not be required as part of the development works.

## 2. SITE FEATURES:

### 2.1. Site Description:

The site is irregular in shape and covers an area of approximately 1659m$^2$ in plan as referenced from the provided survey drawing. It is located on the low west side of Riverview Road within steeply west dipping topography. The elevation varies between a high of RL31.6m adjacent to the southeast corner and a low of RL0.7m near the west boundary of the site. It has north (combined), east and south boundaries of approximately 69.7m, 18.3m and 70.3m respectively as determined from the survey plan. The west boundary is irregular and defined by the mean high-water mark however is approximately 26.8m measured in a straight line.

The front of the site contains a steeply inclined driveway accessed from Riverview Road easement to the east and is partially supported by a retaining wall up to approximately 1.0m in height.

The site residence is accessed via a curved flagstone path at the base of the driveway and comprises a two-storey brick and timber structure with rear timber deck.

The rear (west) of the site is accessed via flagstone path to the north of the residence which leads down to the foreshore where a timber boatshed and existing sandstone boulder seawall is located. Timber retaining walls up to approximately 0.8m height support the slope above the pathway. The site is densely vegetated with numerous mature trees present both within the front and rear of the site.

An aerial view of the site and surrounding properties is provided in Photograph 1, obtained from NSW Government spatial data website SixMaps.


*Photograph 1: Aerial view of the site (outlined red) and immediate surrounds*

The site is bordered to the north, east, south and west by 169 Riverview Road, Riverview Road easement, 165 Riverview Road and Pittwater foreshore respectively.

No.169 contains a single storey timber and sandstone dwelling with an access driveway and front and rear gardens. The house structure is approximately 15.0m from the shared boundary. The property is at a similar level to the site immediately adjacent to the shared boundary and shares similar topography.

No.165 contains a three-storey residential metal dwelling with access driveway and front and rear gardens. The house structure is approximately 2.5m from the shared boundary. The property is at a similar level to the site immediately adjacent to the shared boundary and shares similar topography.

### 2.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet indicates that the site is underlain by Newport Formation (Upper Narrabeen Group) rock which is of middle Triassic Age. The Newport Formation typically comprises interbedded laminite, shale and quartz to lithic quartz sandstones and pink clay pellet sandstones.

Narrabeen Group rocks are dominated by shales and thin siltstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise interbedded shale and siltstone beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases large space convex joints. The shale often forms deeply weathered silty clay soil profiles (medium to high plasticity) with thin silty colluvial cover. An extract of the relevant geological sheet is provided as Extract 1.


*Extract 1: Extract from the Sydney Series 9130 Geology Sheet with the site (outlined and circled red).*

### 2.3 Acid Sulphate Soils

Reference to the relevant Pittwater LEP Acid Sulphate Soils (ASS) map ASS_015 indicates that the east of the site lies within land classified as Class 5 Acid Sulphate Soils risk. The foreshore is classified as Class 1 ASS risk and is shown on the ASS Soils Map _015, an extract of which is provided as Extract 2.


*Extract 2: Extract from the Pittwater LEP ASS Soils Map_015 with site indicated (outlined red)*

## 3. FIELD WORK:

### 3.1. Methods:

The fieldwork comprised geotechnical inspection/mapping of the site which was undertaken by a Senior Engineering Geologist on the 11 January 2021.

The geotechnical mapping comprised a visual inspection of the site and adjacent properties to assess potential geotechnical issues relevant to the proposed development. It involved a photographic record of site conditions as well as geological/geomorphological mapping of the site and adjacent land with examination of soil slopes, rock outcrops, vegetation and existing structures to assess the stability of the site.

Explanatory notes are included in Appendix: 1. Mapping information is shown in Figure: 1.

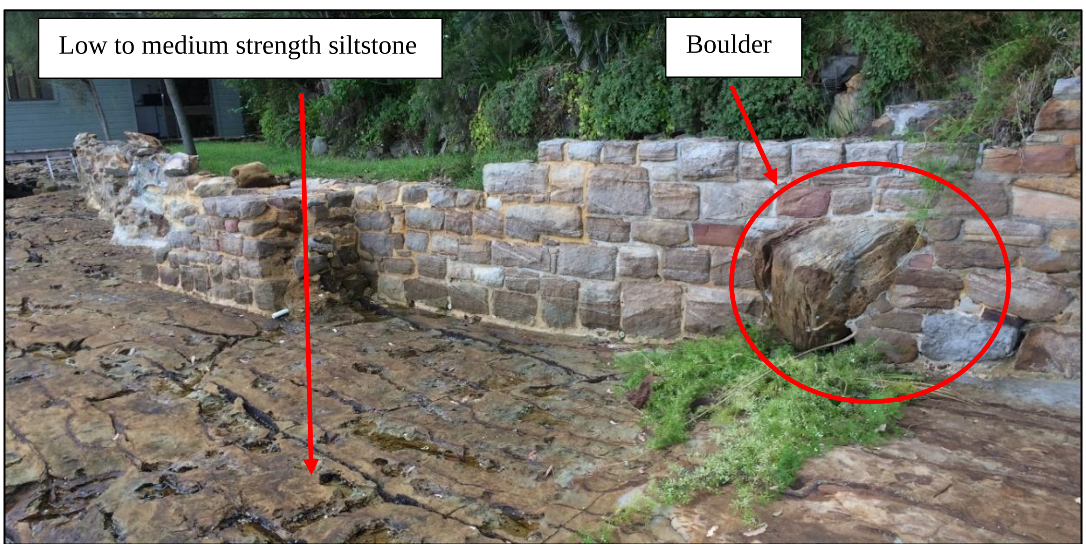
**3.2 Anticipated Ground Conditions:**

Based on the field inspection (See Photograph 2) it is anticipated that the ground conditions will comprise recent Quaternary sediments (silt, sand and clay) overlying bedrock which may vary in strength and characteristics.

**3.3 Site Stability:**

No.167 Riverview Road lies to the west of the carriageway which comprises a gently north dipping asphalt pavement with concrete curbing and appears in good condition where it passes the site. A sandstone rock cutting is present on the east side of Riverview Road near the site and appeared stable with no signs of potential movement observed.

Bedrock outcrops were observed within the roadway cutting however the outcrops are thought to represent strata of the Hawkesbury Sandstone and unlikely representative of the geological conditions underlying the site. What is thought to represent sandstone boulders originating from the Hawkesbury Sandstone upslope were observed within the rear garden of the property however no indications of likely movement or mechanism to induce movement were identified. In situ bedrock was observed within the rear of the property adjacent to the foreshore and comprised low to medium strength siltstone/sandstone and is shown in Photograph 2. Additionally, a boulder was also noted within a low retaining wall at the base of the slope.




*Photograph 2: View looking broadly east at the base of the slope within the west of the site.*

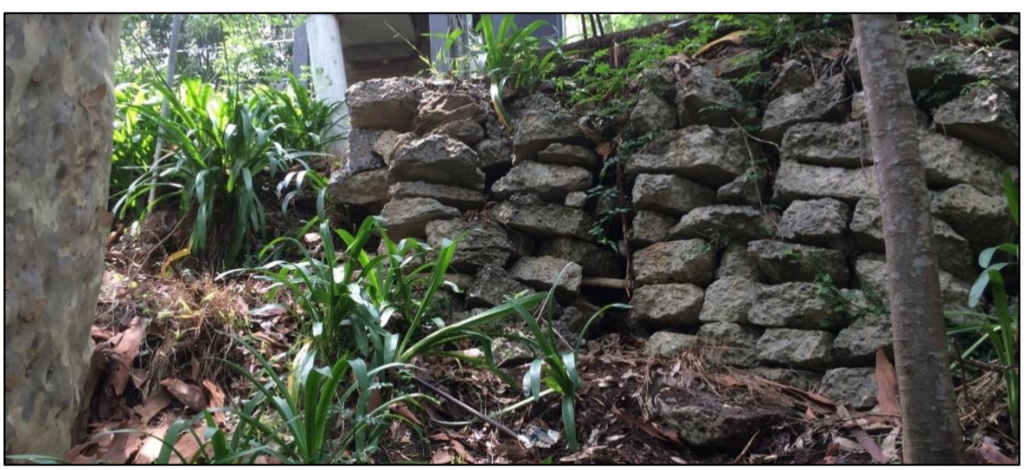
Signs of instability (significant cracking in the pavement/brickwork/render etc.) where not observed within the roadway or within the site residence however some rotation of the low wooden retaining walls was observed (see Photograph 3). Brick columns supporting the rear deck also appeared to be in good condition (See Photograph 4).

*Photograph 3: View of slight rotation of retaining wall*

*Photograph 4: View of the deck support columns*

In addition, some displacement of a metal handrail next to the flagstone path within the rear of the site was observed. It is considered that the movement observed in the wooden retaining wall and handrail is likely to be the result of inadequate construction techniques or near surface creep movements and do not represent a deep-seated stability issue.

The retaining wall adjacent to the site access appeared to have been constructed from stacked, unmortared concrete blocks/fragments. The retaining wall did not appear to be engineered and will likely require replacement/remediation to provide longevity of support to the access driveway.



*Photograph 5: View of the retaining wall near the access driveway looking broadly east*

Signs of hummocky ground, back scars, tilting trees or any other signs of potential instability were not observed in the rear garden of the property.

The properties to the north and south of the site (No.169 and No.165 respectively) did not appear to be displaying any signs of distress, however observations were limited due to site conditions.

## 4. COMMENTS:

### 4.1 Ground Model

Based on the exposed conditions at the foreshore it is anticipated that the ground conditions that will be encountered during construction of the new support piers will comprise Quaternary sediments underlain by variable strength bedrock.

### 4.2. Geotechnical Assessment:

A credible landslip hazard was not identified during the assessment therefore landslip hazard is considered 'Acceptable' however minor signs of potential creep movements likely due to lightweight structures founded at a shallow depth within colluvial soils were observed.

It is understood piers will support the new domestic marine facilities (formed above the surface) which are proposed to be extended to bedrock. It is further understood that the method of pier installation will not result in the removal of any soil which may overlie bedrock or lowering of the groundwater table.

Based on the proposed works and location, rock excavation equipment is not envisaged therefore, vibration monitoring will not be required.

An ASS Hazard zone 1 lies within the west of the site associated with Pittwater foreshore and sediments below the water table. Based on the scope of the proposed works, lowering of the water table is not envisaged and excavation of AS bearing soils will not occur due to the method of pier installation. In accordance with Pittwater LEP 2014, (Section 7.1, Section 6, (b)), and in line with the requirements of the NSW Government ASS Manual, an ASS Management Plan (ASSMP) in association with the Development Consent is not required for the works.

### 4.3. Site Specific Risk Assessment:

Based on our site mapping, no credible geological/geotechnical landslip hazards were identified which need to be considered in relation to the existing site and proposed development works. As such a risk assessment is not required as the works are considered separate from, and not affected by a geotechnical landslip hazard.

### 4.4. Conditions Relating to Design and Construction Monitoring:

To comply with Councils conditions and to enable us to complete Forms: 2b and 3 required 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 the structural design drawings for compliance with the recommendations of this report prior to construction (Required for issue of Council Form 3)
2. Inspect completed works to ensure construction activity has not created any new hazards. (Required for issue of Council Form 3)

The client and builder should make themselves familiar with the Councils Geotechnical Policy and the requirements spelled out in this report for inspections during the construction phase. Crozier Geotechnical Consultants <u>cannot</u> sign Form: 3 of the Policy if it has not been called to site to undertake the required inspections.

### 4.5. Design Life of Structure:

We have interpreted the design life requirements specified within Council's Risk Management Policy to refer to structural elements designed to support the existing structures, 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 instability,
- maintenance of trees/vegetation on this and adjacent properties.

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

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

- The conditions on the block don't change from those present at the time this report was prepared, except for the changes due to this development.
- There is no change to the property due to an extraordinary event external to this site
- The property is maintained in good order and in accordance with the guidelines set out in;
  a) CSIRO sheet BTF 18
  b) Australian Geomechanics "Landslide Risk Management" Volume 42, March 2007.
  c) AS 2870 – 2011, Australian Standard for Residential Slabs and Footings

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to relevant professionals (e.g. structural engineer, geotechnical engineer or Council). Where the property owner has any lack of understanding or concerns about the implementation of any component of the maintenance and inspection program the relevant engineer should be contacted for advice or to complete the component. It is assumed that Council will control development on neighbouring properties, carry out regular inspections and maintenance of the road verge, stormwater systems and large trees on public land adjacent to the site so as to ensure that stability conditions do not deteriorate with potential increase in risk level to the site.

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

## 5. CONCLUSION:

The site is partially located within an ASS Risk Zone 1, however the proposed works including the method of pier installation is such that excavation and exposure of potential ASS will not occur therefore an ASS Management Plan is not required, and the proposed works are in compliance with Pittwater LEP 2014.

No credible landslip hazards were identified, and no new landslip hazards will be created by the development works.

The proposed works are considered suitable for the site and may be completed with negligible impact to existing nearby structures within the site or on neighbouring properties provided the recommendations of this report and any future geotechnical directive are implemented.

The recommendations and conclusions in this report are based on a site walkover. However, the results of the assessment provide a reasonable basis for the Development Application and preliminary design.

The risks associated with the proposed development can be maintained within 'Acceptable' risk management criteria of the Councils Risk Management Policy 2001 with negligible impact to neighbouring properties or structures provided the recommendations of this report and any future geotechnical directive are implemented. As such the site is considered suitable for the proposed construction works provided that the recommendations outlined in this report are followed.

Kieron Nicholson

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

**6. REFERENCES:**


1. Australian Geomechanics Society 2007, "Landslide Risk Assessment and Management", Australian Geomechanics Journal Vol. 42, No 1, March 2007.
2. Geological Society Engineering Group Working Party 1972, "The preparation of maps and plans in terms of engineering geology" Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. E. Hoek & J.W. Bray 1981, "Rock Slope Engineering" By The Institution of Mining and Metallurgy, London.
4. C. W. Fetter 1995, "Applied Hydrology" by Prentice Hall. V. Gardiner & R. Dackombe 1983, "Geomorphological Field Manual" by George Allen & Unwin.

# Appendix 1

CROZIER GEOTECHNICAL CONSULTANTS

Crozier Geotechnical Consultants ABN: 96 113 453 624
Unit 12/ 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Email: info@croziergeotech.com.au
Crozier Geotechnical Consultants, a division of PJC Geo-Engineering Pty Ltd

# NOTES RELATING TO THIS REPORT

**Introduction**

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

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

**Description and classification Methods**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Standard Penetration Tests

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

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

The test results are reported in the following form.

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

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

## Cone Penetrometer Testing and Interpretation

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

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

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

The information provided on the plotted results comprises: -

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

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

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

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

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

$Q_c$ = (12 to 18) $C_u$

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

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

## Dynamic Penetrometers

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

Two relatively similar tests are used.

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

## Laboratory Testing

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

## Borehole Logs

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

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

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

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

## Ground Water

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

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

## Engineering Reports

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

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

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

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

### Site Anomalies

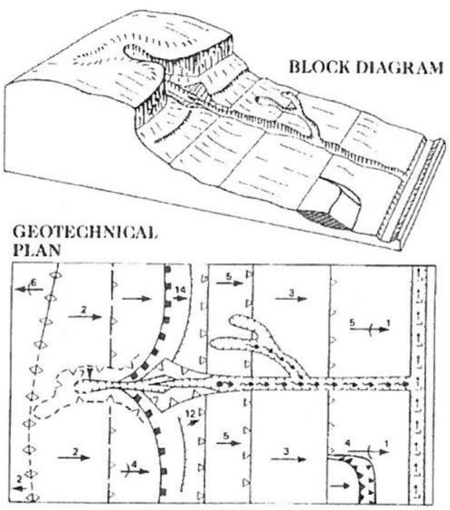
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some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

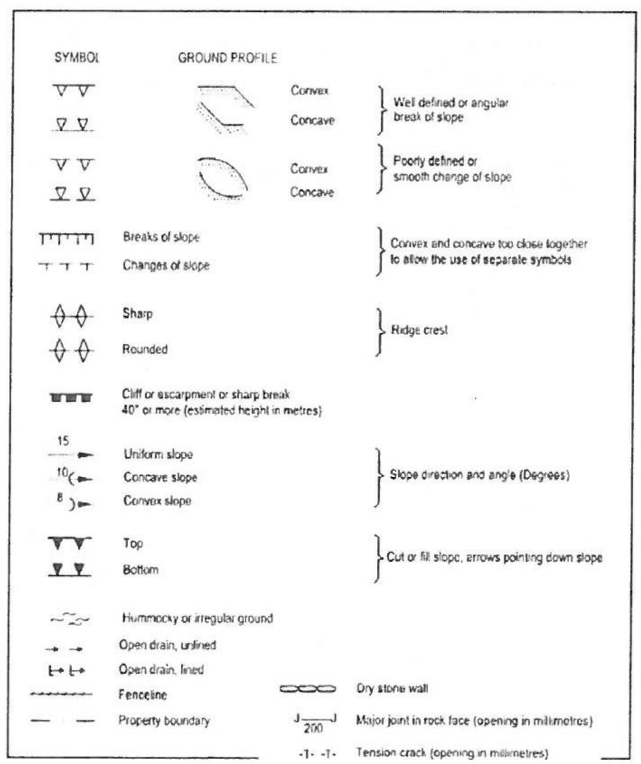
### Reproduction of Information for Contractual Purposes

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

### Site Inspection

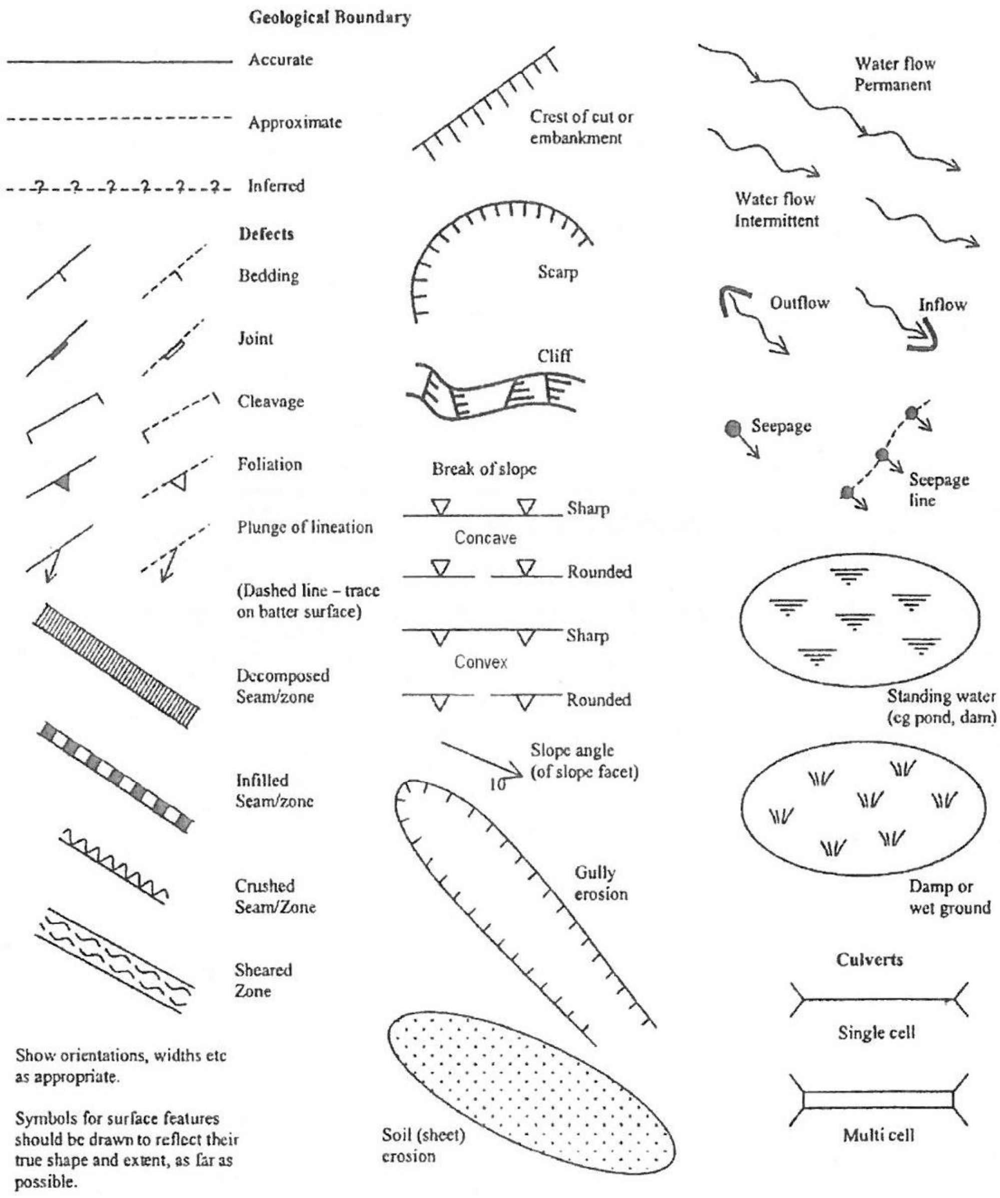
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.




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

## APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY




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

# Appendix 2

# APPENDIX A

## DEFINITION OF TERMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# APPENDIX C: LANDSLIDE RISK ASSESSMENT

# QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

## *QUALITATIVE MEASURES OF LIKELIHOOD*

| Approximate Annual Probability | | Implied Indicative Landslide Recurrence Interval | | Description | Descriptor | Level |
|---|---|---|---|---|---|---|
| **Indicative Value** | **Notional Boundary** | | | | | |
| $10^{-1}$ | $5 \times 10^{-2}$ | 10 years | 20 years | The event is expected to occur over the design life. | ALMOST CERTAIN | A |
| $10^{-2}$ | $5 \times 10^{-3}$ | 100 years | 200 years | The event will probably occur under adverse conditions over the design life. | LIKELY | B |
| $10^{-3}$ | $5 \times 10^{-4}$ | 1000 years | 2000 years | The event could occur under adverse conditions over the design life. | POSSIBLE | C |
| $10^{-4}$ | $5 \times 10^{-5}$ | 10,000 years | 20,000 years | The event might occur under very adverse circumstances over the design life. | UNLIKELY | D |
| $10^{-5}$ | $5 \times 10^{-6}$ | 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.