Site Investigation and
Slope Stability Assessment Report

DATE: 2nd of July, 2013

YOUR REF: N/A
OUR PROJECT JOB NUMBER: GEO116175-B

For
10 x Mackay
PO Box 11802
Mackay Caneland Qld 4740

SITE ADDRESS - Lot 8 on SP  121186 (No.15) Nunkeri Drive, North Mackay
TABLE OF CONTENTS

1.0 INTRODUCTION

2.0 SCOPE AND METHOD OF INVESTIGATIONS

2.1 Qualifications of Responsible Firm

3.0 PROPOSED DEVELOPMENT

4.0 GEOTECHNICAL SITE INVESTIGATION

4.1 Site Description
4.2 Field Work and Laboratory Testing
4.3 Subsurface Conditions
4.4 Groundwater
4.5 Site Classification

5.0 SLOPE STABILITY ASSESSMENT

5.1 Stability Assessment Findings
5.2 Hazard Assessment
5.3 Risk Assessment

6.0 RECOMMENDATIONS

6.1 House Design
6.2 Earthworks
6.3 Foundations
6.4 Drainage
6.5 Erosion Control and Landscaping

7.0 CONCLUSION

APPENDICES

Qualitative Terminology For Use in Assessing Risk to Property
Stability of Retaining Structures
Hillside Construction Guidelines
1.0 INTRODUCTION

This report represents the results of a geotechnical walk over assessment of stability investigation carried out by STA Consulting Engineers on the 18th of June, 2013 at Lot 8 on SP 121186 (No.15) Nunkeri Drive, North Mackay.

2.0 SCOPE AND METHOD OF INVESTIGATIONS

The aim of this report was undertake a soils investigation enabling a site classification in accordance with AS2870 and to assess the potential risk of slope instability or Landslide risk for the proposed residential development in it’s existing and post developed state.

The methodology incorporated by STA Consulting Engineers in order to determine the Site Classification and Landslide risk for this site was obtained incorporating the following criteria :-

- Guidelines developed by the Australian Geomechanics Society (AGS), Landslide Risk Management, Volume 42 No. 1, March 2007.
- Landslide Frequency Assessment in accordance with the report “A Method of Zoning Landslide Hazards”, prepared by MacGregor and Taylor 2001.
- A review of existing Hazard mapping (where available), aerial photographs and various published information to assist in identifying past activity.
- A Field investigation in order to determine the subsurface conditions and to provide a site classification in accordance with AS2870-2011.
- A walkover survey to record surface indicators of slope instability and to assess the ground slope/s and general site conditions.

- Site Classification Criteria :

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS 1289</td>
<td>Methods of testing soils for engineering purposes</td>
</tr>
<tr>
<td>AS 1726</td>
<td>Site Investigation Code</td>
</tr>
<tr>
<td>AS 2870</td>
<td>Classification of site in accordance with &quot;Residential Slab &amp; Footings&quot;</td>
</tr>
<tr>
<td>AS 3798</td>
<td>Guidelines on earthworks for commercial and residential development</td>
</tr>
</tbody>
</table>

2.1 Qualifications of Responsible Firm

This report is prepared by a Registered Professional Engineer of Queensland (RPEQ) specialising in geotechnical engineering.

3.0 PROPOSED DEVELOPMENT

It is understood the proposed development at Lot 8 on SP 121186 (No.15) Nunkeri Drive, North Mackay is to consist of a single and double storey, split levelled residential construction supported by slab on ground. The upper and lower slabs are separated by an engineered masonry block retaining wall. The external finish is to be rendered ‘Harditex’ cladding to the lower ground floor area and typical cladding to the remainder of the structure. The roof is a light weight sheet metal.

Earthworks are to involve cut and filling to the upper and lower pad areas in order to create level building platforms.
4.0 GEOTECHNICAL SITE INVESTIGATION

4.1 Site Description

At the time of the investigation the block was vacant. The vegetation consisted of grass and trees, the tested area had a gentle to steep slope and the drainage was moderate.

4.2 Fieldwork & Laboratory Testing

Three bore holes were undertaken across the site using a power auger drill rig mounted at the rear of a four wheel drive ute to a maximum depth of 2500 mm. Dynamic Cone Penetrometer (D.C.P) tests were also undertaken at the time of the site investigation.

The bore holes were drilled using solid flight augers fitted with a steel ‘V’ shaped bit or tungsten carbide bit. An authorised representative from STA Consulting Engineers set out the bore holes locations from existing site features, directed sampling and logged bore hole profiles. Engineering logs of the bore holes are presented in Section 3, together with Explanation Sheets defining the terms and symbols used in the preparation of the logs.

Representative samples of residual soil was collected for the purpose of Laboratory testing. These tests include the following:-

- Moisture Contents
- Liquid Limit (LL)
- Linear Shrinkage (LS)
- Shrink /Swell (Iss)

Results of the Laboratory tests are indicated under Section 3.0 Soil Profile and Laboratory Results.

4.3 Subsurface Conditions

Reference to the Australia 1 : 250,000 Geological Series (Mackay) Sheet SF 55-8 indicates that the site is predominately underlain by Microdiorite and Minor Hornfelsd sediments of the Tertiary Period.

The ground conditions encountered were generally as follows:-

- Bore Hole # 1 - a just moist and stiff gravelly silty clay, with fine to medium gravels becoming coarse with depth overlying a dry and moderately strong weathered rock. Test hole terminated due to refusal on to weathered rock at 2.5 metres.

- Bore Hole # 2 - a just moist and medium dense silty sand with some clay fines throughout, fine to medium gravels observed at approximately 1.0 metre, becoming medium dense to dense overlying a dry and moderately strong weathered rock. Test hole terminated due to refusal on to weathered rock at 1.8 metres.

- Bore Hole # 3 - a just moist and medium dense to dense silty sand with fine to medium gravels observed at approximately 0.5 metres overlying a dry and moderately strong weathered rock. Test hole terminated due to refusal on to weathered rock at 1.1 metres.

Note: There is a danger that by simplifying the geological conditions as described above, small-scale variations that may have significant engineering implications can be overlooked. Where specific information is required, the reader should in all instances refer to the bore hole logs in Section 3 of this report.

Where the drill rig was unable to penetrate the rock, it is anticipated that the bearing capacity of the rock is in excess of 400 kPa.

4.4 Groundwater

Groundwater was not identified at the time of the subsurface investigation. However seepage is likely occur at the interface of the natural soils and weathered rock profile after prolonged rainfall events.
4.5 Site Classification

After assessing the laboratory test results, on site conditions and surrounding conditions in accordance with AS 2870. This site has been classified: Class “P”.

This site has been classified as a Class "P" due to the following :-

- The abnormal moisture and disturbed ground caused by the removal of a large tree within the area of the proposed building footprint and the potential influence on the proposed foundation performance.

This report has been classified as a Class “P” due to reasons described, however the site characteristics are similar to that of a Class “M”.

5.0 SLOPE STABILITY ASSESSMENT

5.1 Stability Walkover Assessment Findings

As requested a visual walk over inspection for assessment of stability was undertaken at Lot 8 on SP 121186 (No.15) Nunkerdi Drive, North Mackay.

The site under review was identified as being a residential allotment regionally located on an elevated hill surrounded by alluvial plains approximately 3.5 kilometres North of the Mackay town centre. The allotment is 854 square metres in area and is positioned at the end of a cul-de-sac overlooking sporting fields to the North, North West.

At the time of the walkover assessment, the following observations were made :-

- Topographically the site is positioned on the lower slopes of the main hill, the crest being approximately 250 metres to the South of the site.
- The natural land shape is considered predominately planar.
- The existing slope rises from the road at 1 to 2 degrees for the first 10 metres into the site to where the grade increases to 15 degrees for as further 10 metres. The site again then levels out on a small bench area approximately 8 to 10 metres wide. To the rear of the bench area the slope increases again to 10 to 12 degrees up to the rear boundary line. This grade continues another 12 to 15 metres into the site at the rear, to where a series of terraced rock/ boulder type retaining walls have been constructed to support filling undertaken for the house platform to the rear.
- Vegetation on and surrounding the site consists of grasses and trees. Indicators of past instability during the life span of this vegetation was not clearly evident. This may include patterns of trees leaning on angles or trees exhibiting basal curvature which may be indicative of hillside creep.
- The site is surrounded by a mix of existing residential construction including slab on ground, split level and pole home type construction. From visual inspection only, all appear to be performing as intended.
- Hummocky or bulging soils were not identified on or at the base of the slope.
- No Tension cracks were observed on or across the slope.
- The street and that above are both kerb and channelled.
- The site is connected to the mains sewer and storm water networks
- A storm water main was observed along the rear boundary of the site.
- Indicators of instability from surrounding man made structures were not identified. This includes but is not limited to signs of rotation or stress in the existing light poles, swimming pools, fence posts the performance of existing structures etc....
- STA Consulting Engineers is not aware of any slope stability hazard map for this local area, therefore we have been unable to compare our interpretation of our findings with that of others.
5.2 Hazard Identification

A Hazard is defined as a condition with the potential for causing an undesirable consequence (the landslide).

The hazard assessment given in this report is consistent with the procedures outlined in the report, “A Method of Zoning Landslide Hazards” by MacGregor and Taylor, 2001. The following major site features have been considered in determining a likelihood estimate or Frequency Analysis in turn, the potential Hazard of the site in order of undertaking the final risk assessment for the proposed building zone and immediate surrounds:

- The Natural Slope Angle
- Local Area Geology
- Concentration of Surface Water
- Evidence of Past Forms of Instability
- Material Strength
- Evidence of Groundwater

From the results of studies undertaken by SMEC in similar terrain a correlation between relative frequency and potential Hazard Rating has been determined as presented in the following table:

<table>
<thead>
<tr>
<th>RELATIVE FREQUENCY</th>
<th>HAZARD RATING</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 6.0</td>
<td>VH (Very High Hazard)</td>
<td>The event is expected to occur.</td>
</tr>
<tr>
<td>2.0 - 6.0</td>
<td>H (High Hazard)</td>
<td>The event will probably occur under adverse conditions.</td>
</tr>
<tr>
<td>0.6 - 2.0</td>
<td>M (Moderate Hazard)</td>
<td>The event could occur under adverse conditions.</td>
</tr>
<tr>
<td>0.2 - 0.6</td>
<td>L (Low Hazard)</td>
<td>The event might occur under very adverse conditions.</td>
</tr>
<tr>
<td>&lt; 0.2</td>
<td>VL (Very Low Hazard)</td>
<td>The event is conceivable but only under exceptional circumstances.</td>
</tr>
</tbody>
</table>

We have completed a Landslide Frequency Analysis and as an opinion, the hazard of such is provisionally considered as being ‘Low’.

5.3 Risk Assessment

Reviewing the intended development for this site, the elements considered within the risk assessment are as follows:

- The intended/proposed buildings and associated out buildings.
- Persons or Occupants on site.

Taking into consideration the potential landslide hazard for the property incorporating the Guidelines developed by the Australian Geomechanics Society (AGS), Landslide Risk Management, Volume 42 No. 1, March 2007 and the potential impacts to persons and or property within or directly adjoining the boundaries of the area assessed, based on our findings the final risk level determined for this site is considered ‘Low’.

The residual risk level given is conditional on the risk mitigation measures outlined within this report being fully implemented and maintained for the expected life of the structure.

The potential implications for the associated risk level are outlined within the table below:

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>VH (Very High Risk)</td>
<td>Extensive investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.</td>
</tr>
<tr>
<td>H (High Risk)</td>
<td>Detailed investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.</td>
</tr>
<tr>
<td>M (Moderate Risk)</td>
<td>May be acceptable provided treatment plan is implemented to maintain or reduce risk levels.</td>
</tr>
<tr>
<td>L (Low Risk)</td>
<td>Can be accepted. Treatment to maintain or reduce risk levels should be defined.</td>
</tr>
<tr>
<td>VL (Very Low Risk)</td>
<td>Accepted. Managed by routine procedures.</td>
</tr>
</tbody>
</table>

Table 2. Implications of Risk Level Classification Australian Geomechanics Society (AGS 2007).
6.0 RECOMMENDATIONS & RISK MITIGATION MEASURES

The area of the proposed structure has been defined as a Low Risk providing the following recommendations are implemented, managed and maintained for the expected life of the structure :

6.1 House Design

As indicated by the client, the proposed development is to consist of a single and double storey, split levelled residential construction supported by slab on ground. The upper and lower slabs are separated by an engineered masonry block retaining wall. The external finish is to be rendered ‘Harditex’ cladding to the lower ground floor area and typical cladding to the remainder of the structure. The roof is a light weight sheet metal.

Earthworks are to involve cut and filling to the upper and lower pad areas in order to create level building platforms.

- STA Consulting Engineers are satisfied that a construction type as described above would be considered acceptable for this site providing the following recommendations outlined are implemented and maintained for the life of the structure.

6.2 Earthworks

- Retain the existing natural contours wherever possible.
- Trees removed from the building pad area, the voids created by their removal, must be excavated, back filled and compacted with suitable material. All fill is to be placed in a controlled manner, benching of the natural ground to assist in the placing of the fill and to key the fill to the dense/stiff ground is to be carried out in accordance with A.S. 3798.
- Cuts 
  - Minimise depth.
  - Limit the extent of site cutting required.
  - Site cuts over 1.5 metres are to be benched or terraced rather than maintaining a single large cut face.
  - Support cut batters with engineered retaining walls or profile to an appropriate slope. For this site, exposed cut batters are to be profiled no greater than 1V : 2H.
  - Where site cut for upper platform area encroaches closer than 3.0 metres from the rear boundary, the cut face is to be supported with and engineered retaining wall rather than maintaining an angled batter.
  - Spoon drains MUST be installed immediately upslope of all cut batters including those retained to capture and divert upslope waters to a suitable outflow. All spoon drains must be maintained for the life of the structure.
- Fills 
  - Minimise height.
  - Strip vegetation and topsoil and key/bench the natural slope prior to filling.
  - Use clean fill materials and compact to engineering standards.
  - Batter to an appropriate slope or support with engineered retaining walls. For this site, exposed fill batters are to be profiled no greater than 1V : 2H.
  - The finished platform must not slope towards the filled embankment which will allow water to flow/cascade over the exposed face. Ponding water on the platform must also be avoided. It is recommended that the platform slope into the toe of the cut where a spoon drain is to be installed to collect and divert water to a suitable outflow. All spoon drains must be maintained for the life of the structure.
  - Re-vegetate exposed areas with shrubs, grasses and ground covers including cut and filled batters, preferably with plants indigenous to the local area.
  - Provide surface drainage and appropriate subsurface drainage.
  - All earthworks to be carried out in accordance with the requirements of Australian Standard AS 3798 - 2007 Guidelines on Earthworks for Commercial and Residential Developments.
6.3 Foundations

- Taking into consideration the intended earthworks on this site, footings/foundations are to be keyed to the natural weathered rock profile around the entire perimeter of the proposed construction.
- On-site foundation inspections including footing, slab & retaining walls must be undertaken by a suitably qualified and experienced Geotechnical Engineer.

6.4 Drainage

**Surface**

- Provide drains at the top of all cut and fill slopes, including those retained.
- Discharge to the rear of the site below and well clear of the nominated building envelope.
- Provide and maintain general falls within drains to prevent blockage by siltation.
- Line spoon drains to minimise the infiltration of surface water and make drains flexible where possible.

**Subsurface**

- Provide filters around all subsurface drainage.
- Provide appropriate drainage behind ALL retaining structures.
- Use flexible pipelines with access for long-term maintenance.
- Prevent the inflow of surface water.

**Septic, Sullage and Rainwater tanks**

- The site is connected to the mains sewer and storm water networks. Due to the limited size of the allotment, rubble drains etc. would not be considered appropriate for this site.
- Storage tanks should be watertight and adequately founded. Overflows are to be piped to a suitable outflow. Do not allow to simply dump onto ground surface at base of storage tanks.

6.5 Erosion Control & Landscape

- Control erosion as this may lead to instability.
- Re-vegetate cleared areas with grasses, ground covers and shrubs, preferably with plants indigenous to the local area.
7.0 CONCLUSION

In conclusion, it is our considered opinion, from a geotechnical viewpoint that the site is suitable for the proposed residence that had been indicated by the client at the time of commissioning this report.

This recommendation is subject to the implementation of the measures specified within this report. On site foundation inspections including footing, slab & retaining walls must be undertaken by a suitably qualified and experienced Geotechnical Engineer.

Thank you for entrusting us with this work, if we can be of any further assistance in this matter, please let us know.

For and on behalf of
STA Consulting Engineers Pty Ltd

Justin J Williamson
A.D. Civil Eng. Cert. Mining Eng

Angelo Iancu
B.Sc., (Civil) R.P.E.Q # 4425

Digitally signed by Angelo Iancu
DN: cn=Angelo Iancu, o=STA Consulting Engineers, ou=Engineering Services, email=angelo.iancu@staconsulting.com.au, c=AU
Date: 2013.07.03 12:35:24 +10'00'
APPENDICES
APPENDIX A

Bore hole results
### Bore Log Sheet

#### Bore Hole #1
- **Client:** 10x Mackay
- **Depth:** 2.5m

**SOIL DESCRIPTION**
- **Date Drilled:** 18/6/2013
- **Drill Method:** Power Auger

**Terms:**
- D.C.P.-: Dynamic Cone Penetrometer
- N’q:-: Allowable Bearing Capacity (kPa)
- PP:-: Pocket Penetrometer Strength (kPa)
- U.T.P.-: Unable to Penetrate

**Note:** kPa value is allowable bearing pressure calculated in accordance with paper 'Determination of allowable bearing pressure under small structures' by M.J Stockwell (June 1977)

#### Bore Hole #2
- **Depth:** 1.8m

**SOIL DESCRIPTION**
- **Drill Method:** Power Auger

#### Bore Hole #3
- **Depth:** 1.1m

**SOIL DESCRIPTION**
- **Drill Method:** Power Auger
Appendix A - Laboratory Results, Site Identification and Wind Assessment

Site Identification

Test Methods: AS1289 3.1.2 (liquid limit), 3.4.1(linear shrinkage), 7.1.1(shrink-swell)

Site Classification Symbols: Y's Range / Value
- 'A': 0 < Ys
- 'B': 0 < Ys ≤ 20
- 'M': 20 < Ys ≤ 40
- 'H1': 40 < Ys ≤ 60
- 'H2': 60 < Ys ≤ 75
- 'E': Ys > 75
- 'P': N/A
- 'O': N/A

Classification by characteristic surface movement as per AS2780-2011

- 'A': Most sand and rock sites with little or no ground movement from moisture changes.
- 'B': Slightly reactive clay sites, which may experience only slight ground movement from moisture changes.
- 'M': Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes.
- 'H1': Highly reactive clay sites, which may experience high ground movement from moisture changes.
- 'H2': Highly reactive clay sites, which may experience very high ground movement from moisture changes.
- 'E': Extremely reactive clay sites, which may experience extreme ground movement from moisture changes.
- 'P': Problem sites which generally have soils associated with uncontrolled fill, abnormal moisture conditions (trees), soft or collapsing soils, landslip etc.

Laboratory Test Results

Sample Location: B.H # 1
Depth of Sample: 600mm
Liquid Limit: 45.0%
Linear Shrinkage: 11.0%
Iss: 2.1%

Calculated Y's Value: 27mm
Y's - characteristic surface movement determined on soil properties only. does NOT include the effects of trees (refer Design Y's Range)

Calculated Y't Value: 7mm
Y't - the calculated potential surface movement due to the tree induced suction change in addition to the normal design suction change.

Design Y's Range

Y's + Yt: 30mm to 40mm

WIND CLASSIFICATION

An authorised representative of STA Consulting Engineers has visited the above site and classified the area by using AS 4055.

WIND LOADING ASSESSMENT

C3

Client
10 x Mackay
PO Box 11802 Mackay Caneland Qld 4740

Site Address
Lot 8 (No.15) Nunkeri Drive, North Mackay
APPENDIX B

Landslide Frequency Analysis
GEOLOGY: Microdiorite and Minor Hornfelsd Sediments

Location: Lot 8 on SP 121186 (No.15) Nunkeri Drive, North Mackay

1. Basic Frequency 0.004

2. Slope Angle

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5 degrees</td>
<td>L</td>
<td>0.1</td>
</tr>
<tr>
<td>Between 5 and 15 degrees</td>
<td>M</td>
<td>0.5</td>
</tr>
<tr>
<td>Between 15 and 30 degrees</td>
<td>M</td>
<td>0.8</td>
</tr>
<tr>
<td>Between 30 and 45 degrees</td>
<td>H</td>
<td>1.2</td>
</tr>
<tr>
<td>More than 45 degrees</td>
<td>M</td>
<td>0.8</td>
</tr>
</tbody>
</table>

3. Slope Shape

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest or ridge</td>
<td>L</td>
<td>0.7</td>
</tr>
<tr>
<td>Planar</td>
<td>M</td>
<td>0.9</td>
</tr>
<tr>
<td>Convex</td>
<td>M</td>
<td>0.9</td>
</tr>
<tr>
<td>Concave</td>
<td>H</td>
<td>1.5</td>
</tr>
</tbody>
</table>

4. Area Geology

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>x Volcanic Rock</td>
<td>H</td>
<td>1.1</td>
</tr>
<tr>
<td>Sedimentary Rock</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>Low Grade Metamorphic rock</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>High Grade Metamorphic rock</td>
<td>L</td>
<td>0.9</td>
</tr>
<tr>
<td>Granite rock</td>
<td>M</td>
<td>1</td>
</tr>
</tbody>
</table>

5. Material Strength

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock at Surface</td>
<td>VL</td>
<td>0.1</td>
</tr>
<tr>
<td>Residual Soil &lt; 1m deep</td>
<td>L</td>
<td>0.5</td>
</tr>
<tr>
<td>Residual Soil &gt; 3m deep</td>
<td>H</td>
<td>1.5</td>
</tr>
<tr>
<td>Colluvial Soil &lt; 1m deep</td>
<td>H</td>
<td>1.5</td>
</tr>
<tr>
<td>Colluvial Soil 1 - 3m deep</td>
<td>VH</td>
<td>2</td>
</tr>
<tr>
<td>Colluvial Soil &gt; 3m deep</td>
<td>VH</td>
<td>4</td>
</tr>
</tbody>
</table>

6. Concentration of Surface water

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge</td>
<td>L</td>
<td>0.7</td>
</tr>
<tr>
<td>Crest</td>
<td>M</td>
<td>0.8</td>
</tr>
<tr>
<td>Upper Slope</td>
<td>M</td>
<td>0.9</td>
</tr>
<tr>
<td>Mid Slope</td>
<td>H</td>
<td>1.2</td>
</tr>
<tr>
<td>x Lower Slope</td>
<td>H</td>
<td>1.5</td>
</tr>
</tbody>
</table>

7. Evidence of Groundwater

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>None Apparent</td>
<td>L</td>
<td>0.7</td>
</tr>
<tr>
<td>Minor Moistness</td>
<td>M</td>
<td>0.9</td>
</tr>
<tr>
<td>Generally Wet</td>
<td>H</td>
<td>1.5</td>
</tr>
<tr>
<td>Subsurface Springs</td>
<td>VH</td>
<td>3</td>
</tr>
</tbody>
</table>

8. Evidence of Instability

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>x No sign of instability</td>
<td>L</td>
<td>0.8</td>
</tr>
<tr>
<td>Minor Irregularity</td>
<td>VH</td>
<td>2</td>
</tr>
<tr>
<td>Major Irregularity</td>
<td>VH</td>
<td>5</td>
</tr>
<tr>
<td>Active Instability</td>
<td>VH</td>
<td>10</td>
</tr>
</tbody>
</table>

Summary

<table>
<thead>
<tr>
<th>Area</th>
<th>Level</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Slope Angle</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>3 Slope Shape</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>4 Area Geology</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>5 Material Strength</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>6 Concentration of surface water</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>7 Evidence of ground water</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>8 Evidence of Instability</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>9 Relative Frequency (2x3x4x5x6x7x8)</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Relative Frequency = 0.5

Area Frequency = 0.002

Hazard Rating = Low

*The numerical factors allocation to these site features are based on judgement and experience*
APPENDIX C

Site Photographs
Figure 1. View South towards site from road.

Figure 2. View South West across site.
Figure 3. View West across bench area.

Figure 4. View along rear boundary area.
APPENDIX D

Site Maps
Figure 5. Google Image.
Figure 7. Geological Map.

- **Md**: Microdiorite, minor hornfelsed sediments
- **Campwyn Beds**: D–Cc, intermediate, basic and acid volcanics, siltstone, sandstone, conglomerate, limestone
- **Qd**: Dune deposits: quartz rich sand, minor lithic sand
- **Qa**: Sand, silt, mud, clay, gravel
- **Qs**: Soil, minor alluvium
Figure 8. Siting and Contour Plan.
Figure 9. Elevations of proposed construction.
APPENDIX E

Qualitative Terminology for use in Assessing Risk to Property
(Appendix C AGS2007)
**QUALITATIVE MEASURES OF LIKELIHOOD**

<table>
<thead>
<tr>
<th>Approximate Annual Probability</th>
<th>Implied Indicative Landslide Recurrence Interval</th>
<th>Description</th>
<th>Descriptor</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicative Value</td>
<td>Notional Boundary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>$5 \times 10^4$</td>
<td>10 years</td>
<td>20 years</td>
<td>ALMOST CERTAIN A</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>$5 \times 10^3$</td>
<td>100 years</td>
<td>200 years</td>
<td>LIKELY B</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>$5 \times 10^4$</td>
<td>1000 years</td>
<td>2000 years</td>
<td>POSSIBLE C</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>$5 \times 10^5$</td>
<td>10,000 years</td>
<td>20,000 years</td>
<td>UNLIKELY D</td>
</tr>
<tr>
<td>$10^{-5}$</td>
<td>$5 \times 10^6$</td>
<td>100,000 years</td>
<td>200,000 years</td>
<td>RARE E</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>$5 \times 10^7$</td>
<td>1,000,000 years</td>
<td>2,000,000 years</td>
<td>BARELY CREDIBLE F</td>
</tr>
</tbody>
</table>

Notes: (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**

<table>
<thead>
<tr>
<th>Approximate Cost of Damage</th>
<th>Description</th>
<th>Descriptor</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicative Value</td>
<td>Notional Boundary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200%</td>
<td>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.</td>
<td>CATASTROPHIC</td>
<td>1</td>
</tr>
<tr>
<td>60%</td>
<td>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.</td>
<td>MAJOR</td>
<td>2</td>
</tr>
<tr>
<td>20%</td>
<td>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.</td>
<td>MEDIUM</td>
<td>3</td>
</tr>
<tr>
<td>5%</td>
<td>Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.</td>
<td>MINOR</td>
<td>4</td>
</tr>
<tr>
<td>0.5%</td>
<td>Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%). See Risk Matrix.)</td>
<td>INsignificant</td>
<td>5</td>
</tr>
</tbody>
</table>

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.
PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

<table>
<thead>
<tr>
<th>LIKELIHOOD</th>
<th>CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)</th>
<th>1: CATASTROPHIC 200%</th>
<th>2: MAJOR 60%</th>
<th>3: MEDIUM 20%</th>
<th>4: MINOR 5%</th>
<th>5: INSIGNIFICANT 0.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - ALMOST CERTAIN</td>
<td>Indicative Value of Approximate Annual Probability</td>
<td>VH</td>
<td>VH</td>
<td>VH</td>
<td>H</td>
<td>M or L (5)</td>
</tr>
<tr>
<td>B - LIKELY</td>
<td>10^{-1}</td>
<td>VH</td>
<td>VH</td>
<td>H</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>C - POSSIBLE</td>
<td>10^{-2}</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>VL</td>
</tr>
<tr>
<td>D - UNLIKELY</td>
<td>10^{-3}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E - RARE</td>
<td>10^{-4}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F - BARELY CREDIBLE</td>
<td>10^{-5}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
(5) For Cell E5, 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

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Example Implications (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VH</td>
<td>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.</td>
</tr>
<tr>
<td>H</td>
<td>Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practical.</td>
</tr>
<tr>
<td>M</td>
<td>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 practical.</td>
</tr>
<tr>
<td>L</td>
<td>Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.</td>
</tr>
<tr>
<td>VL</td>
<td>Acceptable. Manage by normal slope maintenance procedures.</td>
</tr>
</tbody>
</table>

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.
AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as "a measure of the probability and severity of an adverse effect to health, property, or the environment." This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Annual Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Certain</td>
<td>1:10</td>
</tr>
<tr>
<td>Likely</td>
<td>1:100</td>
</tr>
<tr>
<td>Possible</td>
<td>1:1,000</td>
</tr>
<tr>
<td>Unlikely</td>
<td>1:10,000</td>
</tr>
<tr>
<td>Rare</td>
<td>1:100,000</td>
</tr>
<tr>
<td>Barely credible</td>
<td>1:1,000,000</td>
</tr>
</tbody>
</table>

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

<table>
<thead>
<tr>
<th>Qualitative Risk</th>
<th>Significance - Geotechnical engineering requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>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 the value of the property.</td>
</tr>
<tr>
<td>High</td>
<td>Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.</td>
</tr>
<tr>
<td>Moderate</td>
<td>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 possible.</td>
</tr>
<tr>
<td>Low</td>
<td>Usually acceptable to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.</td>
</tr>
<tr>
<td>Very Low</td>
<td>Acceptable. Manage by normal slope maintenance procedures.</td>
</tr>
</tbody>
</table>

172
Australian Geomechanics Vol 42 No 1 March 2007
Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in, we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are aversive to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to life also stipulate a tolerable risk to people. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

<table>
<thead>
<tr>
<th>Risk (deaths per participant per year)</th>
<th>Activity/Event Leading to Death (NSW data unless noted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1,000</td>
<td>Deep sea fishing (UK)</td>
</tr>
<tr>
<td>1:1,000 to 1:10,000</td>
<td>Motor cycling, horse riding, ultra-light flying (Canada)</td>
</tr>
<tr>
<td>1:2,000</td>
<td>Motor vehicle use</td>
</tr>
<tr>
<td>1:3,000</td>
<td>Fall</td>
</tr>
<tr>
<td>1:7,000</td>
<td>Drowning</td>
</tr>
<tr>
<td>1:160,000</td>
<td>Fire/burn</td>
</tr>
<tr>
<td>1:660,000</td>
<td>Choking on food</td>
</tr>
<tr>
<td>1:1,000,000</td>
<td>Scheduled airlines (Canada)</td>
</tr>
<tr>
<td>1:2,300,000</td>
<td>Train travel</td>
</tr>
<tr>
<td>1:32,000,000</td>
<td>Lightning strike</td>
</tr>
</tbody>
</table>

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners, local councils, planning authorities, developers, insurers, lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia; whose members are professional/technically engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments’ National Disaster Mitigation Program.
APPENDIX F

Stability of Retaining Structures
Stability of Retaining Structures

Geotechnical stability of all proposed retaining structures must be carried out against sliding, overturning and global slope instability. The retaining structures must also be stable against bearing capacity failure (or excessive base settlements). Moreover, the retaining structure itself must be adequately designed against any potential structural failures such as flexural failure or shear failure.

Fig. 7: Typical retaining structure and the lateral earth pressure distributions

Figure 7 shows a typical retaining structure including lateral earth pressure distributions. The retained soil behind the retaining structure will exert active lateral earth pressure if the retaining structure allows some lateral movement; otherwise lateral earth pressure at rest ($K_o$ condition) should be used during design and stability assessments. The soil in front of the wall will cause passive earth pressure, as shown in Fig. 7.

All development applications involving retaining structures must assess the geotechnical stability and factor of safety against the following:

a) Sliding caused by the active earth pressure and resistance by passive earth pressure and frictional force at the base the retaining structure;

b) Overturning about the toe (point O in Fig. 7) as a result of driving moment caused by the active earth pressure and resisting moment caused by the passive earth pressure, the self-weight of the retaining structure and weight of the retained soils behind the structure; and

c) Global slope instability considering a large slip circle passing through the underneath of the retaining structure and the retained soils.

The stability assessment shall ensure that all retaining structures will achieve a factor of safety (FOS) > 1.5 against sliding, overturning and global slope instability.

Referenced “Geotechnical Stability Assessment Guidelines JUNE 2007: Version 1.0 Gold Coast City Council” Section 5.2 Page 19.
Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

**WHY ARE THESE PRACTICES GOOD?**

**Roadways and parking areas** - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

**Cuttings** - are supported by retaining walls (GeoGuide LR6). **Retaining walls** - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

**Sewage** - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground. **Surface water** - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfill the same purpose (GeoGuide LR5).

**Surface loads** - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, you should engage a geotechnical practitioner to find out.

**Flexible structures** - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality. **Vegetation clearance** - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

**ADOPT GOOD PRACTICE ON HILLSIDE SITES**

Australian Geomechanics Vol 42 No 1 March 2007
Why are these practices poor?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide. Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

Don't cut corners on hillside sites - obtain advice from a geotechnical practitioner

More information relevant to your particular situation may be found in other Australian GeoGuides: