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KDC Group

Proposed "Diamond" Apartment
7-9 Bent Street, Gosford

Report on
Geotechnical Investigation

3315-R1
9 October 2015

DOCUMENT AUTHORISATION

Proposed "Diamond" Apartment
7-9 Bent Street, Gosford

Report on Geotechnical Investigation

Prepared for KDC Group

Prepared by Asset Geotechnical Engineering Pty Ltd

3315-R1
9 October 2015

For and on behalf of
Asset Geotechnical Engineering Pty Ltd

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DOCUMENT CONTROL

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Contents

Figures

Appendices

1. INTRODUCTION

1.1 General

This report presents the results of a geotechnical investigation for the above project. The investigation was commissioned on 24 August 2015 by Simone Khiralla of KDC Group. The work was carried out in accordance with the proposal by Asset Geotechnical Engineering Pty Ltd dated 26 August 20125, reference P3315-P1.

Drawings supplied to us for this investigation comprised:
- Architectural plans by ADG Architects (Project No. 15026, Drawing Nos PR00 – PR16, Dated 27 August 2015).
- Site plan by ADG Architects (Project No. 15026, Drawing No SK01, Dated 14 August 2015).

Based on the supplied drawings, we understand that the project involves construction of a new apartment building containing about 140 units over 21 floors plus three basement levels. The proposed finished floor level of Basement 3 is RL 26.35m AHD. We have assumed an average excavation depth of 9m, varying from about 12m along the western boundary to about 6m along the eastern boundary.

1.2 Scope of Work

The main objectives of the investigation were to assess the surface and subsurface conditions and to provide comments and recommendations relating to:
- Key geotechnical constraints to the development
- Excavation conditions, methodology and monitoring
- Subgrade preparation and earthworks
- Suitable foundations
- Allowable bearing pressure and shaft adhesion for piles
- Excavation support methodology and design parameters
- Maximum allowable permanent and temporary batter slopes
- Geotechnical treatment and parameters for vertical rock face support
- Groundwater and dewatering.
- Slope instability risk assessment.

In order to achieve the project objectives, the following scope of work was carried out:
- A review of existing regional maps and reports relevant to the site, held within our files.
- Walkover observations of site condition and instability assessment.
- Clearance of underground services at proposed test locations using hand auger up to depth of 0.5 m.
- Visual observations of surface features.
- Drilling and logging of two boreholes down to refusal on bedrock.
- Continuing rock coring and logging in one of the boreholes to a target depth of nominally 3m below basement level along the western boundary.
- Standard Penetrometer Testing (SPT) within the soils to aid with assessment of insitu conditions
- Point Load Strength Index Testing on recovered rock core.
- Installation of one piezometer for future monitoring of the groundwater level.
- Engineering assessment and reporting.

This report must be read in conjunction with the attached “Important Information about your Geotechnical Report” in Appendix A. Particular attention is drawn to the limitations inherent in site investigations and the importance of verifying the subsurface conditions inferred herein.

2. SITE DESCRIPTION

The site comprises 3 blocks (No.7, No.9 and No 156 Bent Street) and is located on the southern side of Bent Street, as shown in Figure 1. It is trapezoidal in shape measuring about 45m deep by about 50m to 80m wide (street frontage). The site is bounded to the west and south by residential developments, to the north by Bent Street, and to the east by Henry Parry Road.

Topographically, the site is located on middle of a moderately steep, westerly facing slope with a gently undulating ground surface. The overall ground surface slopes in the region are about 15°.

The existing development at No.9 comprises a three-storey residence. The rear part of the site (No. 156 Bent Street) is a garden area and is undeveloped.

Vegetation comprises scattered cover of trees and medium grass cover and garden areas around the existing buildings. Thicker density vegetation is present near the eastern boundary of the site.

3. FIELDWORK AND LABORATORY TESTING

3.1 Borehole Investigation

The fieldwork was undertaken on 9th September 2015 under the full time supervision of a Geotechnical Engineer from Asset.

Two boreholes were drilled (BH1 and BH2) using a ute-mounted drilling rig. Each borehole was initially drilled using hand auger to a depth of 0.5m to reduce the risk of striking buried services. The boreholes were then continued using the drilling rig down to refusal on bedrock at depths of 2.9m and 1.3m for BH1 and BH2 respectively. Standard Penetration Testing (SPT) carried out at typical 1.5m depth intervals in both the boreholes. Borehole BH1 was continued by NMLC coring to the termination depth of 11.9m.

The locations of the boreholes are shown on the attached Figure 2. Engineering logs are provided in Appendix B and explanatory notes are provided in Appendix A.

The borehole locations were set out by our Geotechnical Engineer by measurements relative to existing site features. The subsurface conditions encountered were logged during drilling. Rock samples were retained for laboratory testing. Surface levels at the test locations were estimated by interpolation from levels shown on the survey plan provided by ADG Architects (Project No. 15026, Drawing No SK01, Dated 14 August 2015).

On completion of logging and sampling, a 50mm diameter PVC standpipe piezometer was installed in borehole BH1 to the recorded termination depth. Borehole BH2 was backfilled with the drilling spoil and trimmed neatly flush or slightly mounded to the adjacent ground surface.

3.2 Core Photography and Laboratory Testing

Recovered rock core was photographed and then delivered to a NATA registered laboratory and tested for point load strength index. Core photographs and test results are attached. Test results are also included on the borehole logs.

4. SUBSURFACE CONDITIONS

4.1 Geology

The Gosford 1:100,000 Geological Map indicates that the site is underlain by the Gosford Subgroup of the Terrigal Formation, comprising interbedded shale, laminite, sandstone, and minor clay seams.

4.2 Subsurface Conditions

A generalised geotechnical model for the site has been developed is shown in Table 1, with a summary of the subsurface the conditions observed at each test location shown in Table 2. For a detailed description of the subsurface conditions, refer the attached engineering logs and explanatory notes. For specific design input, reference should be made to the logs and/or the specific test results, in lieu of the following summary.

Table 1 - Generalised Site Geotechnical Model

Layer	Origin	Description	Soil Density / Consistency	Assessed Rock Classification[1]
Unit 1	Topsoil	ORGANIC SOIL, fine grained, dark brown, wet	Soft to very soft	– –
Unit 2 (BH1)	Fill	CONCRETE 50mm thick overlying Silty SAND, fine to medium grained, mottled brown/red, moist	Medium dense	– –
Unit 3	Residual Soil	Silty / Clayey SAND, fine to medium grained, light grey, moist to dry	Medium dense to very dense	– –
Unit 4a	Bedrock	SANDSTONE / Mudstone, mottled orange brown to red brown / grey with layer of Claystone, low strength, defect spacing typically 200-600mm	– –	Class 3 Sandstone
Unit 4b	Bedrock	SANDSTONE / Mudstone, mottled orange brown to red brown / grey with layer of Claystone, medium strength, defect spacing typically 200-600mm	– –	Class 2 Sandstone
Unit 4c	Bedrock	SANDSTONE, light to dark grey, coarse grained grading to fine grained, high strength, defect spacing typically >600mm	– –	Class 1 Sandstone

Table 2 – Generalised Subsurface Conditions (m)

Layer	Origin	BH1	BH2
Unit 1	Topsoil	0.0 – 0.1	0-0.1
Unit 2	Fill	0.1 – 1.2	– –
Unit 3	Residual Soil	1.2 – 2.9	0.1 – 1.3
Unit 4a	Bedrock	2.9 – 4.5	1.3m +
Unit 4b	Bedrock	4.5 – 6.8	– –
Unit 4c	Bedrock	6.8 – 11.9	– –

[1] Pells, P.J.N., Mostyn, G. & Walker, B.F., *Foundations on Sandstone and Shale in the Sydney Region*, Australian Geomechanics Journal, December 1998

4.3 Groundwater

Groundwater was not observed during auger drilling. Due to the introduction of water whilst coring, observation of groundwater below auger refusal was not possible. No readings of the piezometer installed in BH1 have been undertaken at this point.

It is expected that groundwater would be present within fractures and defects deeper within the bedrock. Long-term piezometer readings would be required to provide further data.

5. DISCUSSIONS & RECOMMENDATIONS

Based on a basement finished floor level of RL 26.35m AHD, and from the results of this investigation, it is assessed that excavation will be predominantly within sandstone bedrock ranging from Class 3 up to Class 1 Sandstone.

Key geotechnical constraints to the development include temporary shoring of soils above rock, vibrations from rock excavation, groundwater control (during construction and long-term), and hazards related to slope instability risk. These are discussed in the following sections.

Recommendations for design and construction of the development are provided in the following sections. The geotechnical report data is summarised in the attached Table R3, as per Gosford City Council requirements.

5.1 Slope Instability Risk

A risk assessment has been carried out for this site with regard to slope instability, using the methods of the AGS publication *"Landslide Risk Management"* [2].

The basis of the risk assessment undertaken for this site and important factors relating to slope conditions and the impacts of the development that commonly influence the risks of slope instability are discussed in the attached "Important Information about your Slope Instability Risk Assessment", and the attached GeoGuides.

The preliminary assessment has been carried out by:

- Consideration of the likely slope failure mechanisms and the likely initiating circumstances that could affect the elements at the site. The type and mode of landslide failure has also been classified.
- **Risk to Property.** For each case, the likely consequences with respect to future development have been considered. The current assessed probability of occurrence of each event has been estimated on a qualitative basis. The consequences and probability of occurrence have been combined for each case to provide the risk assessment.
- **Risk to Life.** For each case, the risk for the person most at risk is assessed based on multiplying the indicative annual probability of the occurrence of the hazard, the probability of spatial impact, the temporal probability, the vulnerability, and the probability of not evacuating. The risk is then compared with acceptable and tolerable risk criteria.

[2] *Landslide Risk Management,* Australian Geomechanics, Vol 42, No. 1, March 2007.

The following general potential hazards/events are identified for this site during construction and relate to slope instability:

1) Slump of steep excavation in soils.
2) Rock wedge failure within rock excavation.

For the hazards / events identified, the elements of the development on the site that are at risk are the proposed basement structure and associated site development comprising services, utilities, and shoring walls. Personnel working within the basement and immediately adjacent to the site, during construction, are also vulnerable. Table A provides our preliminary risk assessment for the site with respect to risk to property, and Table B provides our preliminary risk assessment for the site with respect to risk to life. The construction-phase of the project is considered to be the critical phase, as the permanent structure will include permanent shoring of the soils above rock, and the rock will have been treated during construction.

Our assessment of the current site conditions is that the risk with respect to property ranges from **High to Very High**, and the risk with respect to life is **Not Tolerable.** Risk mitigation during construction will be required in order to allow the proposed development to proceed.

Where development takes into consideration the possible failure mechanisms and adopts the good engineering practice for hillside development and the recommendations of this report (including hazard treatment), it is envisaged that the outcome of such a development would be **Low** to **Very Low** risk assessed with respect to property, and the risk with respect to life would be **Acceptable**. Further geotechnical input is considered essential to ensure that these risk outcomes are achieved. The development should be carried out in accordance with good engineering practice that is described in the attached GeoGuides, and in accordance with the general recommendations in the following sections.

5.2 Risk Treatment

Risk treatment is not considered necessary prior to development. Risk treatment is required during the development, and is described below. For preliminary budgeting purposes, we estimate that these risk mitigation works could be of the order of $50,000 to $100,000. Geotechnical inspections and further guidance required during the works could be of the order of $5,000 to $10,000.

5.2.1 *Hazard 1*

Soil slopes must be battered at no steeper than 1H:1V temporary, and must be provided with permanent support by engineered retaining. If temporary batters are not desirable or cannot be accommodated, temporary shoring (e.g. anchored retaining walls) will be required.

5.2.2 *Hazard 2*

Inspection of the rock excavation must be carried out by a geotechnical engineer at every 2m vertical lift height, to check for adversely oriented joints or other defects. Remedial works must be implemented where directed by the geotechnical engineer. This could include temporary bolting of potentially unstable rock wedges, and shotcreting or grouting of weathered seams.

5.3 Temporary Shoring

Temporary shoring of the soils above rock could be carried out using bored piles with shotcrete infill and rock anchors.

Design of temporary shoring for carrying vertical loading should be in accordance with Section 5.10, and for lateral pressures it should be in accordance with Section 5.11.

Detailed construction supervision, monitoring and inspections will be required during the piling and subsequent bulk excavation to ensure an adequate standard of workmanship and to minimise potential problems.

5.4 Groundwater Seepage Control

In order to construct the basement, it will be necessary to control possible groundwater seepage. This should be achievable using conventional sump-and-pump techniques, and is not expected to adversely affect adjoining developments. Further advice should be sought if higher inflows are encountered that cannot be controlled using such methods.

The quantity of seepage expected to flow into the excavation during construction is unknown. It will depend on the jointing / fracturing of the underlying sandstone bedrock, and the flow path length. At this stage no in situ or laboratory permeability tests of the site subsurface profile has been undertaken. However, based on the borehole soil description of the sandy clays and with reference to empirical charts, we anticipate that the mass permeability of the sandstone bedrock would be in the order of 10^{-5} to 10^{-7} cm/sec.

5.5 Excavation

The excavation for the proposed development is anticipated to be partially within soils, and mostly within sandstone bedrock. Excavation within the soils would be achievable using conventional earthmoving equipment (i.e. hydraulic excavator bucket).

Excavation within the less weathered bedrock will likely require use of ripper tooth fitted to a hydraulic excavator bucket, a dozer fitted with ripper tooth, or a hydraulic hammer fitted to an excavator, possibly supplemented by rock saw and rock splitting techniques. We note that assessed Class 2 and 1 sandstone was encountered, which will likely require heavy equipment to excavate.

Australian Standard AS 2187: Part 2-2006 recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 “Evaluation and measurement for vibration in buildings Part 2” as they “are applicable to Australian conditions”. The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (e.g. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

For residential structures, BS 7385 recommends vibration criteria of 7.5 mm/s to 10 mm/s for frequencies between 4 Hz and 15 Hz, and 10 mm/s to 25 mm/s for frequencies between 15 Hz to 40 Hz and above. These values would normally be applicable for new residential structures or residential structures in good condition. Higher values would normally apply to commercial structures, and more conservative criteria would normally apply to heritage structures.

However, structures can withstand vibration levels significantly higher than those required to maintain comfort for their occupants. Human comfort is therefore likely to be the critical factor in vibration management.

Excavation methods should be adopted which limit ground vibrations at the adjoining developments to not more than 10mm/sec. Vibration monitoring is recommended to verify that this is achieved. However, if the contractor adopts methods and / or equipment in accordance with the recommendations in Table 3 for a ground vibration limit of 5mm/sec, vibration monitoring may not be required.

The limits of 5mm/sec and 10mm/sec are expected to be achievable if rock breaker equipment or other excavation methods are restricted as indicated in Table 3.

Table 3 – Recommendations for Rock Breaking Equipment

Distance from adjoining structure (m)	Maximum Peak Particle Velocity 5mm/sec		Maximum Peak Particle Velocity 10mm/sec*	
	Equipment	Operating Limit (% of Maximum Capacity)	Equipment	Operating Limit (% of Maximum Capacity)
1.5 to 2.5	Hand operated jackhammer only	100	300 kg rock hammer	50
2.5 to 5.0	300 kg rock hammer	50	300 kg rock hammer or 600 kg rock hammer	100 50
5.0 to 10.0	300 kg rock hammer or 600 kg rock hammer	100 50	600 kg rock hammer or 900 kg rock hammer	100 50

* Vibration monitoring is recommended for 10mm/sec vibration limit.

At all times, the excavation equipment must be operated by experienced personnel, according to the manufacturer's instructions, and in a manner consistent with minimising vibration effects.

Use of other techniques (e.g. chemical rock splitting, rock sawing), although less productive, would reduce or possibly eliminate risks of damage to adjoining property through vibration effects transmitted via the ground. Such techniques may be considered if an alternative to rock breaking is necessary. If rock sawing is carried out around excavation boundaries in not less than 1m deep lifts, a 900 kg rock hammer could be used at up to 100% maximum operating capacity with an assessed peak particle velocity not exceeding 5 mm/sec, subject to observation and confirmation by a Geotechnical Engineer at the commencement of excavation.

It is pointed out that the rock classification system used in Table 1 is intended primarily for use in design of foundations, and is not intended to be used to directly assess rock excavation characteristics. Excavation contractors should refer to the detailed engineering logs, core photographs, laboratory strength tests, and inspection of rock core, and should not rely solely on the rock classifications presented in geotechnical engineering reports, when assessing the suitability of their excavation equipment for the proposed development. Further geotechnical advice must be sought if rock excavation characteristics are critical to the proposed development.

It should be noted that vibrations that are below threshold levels for building damage may be experienced at adjoining developments. Rock excavation methodology should also take into account acceptable noise limits as per the “Interim Construction Noise Guideline” (NSW EPA).

5.6 Subgrade Preparation

The following general recommendations are provided for subgrade preparation for earthworks, pavements, slab-on-ground construction, and minor structures:

- Strip existing fill and topsoil. Remove unsuitable materials from site (e.g. material containing deleterious matter). Stockpile remainder for re-use as landscaping material or remove from site.
- Excavate residual clayey soils and rock, stockpiling for re-use as engineered fill or remove to spoil. Rock could be stockpiled separately from clayey soils, for select use beneath pavements.
- Where rock is exposed in bulk excavation level beneath pavements, rip a further 150mm.
- Where rock is exposed at footing invert level, it should be free of loose, “drummy" and softened material before concrete is poured.
- Where soil is exposed at bulk excavation level, compact the upper 150mm depth to a dry density ratio (AS1289.5.4.1–2007) not less than 100% Standard.
- Areas which show visible heave under compaction equipment should be over-excavated a further 0.3m and replaced with approved fill compacted to a dry density ratio not less than 100%.

Further advice should be sought where filling is required to support major structures.

Any waste soils being removed from the site must be classified in accordance with current regulatory authority requirements to enable appropriate disposal to an appropriately licensed landfill facility. Further advice should be sought from a specialist environmental consultant if required.

5.7 Filling

Where filing is required, place in horizontal layers not more than 0.3m loose thickness over prepared subgrade and compact to a dry density ratio not less than 95% Standard beneath pavements and 98% Standard beneath structures. The moisture content during compaction should be maintained at ±2% of Standard Optimum. Compact the upper 150mm of subgrade to a dry density ratio not less than 100% Standard.

Filling within 1.5m of the rear of retaining walls should be compacted using light weight equipment (e.g. hand-operated plate compactor or ride-on compactor not more than 3 tonnes static weight) in order to limit compaction-induced lateral pressures. The layer thickness should be reduced to 0.2m maximum loose thickness.

Any soils to be imported onto the site for the purpose of back-filling and re-instatement of excavated areas should be free of contamination and deleterious material, and should include appropriate validation documentation in accordance with current regulatory authority requirements which confirms its suitability for the proposed land use. Further advice should be sought from a specialist environmental consultant if required.

5.8 Batter Slopes

Recommended maximum slopes for permanent and temporary batters are presented in Table 6.

Table 6 – Recommended Maximum Batter Slopes

Unit	Maximum Batter Slope (H : V)	
	Permanent	Temporary
Fill & Residual Soils	2 : 1	1 : 1
Class 3–1 Sandstone	vertical *	vertical *

* subject to inspection by a geotechnical engineer and carrying out remedial works as recommended (e.g. shotcrete, rock bolting).

5.9 Site Classification

Due to the presence of trees, fill, existing site structures (causing abnormal moisture conditions), and observed ground surface slopes, the site is classified as a Class P (Problem) Site in accordance with AS 2870–2011 "Residential Slabs and Footings". However, we note that the proposed structures do not fall into the category of structures covered by this standard, and footings should be designed as per the recommendations given in Section 5.10.

5.10 Footings

Edge beams for slab, pad footings and rock socketed piles may be designed for the parameters in Table 7. Further advice should be sought if ultimate limit state parameters are required.

Table 7 – Footing Design Parameters

Sandstone Founding Stratum	Maximum Allowable (Serviceability) Values (kPa)		
	End Bearing	Shaft Friction – Compression	Shaft Friction – Tension
Class 3	3,500	350	50
Class 2	3,500 / 6,000*	600	70
Class 1	3,500 / 6,000*	600	200

* If bearing pressures exceeding 3,500 kPa are adopted, it will be necessary to carry out cored boreholes in at least 50% of footings and spoon testing in remainder.

Settlements for footings on rock are anticipated to be about 1% of the minimum footing dimension, based on serviceability parameters as per Table 7.

An experienced Geotechnical Engineer should review footing designs to check that the recommendations of the geotechnical report have been included, and should assess footing excavations to confirm the design assumptions.

5.11 Excavation Support

Excavation of soil and rock results in stress changes in the remaining material, and some ground movement is inevitable. The magnitude and extent of lateral and vertical ground movements will depend on the design and construction of the excavation support system. Experience and published data suggest that lateral movements of an adequately designed and installed retention system in soil and weathered rock will typically be in the range of 0.2% to 0.5% of the retained height. The extent of the horizontal movement behind the excavation face typically varies from 1.5 to 3 times the excavated height.

5.11.1 *Excavation Support Construction Methodology*

Where temporary or permanent batter slopes for soils as per Section 5.8 cannot be accommodated in the development or are not desired, temporary shoring and/or permanent retaining will be required.

Design of retaining walls will need to consider both long–term (i.e. permanent) and short–term (i.e. during construction) loading conditions, as well as the possible impact on adjoining developments.

In the long–term, the ground and basement floor slabs will provide bracing at the top and bottom (and possibly mid-points in some areas). Therefore, basement retaining walls should be designed as braced walls for the long–term loading condition.

In the short–term (i.e. during construction), the design of the basement retaining wall will depend on the method of construction adopted. We consider that the most likely suitable method would be to drill shoring piles and install anchors as necessary, with shotcrete infill panels placed progressively during excavation.

5.11.2 *Excavation Support Design Parameters*

Support system design may be based on the parameters given in Table 8. Cantilever walls or walls with only a single row of anchors / props may be designed for a triangular earth pressure distribution with the lateral pressure being determined as follows:

$\sigma_z = K_{o,a,p}\ z\ \gamma$ where

σ_z = lateral earth pressure (kPa) at depth z
$K_{o,a,p}$ = earth pressure coefficient
o = 'at rest', a = 'active', p = 'passive'
z = depth (m)
γ = unit weight of soil / rock (kN/m^3)

Table 8 – Excavation Support Design Parameters

Material	Moist Unit Weight (γ_m) kN/m^3	'Active' Lateral Earth Pressure Coefficient [1] (K_a)	'At Rest' Coefficient [1] (K_o)	'Passive' Coefficient (K_p)
Fill & Residual Soils	18.0	0.35	0.5	N/A

Notes to table:

1. These values assume that some wall movement and relaxation of horizontal stress will occur due to the excavation. Actual in-situ K_0 values may be higher.

The parameters for the 'at rest' condition (K_o) should be used for design of lateral earth pressures where adjacent footings/structures are located within the 'zone of influence' of the wall. The 'zone of influence' may be taken as a line extending upwards and outwards at 45° above horizontal from the base of the wall. Piles for cantilever walls should be socketed below bulk excavation level by a depth at least equal to the retained height. For assessment of passive restraint embedded below excavation level, we recommend a triangular pressure distribution.

Walls supported by multiple rows of anchors / props may be designed for a uniform lateral earth pressure of 0.65 γ H K_a where γ = unit weight of retained material, H = height of wall, and K_a = earth pressure coefficient (Table). Piles for braced walls should be socketed at least 0.75m below basement subgrade level to provide toe "kick-in" resistance until the slab can be poured.

5.11.3 *Surcharge*

Allowance must also be made for surcharge loadings and footing loads from adjacent structures.

5.11.4 *Permanent Drainage and Groundwater Control*

Where adequate subsoil drainage is provided behind walls, no allowance for groundwater is considered necessary. Control of groundwater seepage through the basement wall or from fractures and other defects in the rock mass should also be allowed for, unless a waterproof basement is designed and constructed.

If permanent seepage collection and is proposed, it should include provision for redundancy of pumps and backup generators as appropriate.

5.12 Potential Impacts on Adjacent Developments

Potential geotechnical risks of construction on adjoining developments could include; vibration effects due to rock excavation, settlement / deflection of adjacent footings due to the basement excavation, and induced settlement due to groundwater drawdown. These risks have been discussed in the relevant sections of this report. We assess that if the development is designed and constructed in accordance with the recommendations given in this report, these affects are anticipated to have negligible impact and be within acceptable limits.

6. LIMITATIONS

In addition to the limitations inherent in site investigations (refer to the attached Information Sheets), it must be pointed out that the recommendations in this report are based on assessed subsurface conditions from limited investigations. In order to confirm the assessed soil and rock properties in this report, further investigation would be required such as coring and strength testing of rock, and should be carried out if the scale of the development warrants, or if any of the properties are critical to the design, construction or performance of the development.

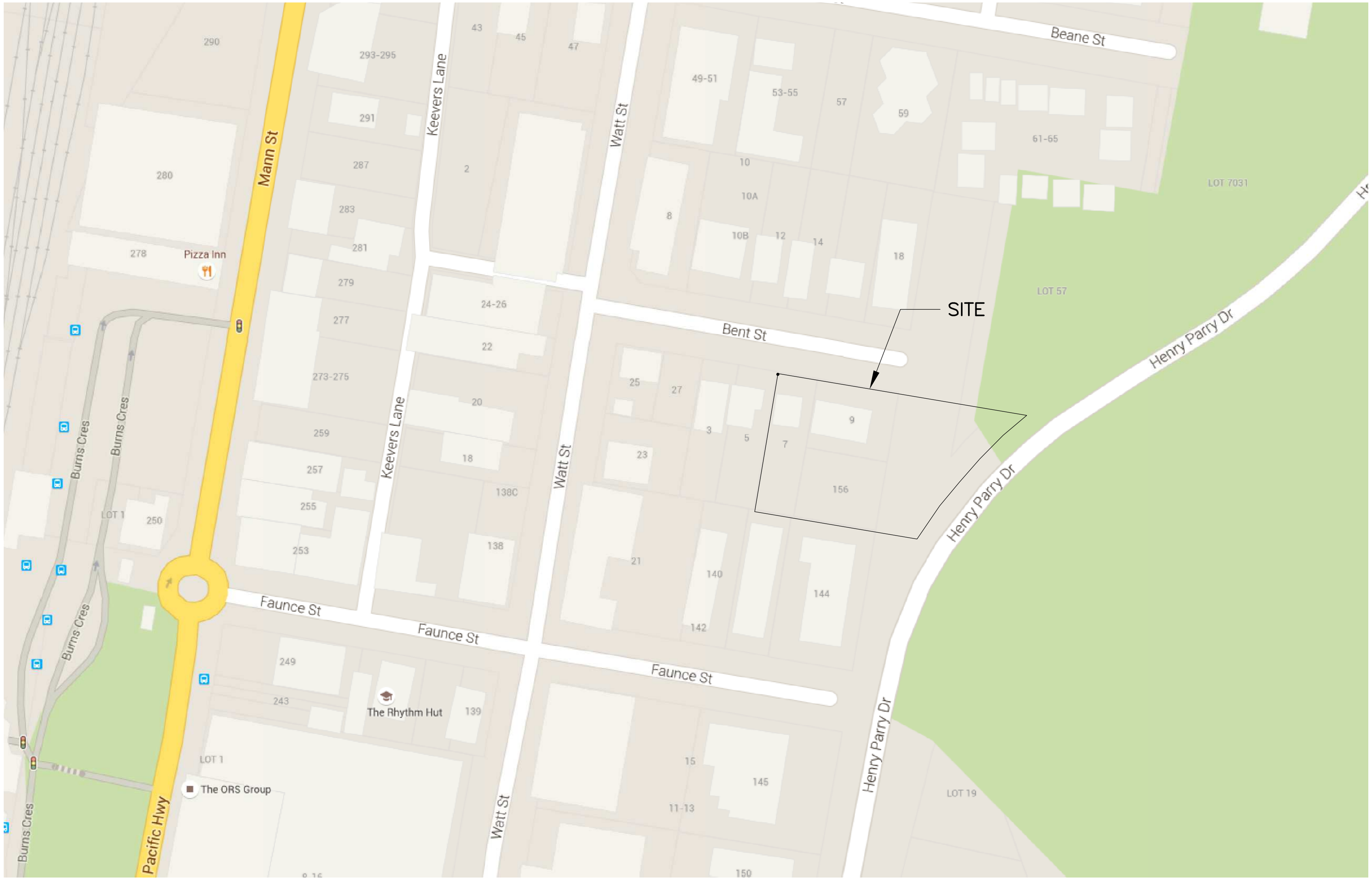
It is recommended that a qualified and experienced Geotechnical Engineer be engaged to provide further input and review during the design development; including site visits during construction to verify the site conditions and provide advice where conditions vary from those assumed in this report. Development of an appropriate inspection and testing plan should be carried out in consultation with the Geotechnical Engineer.

This report may have included geotechnical recommendations for design and construction of temporary works (e.g. temporary batter slopes or temporary shoring of excavations). Such temporary works are expected to perform adequately for a relatively short period of time only, which could range from a few days (for temporary batter slopes) up to six months (for temporary shoring). This time period depends on a range of factors including but not limited to: site geology; groundwater conditions; weather conditions; design criteria; and level of care taken during construction. If there are factors which prevent temporary works from being completed and/or which require temporary works to function for periods longer than originally designed, further advice must be sought from the Geotechnical Engineer and Structural Engineer.

This report and details for the proposed development must be submitted to relevant regulatory authorities that have an interest in the property (e.g. Council) or are responsible for services that may be within or adjacent to the site, for their review prior to commencement of construction.

The document "Important Information about your Geotechnical Report" in Appendix A provides additional information about the uses and limitations of this report.

FIGURES



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PPROPOSED "DIAMOND" APARTMENT
7–9 BENT STREET, GOSFORD
for
KDC GROUP

SITE LOCALITY

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PROPOSED "DIAMOND" APARTMENT
7–9 BENT STREET, GOSFORD
for
KDC GROUP

TEST LOCATIONS

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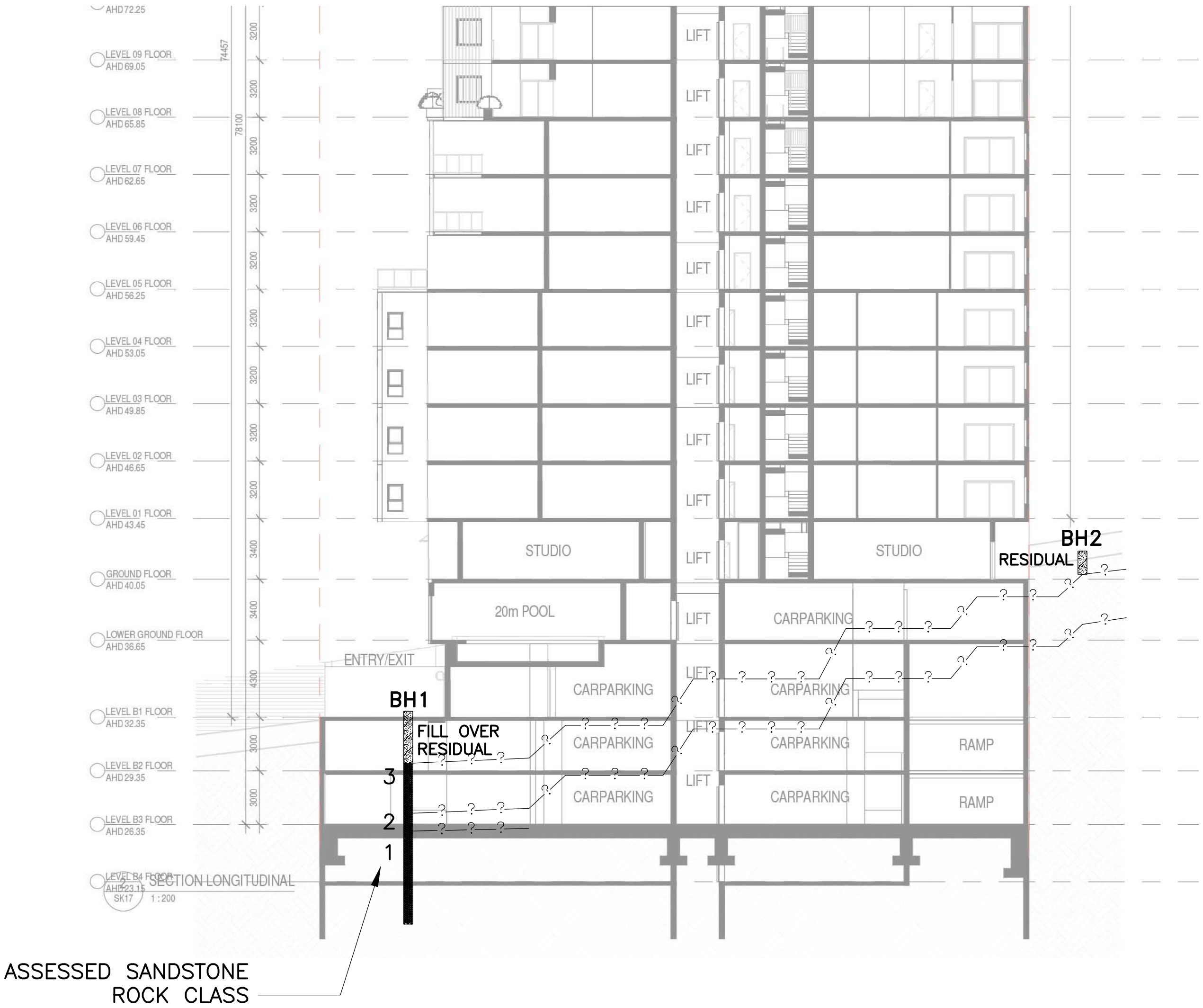

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issue	date	description
A	14.09.15	INITIAL ISSUE

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PROPOSED "DIAMOND" APARTMENT
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for
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INTERPRETED SECTION A–A

drawn: MA
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APPENDIX A

Important Information about your Geotechnical Report
Important Information about your Slope Instability Risk Assessment
GeoGuides (pp1-17)

Important Information about your Geotechnical Report

SCOPE OF SERVICES

The geotechnical report ("the report") has been prepared in accordance with the scope of services as set out in the contract, or as otherwise agreed, between the Client and Asset Geotechnical Engineering Pty Ltd ("Asset"), for the specific site investigated. The scope of work may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

The report should not be used if there have been changes to the project, without first consulting with Asset to assess if the report's recommendations are still valid. Asset does not accept responsibility for problems that occur due to project changes if they are not consulted.

RELIANCE ON DATA

Asset has relied on data provided by the Client and other individuals and organizations, to prepare the report. Such data may include surveys, analyses, designs, maps and plans. Asset has not verified the accuracy or completeness of the data except as stated in the report. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations ("conclusions") are based in whole or part on the data, Asset will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Asset.

GEOTECHNICAL ENGINEERING

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared for a specific client, for a specific project and to meet specific needs, and may not be adequate for other clients or other purposes (e.g. a report prepared for a consulting civil engineer may not be adequate for a construction contractor). The report should not be used for other than its intended purpose without seeking additional geotechnical advice. Also, unless further geotechnical advice is obtained, the report cannot be used where the nature and/or details of the proposed development are changed.

LIMITATIONS OF SITE INVESTIGATION

The investigation programme undertaken is a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions. The data derived from the site investigation programme and subsequent laboratory testing are extrapolated across the site to form an inferred geological model, and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation, the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

The engineering logs are the subjective interpretation of subsurface conditions at a particular location and time, made by trained personnel. The actual interface between materials may be more gradual or abrupt than a report indicates.

Therefore, the recommendations in the report can only be regarded as preliminary. Asset should be retained during the project implementation to assess if the report's recommendations are valid and whether or not changes should be considered as the project proceeds.

SUBSURFACE CONDITIONS ARE TIME DEPENDENT

Subsurface conditions can be modified by changing natural forces or man-made influences. The report is based on conditions that existed at the time of subsurface exploration. Construction operations adjacent to the site, and natural events such as floods, or ground water fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. Asset should be kept appraised of any such events, and should be consulted to determine if any additional tests are necessary.

VERIFICATION OF SITE CONDITIONS

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that Asset be notified of any variations and be provided with an opportunity to review the recommendations of this report. Recognition of change of soil and rock conditions requires experience and it is recommended that a suitably experienced geotechnical engineer be engaged to visit the site with sufficient frequency to detect if conditions have changed significantly.

REPRODUCTION OF REPORTS

This report is the subject of copyright and shall not be reproduced either totally or in part without the express permission of this Company. Where information from the accompanying report is to be included in contract documents or engineering specification for the project, the entire report should be included in order to minimize the likelihood of misinterpretation from logs.

REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the Client and no other party. Asset assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of Asset or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

DATA MUST NOT BE SEPARATED FROM THE REPORT

The report as a whole presents the site assessment, and must not be copied in part or altered in any way.

Logs, figures, drawings, test results etc. included in our reports are developed by professionals based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

PARTIAL USE OF REPORT

Where the recommendations of the report are only partially followed, there may be significant implications for the project and could lead to problems. Consult Asset if you are not intending to follow all of the report recommendations, to assess what the implications could be. Asset does not accept responsibility for problems that develop where the report recommendations have only been partially followed if they have not been consulted.

OTHER LIMITATIONS

Asset will not be liable to update or revise the report to take into account any events or emergent circumstances or fact occurring or becoming apparent after the date of the report.

Important Information about your Slope Instability Risk Assessment

1. BASIS OF THE ASSESSMENT

Our assessment of the stability of the land is presented in the framework of Landslide Risk Management (Australian Geomechanics Society, Vol 42, No 1, March 2007). The attached GeoGuides provide further information on landslide risk management and maintenance.

This assessment is based on a visual inspection of the property and also the immediate adjoining land. Limited subsurface investigation may also have been undertaken as part of this appraisal. Slope monitoring has not been carried out within or adjacent to the property for the purpose of this appraisal. The opinions expressed in this report also take into account our relevant local experience.

The property is within an area where landslip and/or subsidence have occurred, or where there is a risk that slope instability may occur. Important factors relating to slope conditions and the impact of development which commonly influence the risks of slope instability are discussed herein.

An owner's decision to acquire, develop or build on land within an area such as this involves the understanding and acceptance of a level of risk. It is important to recognise that soil and rock movements are an ongoing geological process, which may be affected by development and land management within the site or on adjoining land. Soil and rock movements may cause visible damage to structures even where the risk of slope failure is considered low. This report is intended only to assess the risk of slope failure, apparent at the time of inspection.

Our opinion is provided on the present risk of slope instability for the land specifically referenced in the title to this report. Foundations suitable for future building development are discussed in relation to slope stability considerations. Limited foundation advice may be provided. If so, advice is intended to guide the footing design for the proposed development. However, this report is not intended as, is not suitable for, and must not be used in lieu of a detailed foundation investigation for final design and costing of foundations, retaining walls or associated structures.

2. LIMITATIONS OF THE ASSESSMENT PROCEDURE

The assessment procedures carried out for this appraisal are in accordance with the recommendations in Landslide Risk Management (Australian Geomechanics Society, Vol 42, No 1, March 2007), and with accepted local practice.

The following limitations must be acknowledged:-

- the assessment of the stability of natural slopes requires a great degree of judgment and personal experience, even for experienced practitioners with good local knowledge;
- the assessment must be based on development of a sound geological model; slope processes and process rates influencing land sliding or landslide potential will vary according to geomorphologic influences;
- the likelihood that land sliding may occur on a given slope is generally hard to predict and is associated with significant uncertainties;
- different practitioners may produce different assessments of risk;
- actual risk of land sliding cannot be determined; risk changes with time;
- consequences of land sliding need to be considered in a rational framework of risk acceptance;
- acceptable risk in relation to damage to property from landslide activity is subjective; it remains the responsibility of the owner and/or local authority to decide whether the risk is acceptable; the geotechnical practitioner can assist with this judgment;
- the extent and methods of investigation for assessment of landslide risk will be governed by experience, by the perceived risk level, and by the degree to which the risk or consequences of land sliding are accepted for a specific project;
- the assessment may be required at a number of stages of the project or development; frequently (due to time or budget constraints imposed by the client) there will be no opportunity for long-term monitoring of the slope behaviour or groundwater conditions, or for on-going opportunity for the slope processes and performance of structures to be reviewed during and after development; such limitations should be recognised as relevant to the assessment.

3. DEVELOPMENT ON SLOPES

Some risk of slope instability is always attached to the development of land on slopes.

Guidelines for hillside construction and examples of good practices for hillside developments are described in the attached GeoGuides.

THE AUSTRALIAN GEOGUIDES
FOR SLOPE MANAGEMENT AND MAINTENANCE

AGS Landslide Taskforce, Slope Management and Maintenance Working Group

The Australian Geomechanics Society (AGS) presents on the following pages a guideline on slope management and maintenance, as part of the landslide risk management guidelines developed under the National Disaster Funding Program (NDMP). This Guideline is aimed at home owners, developers and local councils, but also has applicability to a larger audience which includes builders and contractors, consultants, insurers, lawyers, government departments and in fact any person, or organisation, with a responsibility for the management or maintenance of a slope. The objective is to inform those with little or no knowledge of geotechnical engineering about landslides.

Each GeoGuide is a stand-alone document, which is formatted so that it can be printed on two sides of a single A4 sheet. It is expected that the set of GeoGuides will increase with time to cover a range of topics. As things stand:

- **GeoGuide LR1** is an introductory sheet that should be read by all users, since it explains what the LR (landslide risk) series is about and defines terms.
- **GeoGuides LR2, 3 and 4** explain why landslides occur and provide information on different types of landslide.
- **GeoGuide LR5** discusses the critical part that water often plays in relation to landslide occurrence and discusses measures that can be adopted to limit its effect.
- **GeoGuide LR6** refers to retaining walls and their maintenance.
- **GeoGuide LR7** puts the concept of landslide risk into an everyday context, so users can relate a particular landslide risk to other risks that they know they are prepared to take, sometimes on a daily basis.
- **GeoGuide LR8** retains the ideas of good and poor hillside construction practice originally provided by an AGS sub-committee in 1985.
- **GeoGuide LR9** concentrates specifically on effluent and surface water disposal, which is an important topic in some development areas.
- **GeoGuide LR10** is specifically aimed at those who have property on the coast and could be susceptible to coastal erosion processes.
- **GeoGuide LR11** provides information about the benefits of keeping records on inspection and maintenance activities and provides a proforma record sheet for users.

It is recognised that the GeoGuides are likely to be upgraded from time to time. Feedback on use and suggested changes should be sent to the National Chair of the Australian Geomechanics Society. The latest versions of the GeoGuides will be downloadable from the AGS website www.australiangemechanics.org

Through the NDMP, Australian governments (at Commonwealth, State and Local Government levels) are also funding the development of a Landslide Zoning Guideline (AGS 2007a), and a Practice Note Guideline (AGS 2007c) to which interested readers seeking in-depth information should refer.

ACKNOWLEDGEMENTS

These guidelines have been prepared by The Australian Geomechanics Society with funding from the National Disaster Mitigation Program, the Sydney Coastal Councils Group, and The Australian Geomechanics Society.

The Australian Geomechanics Society established a Working Group within a Landslide Taskforce to develop the guidelines. The development of the guidelines was managed by a Steering Committee. Membership of the Working Group, Taskforce and Steering Committee is listed in the Appendix.

Drafts of these GeoGuides have been subject to review by members of the AGS Landslide Taskforce, members of the geotechnical profession and local government.

REFERENCES

AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management. Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1.

AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1,

AGS (2007e). The Australian GeoGuides for slope management and maintenance –. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No 1, - this paper.

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips

AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

LR1 - Introduction	LR2 - Landslides	LR3 - Landslides in Soil
LR4 - Landslides in Rock	LR5 - Water & Drainage	LR6 - Retaining Walls
LR7 - Landslide Risk	LR8 - Hillside Construction	LR9 - Effluent & Surface Water Disposal
LR10 - Coastal Landslides	LR11 - Record Keeping	

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

Consequence	the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life.
Discontinuity	in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground.
Equilibrium	the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite.
Factor of safety (FOS)	theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one.
Failure	when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function.
Geotechnical practitioner	when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner.
Hazard	a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time.
Landslide	the movement, or the potential movement, of a mass of rock, debris, or earth down a slope.
Likelihood	a qualitative description of probability, or frequency, of occurrence.
Partial saturation	the condition in the ground above the water table where both air and water are present as well as soil, or rock.
Perched water table	a water table above the true water table supported by a low permeability stratum.
Permeability	a measure of the ability of the ground to allow water to flow through it.
Risk	a measure of the probability and severity of an adverse effect to life, health, property or the environment.
Slip failure	landslide.
Stable	the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure.
Retaining structure	anything built by humans which is intended to support the ground and inhibit failure.
Structure	in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location.
Tension crack	a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent , failure.
Water table	the level in the ground below which it is saturated and the voids are filled with water.

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

LANDSLIDES

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au .

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 - Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0°- 10°	1 on 6	Easy walking.
Moderate	10°- 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18°- 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27°- 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45°- 64°	1 on 0.5	Need rope access to climb slope
Cliff	64°- 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84°- 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

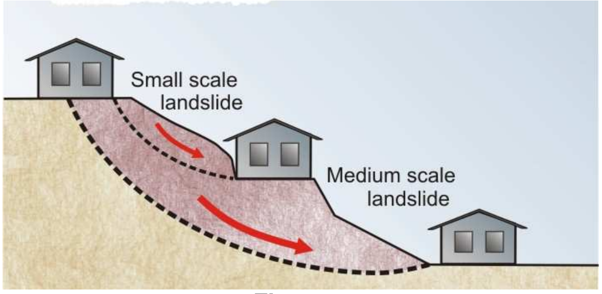

Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

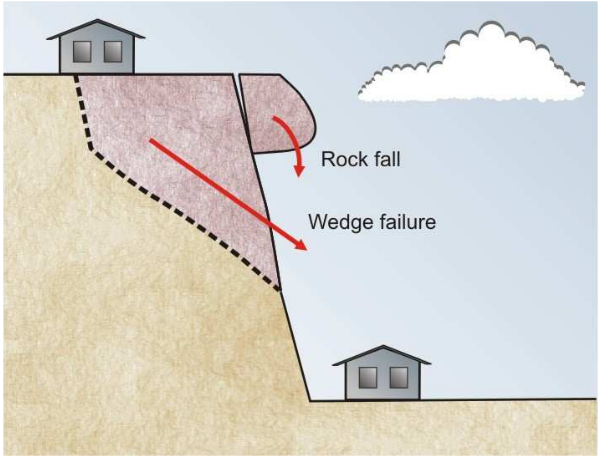

Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

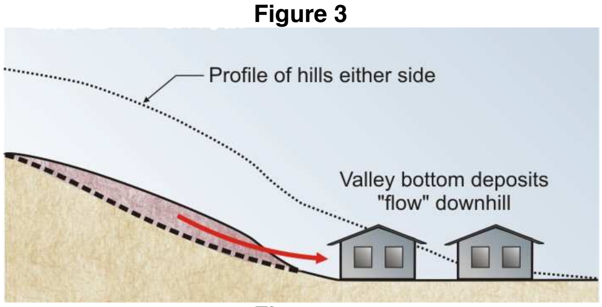

Figure 4

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

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- 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 geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

LANDSLIDES IN SOIL

Landslides occur on soil slopes and the consequences can include damage to property and loss of life. Soil slopes exist in all parts of Australia and can even occur in places where rock outcrops can be seen on the surface. If you live on, or below, a soil slope it is important to understand why a landslide might occur and what you can do to reduce the risk it presents.

It is always worth asking the question *"why is this slope here?"*, because the answer often leads to an understanding of what might happen in the future. Slopes are usually formed by weathering (breakdown) and erosion (physical movement) of the natural ground - the "parent material". Many factors are involved including rain, wind, chemical change, temperature variation, plant growth, animal activity and our own human enthusiasm for development. The general process is outlined in Figure 1.

The upper levels of the parent material progressively weather over thousands, or millions, of years, losing strength. This can result in a surface layer which looks similar to the parent material (although its colour has probably changed) but has the strength of a soil - this is called "residual soil". At some stage the weathered surface layer is exposed to the elements and fragments are transported down the slope. In this context a fragment could be a single sand grain, a boulder, or a landslide. The time scale could be anything from a few seconds to many thousands of years. The transported fragments often collect on the lower slopes and form a new soil layer that blankets the original slope - "colluvium". If material reaches a river or the sea it is deposited as "alluvium" or as a "marine deposit". With appropriate changes in river and sea level this material can again find itself on the surface to commence another cycle of weathering and erosion. In places often, but not only, near the coast, this can include sand sized fragments which form beaches and are sometimes blown back onto the land to form dunes.

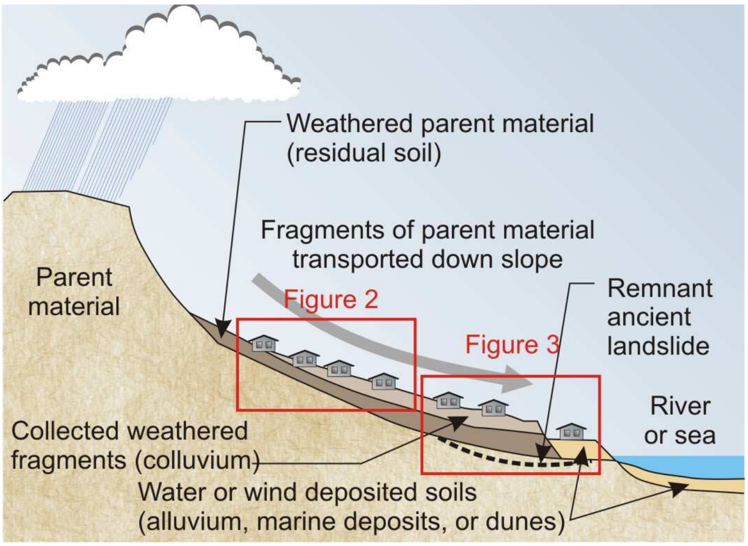

Figure 1

Landslides can occur almost anywhere on a soil slope. Slides can be rotational, translational, or debris flows (see GeoGuide LR2) and may have a number of causes.

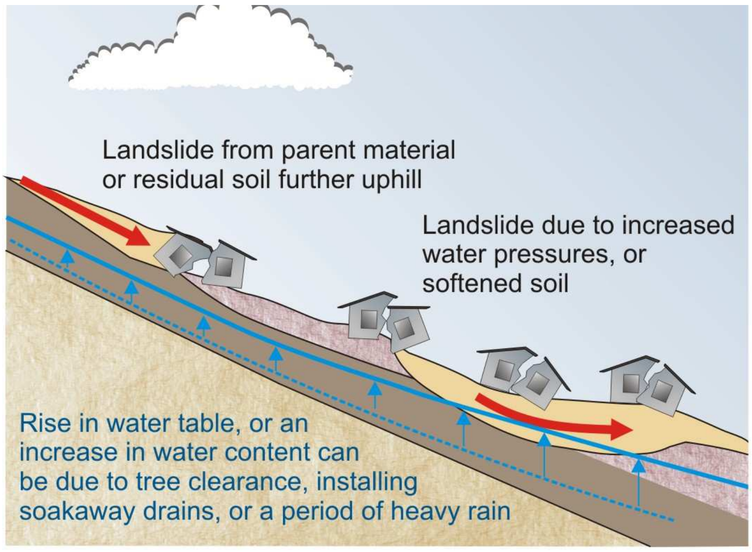

Figure 2

AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

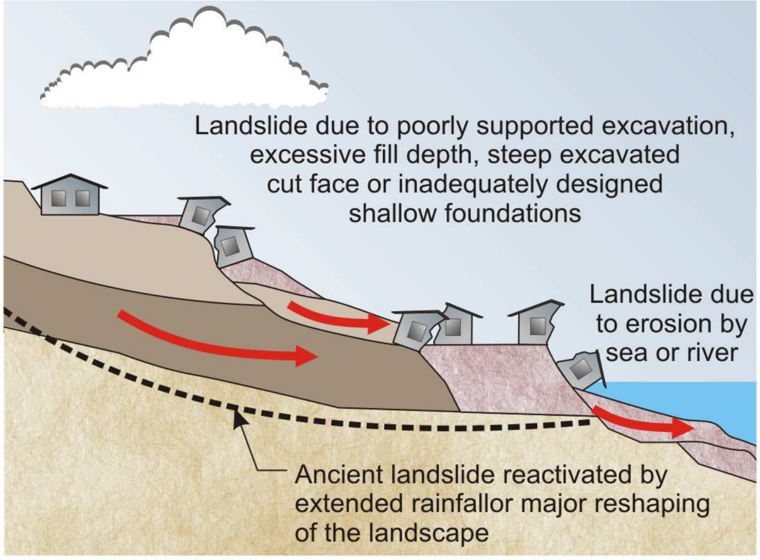

Figure 3

Some of the more common causes of landslides in soil are:

1) Falls of the parent material or residual soil from above, due to natural weathering processes (Figure 2).
2) Increased moisture content and consequent softening of the soil, or a rise in the water table. These can be due to excessive tree clearance, ill-considered soak-away drainage or septic systems, or heavy rainfall (Figure 2).
3) Excavation without adequate support, increased surface load from fill placement, or inadequately designed shallow foundations (Figure 3).
4) Natural erosion at the toe of the slope due to scour by a river or the sea (Figure 3).
5) Re-activation of an ancient landslide (Figure 3).

Most soil slopes appear stable, but they all achieved their present shape through a process of weathering and erosion and are often sensitive to minor changes in the factors that affect their stability. As a general rule, human activities only improve the situation if they have been designed to do so. Once this idea is understood, it is probably easy to see why the following basic rules are so important and should not be ignored without seeking site specific advice from a geotechnical practitioner:

- Do not clear trees unnecessarily.
- Do not cut into a slope without supporting the excavated face with an engineer designed structure.
- Do not add weight to a slope by placing earth fill or constructing buildings with inadequately designed shallow foundations (Note: in certain circumstances weight is added to the toe of a slope to inhibit landslide movement, but this must be carried out in accordance with a proper engineering design).
- Do not allow water from storm water drains, or from septic waste or effluent disposal systems to soak into the ground where it could trigger a landslide.

More information in relation to good and poor hillside construction practice is given in GeoGuide LR8. With appropriate engineering input it is often possible to reduce the likelihood, or consequences, of a landslide and so reduce the risk to property and to life. Such measures can include the construction of properly designed storm water and sub-soil drains, surface protection (GeoGuide LR5) and retaining walls (GeoGuide LR6). **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.**

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
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- GeoGuide LR10 - Coastal Landslides
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LANDSLIDES IN ROCK

Rocks have been formed by many different geological processes and may have been subjected to intense pressure, large scale distortion, extreme temperature and chemical change. As a result there are many different rock types and their condition varies enormously. Rock strength varies and is often significantly reduced by the presence of discontinuities (GeoGuide LR1). You may think that rock lasts forever, but in reality it weathers under the combined effects of water, wind, chemical change, temperature variation, plant growth and animal activity and erodes with time. Rock is often the parent material that ends up forming soil slopes (GeoGuide LR3). Inevitably different rocks have different physical and chemical characteristics and they weather and erode to form different types of soil.

Weathering can lead to landslides (GeoGuide LR2) on rock slopes. The type of landslide depends on the nature of rock, the way it has weathered and the presence or absence of discontinuities. It is hard to generalise, though normally a specific combination of discontinuities and material types will be the determining factor and these are often underground and out of sight. Typical examples are provided in the figures 1 to 4. A geotechnical practitioner can assess the landslide risk and propose appropriate maintenance measures. This often entails making geological observations over an area significantly larger than the site and a review of available background information, including records of known landslides and aerial photographs. Depending on the amount of information available, geotechnical investigation may or may not be needed. Every site is different and every site has to be assessed individually.

<u>It is impossible to predict exactly when a landslide will occur on a rock slope, but failure is normally sudden and the consequences can be catastrophic.</u>

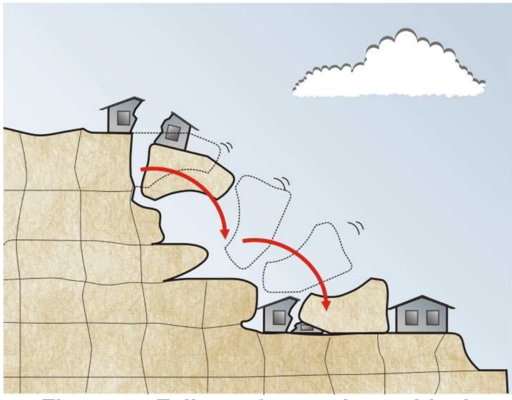

Figure 1 - Failure of an undercut block

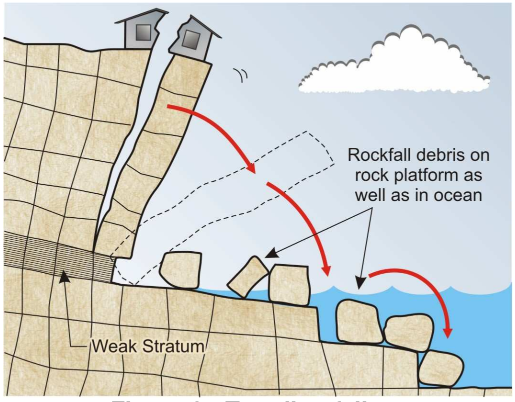

Figure 2 - Toppling failure

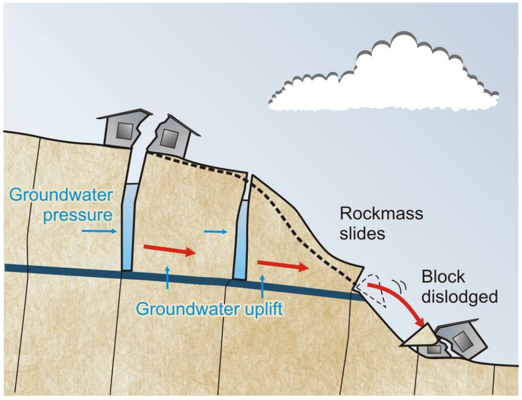

Figure 3 - Block slide on weak layer

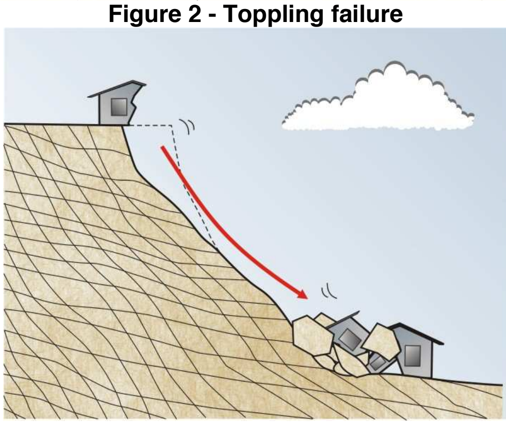

Figure 4 - Wedge failure along discontinuities

If the landslide risk is assessed as being anything other that Low, or Very Low, (GeoGuide LR7) it may be possible to carry out work aimed at reducing the level of risk.

The most common options are:

1) Trimming the slope to remove hazardous blocks of rock.
2) Bolting, or anchoring, to fix hazardous blocks in position and prevent movement.
3) Installation of catch fences and other rockfall protection measures to limit the impact of rockfalls.
4) Deep drainage designed to limit changes in the ground water table (GeoGuide LR5).

Although such measures can be effective, they need inspection and on-going maintenance (GeoGuide LR11) if they are to be effective for periods equivalent to the life of a house. **<u>Design should be undertaken by a geotechnical practitioner and will normally require local council approval.</u>** It should be appreciated that it may not be viable to carry out remedial works in all circumstances: for example where the landslide is on someone else's property, where the cost is out of proportion to the value of the property, or where the risk inherent in carrying out the work is actually greater than the risk of leaving things as they are. In situations such as these, development may be considered inappropriate.

ROCK SLOPE HAZARD REDUCTION MEASURES

Removal of loose blocks - may be effective but, depending on rock type, ongoing erosion can result in more blocks becoming unstable within a matter of years. Routine inspection, every 5 or so years, may be required to detect this.

Rock bolts and rock anchors (Figure 5) - can be installed in the ground to improve its strength and prevent individual blocks from falling. Rock bolts are usually tightened using a torque wrench, whilst rock anchors carry higher loads and require jacking. Both can be designed to be "permanent" using stainless steel, or sheathing, to inhibit corrosion, but the cost can be up to 10 times that of the "temporary" alternative. You should inspect rock bolts and rock anchors for signs of water seepage, rusting and deterioration around the heads at least once every 5 years. If you notice any of these warning signs, have them checked by a geotechnical practitioner. It is recommended that you keep copies of design drawings and maintenance records (GeoGuide LR11) for the anchors on your site and pass them on to the new owner should you sell.

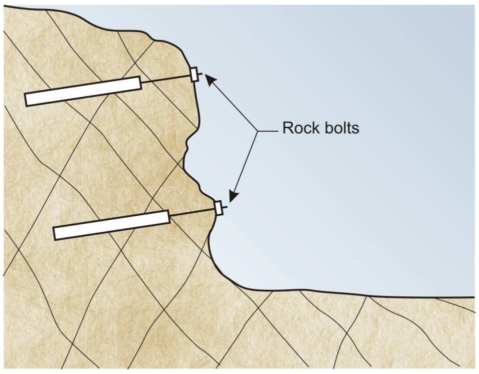

Figure 5

Rock fall netting, catch fences and catch pits (Figure 6) - are designed to catch or control falling rocks and prevent them from damaging nearby property. You should inspect them at least once every 5 years, and after major falls, and arrange for fallen and trapped rocks to be removed if they appear to be filling up. Check for signs of corrosion and replace steel elements and fixings before they lose significant strength.

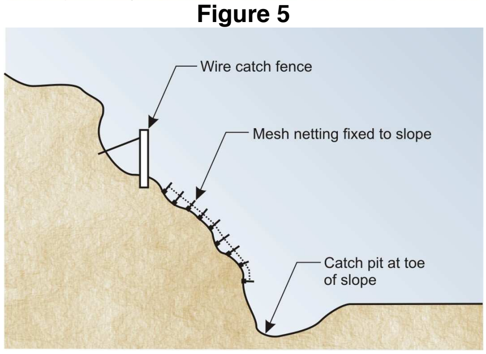

Figure 6

Cut-off drains (Figure 7) - can be used to intercept surface water run-off and reduce flows down the cliff face. Suitable drains are often excavated into the rock, or constructed from mounds of concrete, or stabilised soil, depending on conditions. Drains must be laid to a fall of at least 1% so they drain adequately. Frequent inspection is needed to ensure they are not blocked and continue to function as intended.

Clear trees and large bushes (Figure 7) - from slopes since roots can prize boulders from the face increasing the landslide hazard.

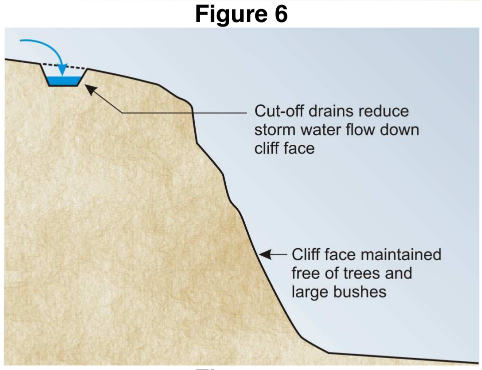

Figure 7

Natural cliffs and bluffs - often present the greatest hazard and yet are easily overlooked, because they have "been there forever". They can exist above a building, road, or beach, presenting the risk of a rock falling onto whatever is below. They also sometimes support buildings with a fine view to the horizon. Cliffs should be observed frequently to ensure that they are not deteriorating. You may find it convenient to use binoculars to look for signs of exposed "fresh" rock on the face, where a recent fall has occurred, or to go to the foot of the cliff from time to time to see if debris is collecting. A thorough inspection of a cliff face is often a major task requiring the use of rope access methods and should only be undertaken by an appropriately qualified professional. If tension cracks are observed in the ground at the top of a cliff take immediate action, since they could indicate imminent failure. **If you have any concerns at all about the possibility of a rock fall seek advice from a geotechnical practitioner.**

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WATER, DRAINAGE & SURFACE PROTECTION

One way or another, water usually plays a critical part in initiating a landslide (GeoGuide LR2). For this reason, it is a key factor to be controlled on sites with more than a low landslide risk (GeoGuide LR7).

Groundwater and Groundwater Flow

The ground is permeable and water flows through it as illustrated in Figure 1. When rain falls on the ground, some of it runs along the surface ("surface water run-off") and some soaks in, becoming groundwater. Groundwater seeps downwards along any path it can find until it meets the water table: the local level below which the ground is saturated. If it reaches the water table, groundwater either comes to a halt in what is effectively underground storage, or it continues to flow downwards, often towards a spring where it can seep out and become surface water again. Above the water table the ground is said to be "partially saturated", because it contains both water and air. Suctions can develop in the partially saturated zone which have the effect of holding the ground together and reducing the risk of a landslide. Vegetation and trees in particular draw large quantities of water out of the ground on a daily basis from the partially saturated zone. This lowers the water table and increases suctions, both of which reduce the likelihood of a landslide occurring.

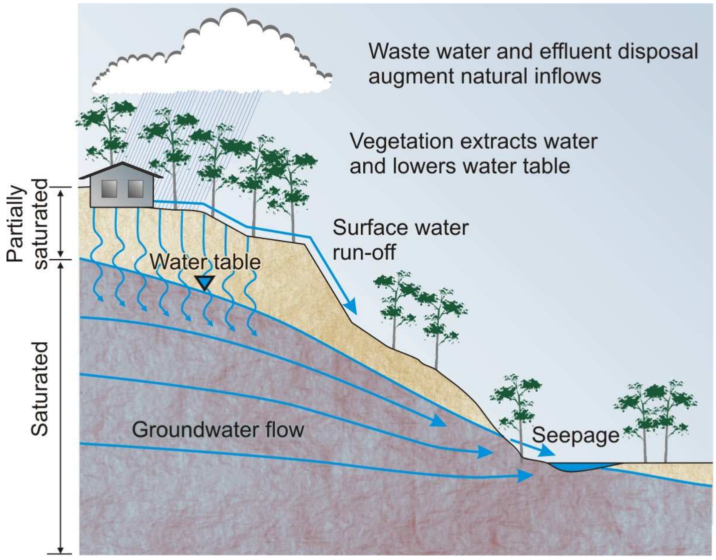

Figure 1 - Groundwater flow

Groundwater Flow and Landslides

The landslide risk in a hillside can be affected by increase in soak-away drainage or the construction of retaining walls which inhibit groundwater flow. The groundwater is likely to rise after heavy rain, but it can also rise when human interference upsets the delicate natural balance. Activities such as felling trees and earthworks can lead to:

- a reduction in the beneficial suctions in the partially saturated zone above the water table.
- increased static water pressures below the water table,
- increased hydraulic pressures due to groundwater flow,
- loss of strength, or softening, of clay rich strata,
- loss of natural cementing in some strata,
- transportation of soil particles.

Any of these effects, or a combination of them, can lead to landslides like those illustrated in GeoGuides LR2, LR3 and LR4.

Limiting the Effect of Water

Site clearance and construction must be carefully considered if changes in groundwater conditions are to be limited. GeoGuide LR8 considers good and poor development practices. Not surprisingly much of the advice relates to sensible treatment of water and is not repeated here. Adoption of appropriate techniques should make it possible to either maintain the current ground water table, or even cause it to drop, by limiting inflow to the ground.

If drainage measures and surface protection are relied on to keep the risk of a landslide to a tolerable level, it is important that they are inspected routinely and maintained (GeoGuide LR11).

The following techniques may be considered to limit the destabilising effects of rising groundwater due to development and are illustrated in Figure 2.

AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

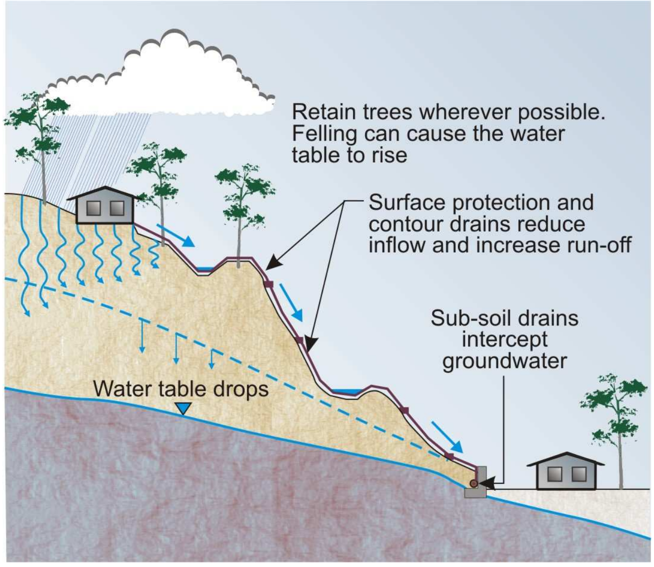

Figure 2 - Techniques used to control groundwater flow

Surface water drains (dish drains, or table drains) - are often used to prevent scour and limit inflow to a slope. Other than in rock, they are relatively ineffective unless they have an impermeable lining. You should clear them regularly, and as required, and not less than once a year. If you live in an area with seasonal rainfall, it is best to do this near the end of the dry season. If you notice that soil or rock debris is falling from the slope above, determine the source and take appropriate action. This may mean you have to seek advice from a geotechnical practitioner.

Surface protection - is sometimes used in addition to surface water drainage to prevent scour and minimise water inflow to a slope. You should inspect concrete, shotcrete or stone pitching for cracking and other signs of deterioration at least once a year. Make sure that weepholes are free of obstructions and able to drain. If the protection is deteriorating, you should seek advice from a geotechnical practitioner.

Sub-soil drains - are often constructed behind retaining walls and on hillsides to intercept groundwater. Their function is to remove water from the ground through an appropriate outlet. It is important that subsoil drains are designed to complement other measures being used. They should be laid in a sand, or gravel, bed and protected with a graded stone or geotextile filter to reduce the chance of clogging. Sub-soil drains should always be laid to a fall of at least 1 vertical on 100 horizontal. Ideally the high end should be brought to the surface, so it can be flushed with water from time to time as part of routine maintenance procedures.

Deep, underground drains - are usually only used in extreme circumstances, where the landslide risk is assessed as not being tolerable and other stabilisation measures are considered to be impractical. They work by permanently lowering the water table in a slope. They are not often used in domestic scale developments, but if you have any on your site be aware that professional maintenance is essential. If they are not maintained and stop working, the water table will rise and a landslide may even occur during normal weather conditions. Both an increase or a reduction in the normal flow from deep drains could indicate a problem if it appears to be unrelated to recent rainfall. If changes of this sort are observed, you should have the drains and your site checked by a geotechnical practitioner.

Documentation - design drawings and specifications for geotechnical measures intended to minimise landslide risk can be of great assistance to a geotechnical specialist, or structural engineer, called in to inspect and report on them. Copies of available documentation should be retained and passed to the new owner when the property is sold (GeoGuide LR11). You should also request details of an appropriate maintenance program for drainage works from the designer and keep that information with other relevant documentation and maintenance records.

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RETAINING WALLS

Retaining walls are used to support cuts and fills. Some are built in the open and backfill is placed behind them (gravity walls). Others are inserted into the ground (cast *in situ* or driven piles) and the ground is subsequently excavated on one side. Retaining walls, like all man-made structures, have a finite life. Properly engineered walls should last 50 years, or more, without needing significant repairs. However, not all walls fit this category. Some, particularly those built by inexperienced tradesmen without engineering input, can deflect and even fail because they are unable to withstand the pressures that develop in the ground around them or because the materials from which they are built deteriorate with time. **Design of retaining walls more than 900mm high should be undertaken by a geotechnical practitioner or structural engineer and normally require local council approval.**

Retaining walls have to withstand the weight of the ground on the high side, any water pressure forces that develop, any additional load (surcharge) on the ground surface and sometimes swelling pressures from expansive clays. These forces are resisted by the wall itself and the ground on the low side. Engineers calculate the forces that the retained ground, the water, and the surcharge impose on a wall (the disturbing force) as well as the maximum force that the wall and ground on the low side can provide to resist them (the restoring force). The ratio of the restoring force to the disturbing force is called the "factor of safety" (GeoGuide LR1). Permanent retaining walls designed in accordance with accepted engineering standards will normally have a factor of safety in the range 1.5 to 2.

Never add surcharge to the high side of a wall (e.g. place fill, erect a structure, stockpile bulk materials, or park vehicles) unless you know the wall has been designed with that purpose in mind.

Never more than lightly water plants on the high side of a retaining wall.

Never excavate at the toe of a retaining wall.

Any of these actions will reduce the factor of safety of the wall and could lead to failure. If in doubt about any aspect of an existing retaining wall, or changes you would like to make near one, seek advice from a geotechnical practitioner, or a structural engineer. This GeoGuide sets out basic inspection requirements for retaining walls and identifies some common signs that might indicate all is not well. GeoGuide LR11 provides information about records that should be kept.

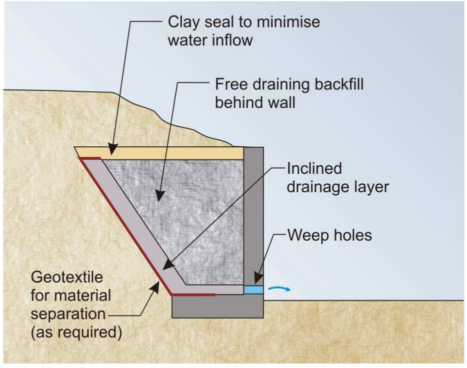

Figure 1- Typical formed concrete wall

GRAVITY WALLS

Gravity walls are so called because they rely on their own weight (the force of gravity) to hold the ground behind in place.

Formed concrete and reinforced blockwork walls (Figure 1) **-** should be built so the backfill can drain. They should be inspected at least once a year. Look for signs of tilting, bulging, cracking, or a drop in ground level on the high side, as any of these may indicate that the wall has started to fail. Look for rust staining, which may indicate that the steel reinforcement is deteriorating and the wall is losing structural strength ("concrete cancer"). Ensure that weep holes are clear and that water is able to drain at all times, as high water pressures behind the wall can lead to sudden and catastrophic failure.

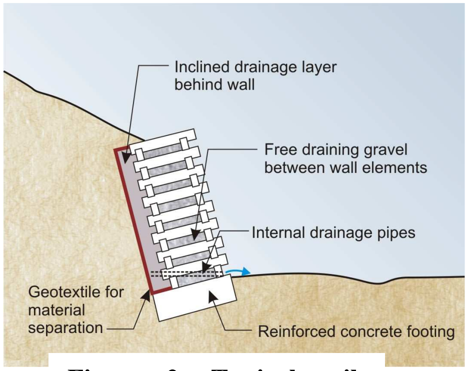

Figure 2 -Typical crib

Concrete "crib" walls (Figure 2) **-** should be filled with clean gravel, or "blue metal" with a nominated grading. Sometimes soil is used to reduce cost, but this is undesirable, from an engineering perspective, unless internal drainage is incorporated in the wall's construction. Without backfill drainage, a soil filled crib wall is likely to have a lower factor of safety than is required. Crib walls should be inspected as for formed concrete walls. In addition, you should check that material is not being lost through the structure of the wall, which has large gaps through it.

Timber "crib" walls - should be checked as for concrete crib walls. In addition, check the condition of the timber. Once individual elements show signs of rotting, it is necessary to have the wall replaced. If you are uncertain seek advice from a geotechnical practitioner, or a structural engineer.

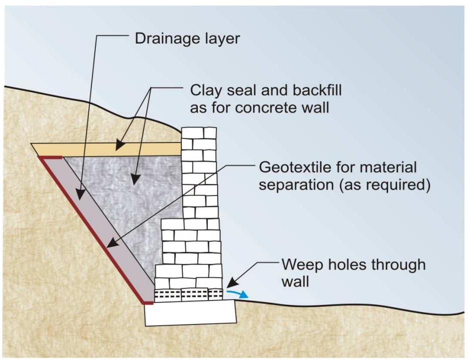

Figure 3 -Typical masonry wall

Masonry walls: natural stone, brick, or interlocking blocks (Figure 3) - more than about 1m high, should be wider at the bottom than at the top and include specific measures to permit drainage of the backfill. They should be checked as for formed concrete walls. Natural stone walls should be inspected for signs of deterioration of the individual blocks: strength loss, corners becoming rounded, cracks appearing, or debris from the blocks collecting at the foot of the wall.

Old Masonry walls (Figure 4) - Many old masonry retaining walls have not been built in accordance with modern design standards and often have a low "factor of safety" (GeoGuide LR1). They may therefore be close to failure and a minor change in their condition, or loading, could initiate collapse. You need to take particular care with such structures and seek professional advice sooner rather than later. Although masonry walls sometimes deflect significantly over long periods of time collapse, when it occurs, is usually sudden and can be catastrophic. Familiarity with a particular situation can instil a false sense of confidence.

Reinforced soil walls (Figure 5) **-** are made of compacted select fill in which layers of reinforcement are buried to form a "reinforced soil zone". The reinforcement is all important, because it holds the soil "wall" together. Reinforcement may be steel strip, or mesh, or a variety of geosynthetic ("plastic") products. The facing panels are there to protect the soil "wall" from erosion and give it a finished appearance.

Most reinforced soil walls are proprietary products. Construction should be carried out strictly in accordance with the manufacturer's instructions. Inspection and maintenance should be the same as for formed concrete and concrete block walls. If unusual materials such as timber, or used tyres, are used as a facing it should be checked to see that it is not rotting, or perishing.

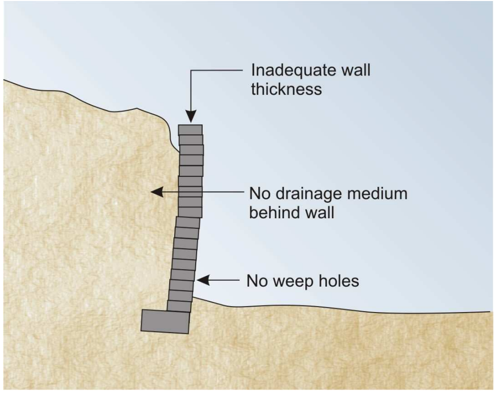

Figure 4 - Poorly built masonry wall

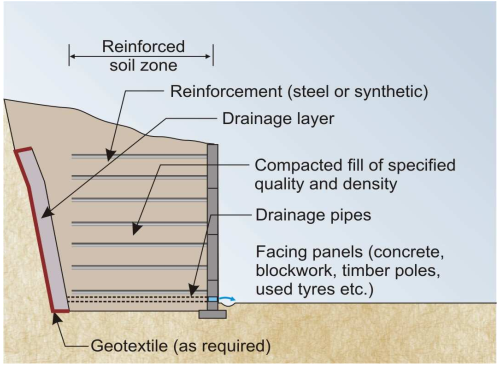

Figure 5 - Typical reinforced soil wall

OTHER WALLS

Cantilevered and anchored walls (Figure 6) **-** rely on earth pressure on the low side, rather than self-weight, to provided the restoring force and an adequate factor of safety. These walls may comprise:

- a line of touching bored piers (contiguous bored pile wall) or
- sprayed concrete panels between bored piers (shotcrete wall) or
- horizontal timber or concrete planks spanning between upright timber or steel soldier piles or
- steel sheet piles.

Depending on the form of construction and ground conditions, walls in excess of 3 m height normally require at least one row of permanent ground anchors.

INSPECTION

All walls should be inspected at least once a year, looking for tilting and other signs of deterioration. Concrete walls should be inspected for cracking and rust stains as for formed concrete gravity walls. Contiguous bored pile walls can have gaps between the piles - look for loss of soil from behind which can become a major difficulty if it is not corrected. Timber walls should be inspected for rot, as for timber crib walls. Steel sheet piles should be inspected for signs of rusting. In addition, you should make sure that ground anchors are maintained as described in GeoGuide LR4 under the heading "Rock bolts and rock anchors".

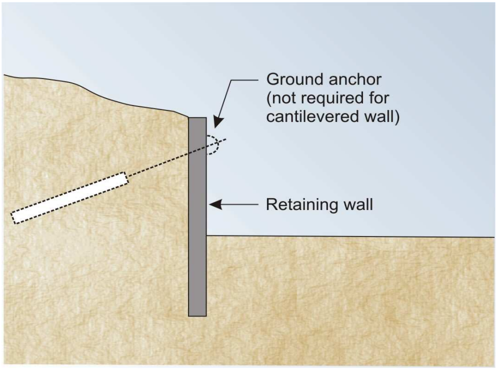

Figure 6 - Typical cantilevered or anchored wall

One of the most important issues for walls is that their internal drainage systems are operational. Frequently verify that internal drainage pipes and surface interception drains around the wall are not blocked nor have become inoperative.

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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 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

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 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**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.
High	H	**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.
Moderate	M	**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.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

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 averse 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 property also stipulate a tolerable risk to life. 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

Risk (deaths per participant per year)	**Activity/Event Leading to Death** (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding , ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

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

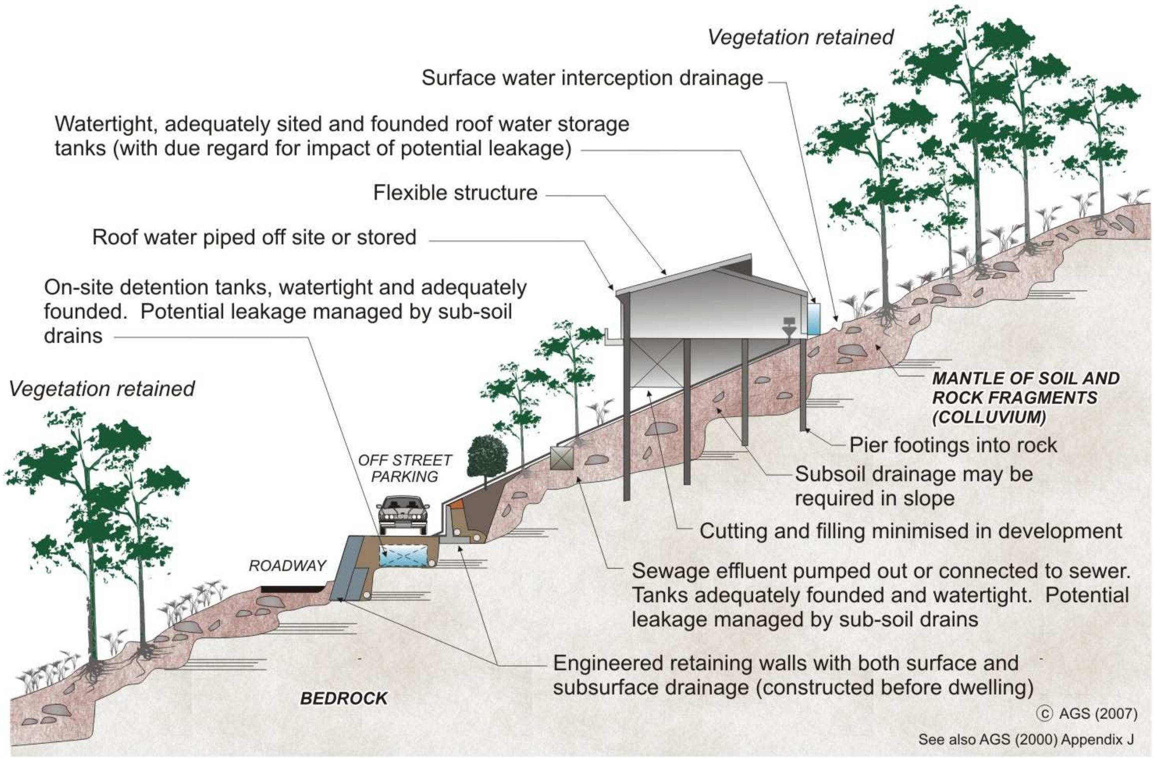
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to 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 geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

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.

EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



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 fulfil 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, or is essentially a soil slope, 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.

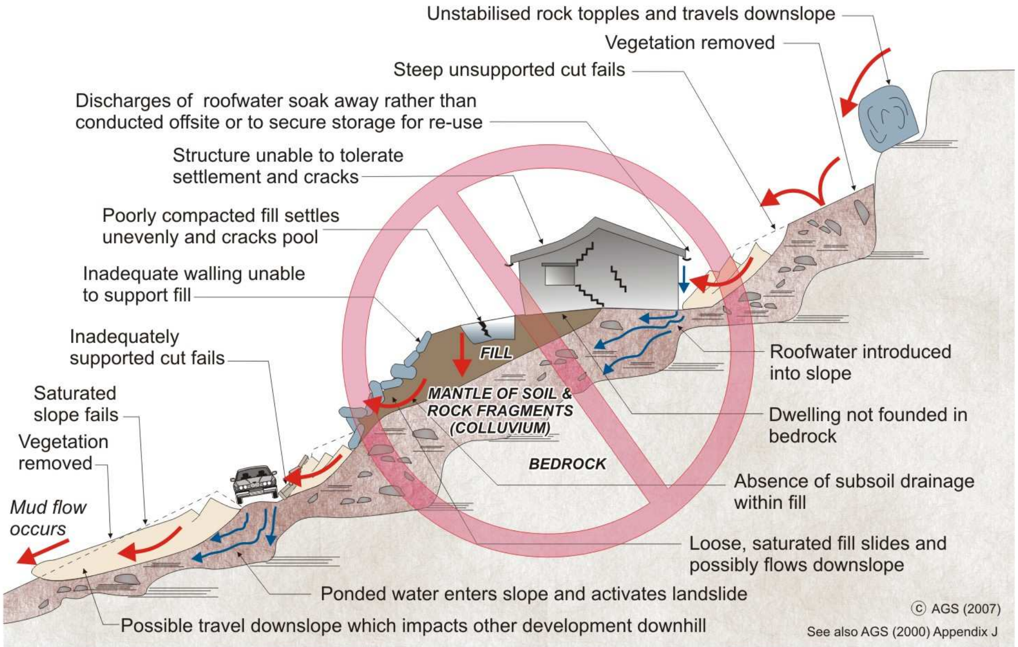
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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 GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



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:

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- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

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APPENDIX B

Soil & Rock Explanation Sheets
Borehole Logs

Soil and Rock Explanation Sheets (1 of 2)

LOG ABBREVIATIONS AND NOTES

METHOD

borehole logs		*excavation logs*	
AS	auger screw *	NE	natural excavation
AD	auger drill *	HE	hand excavation
RR	roller / tricone	BH	backhoe bucket
W	washbore	EX	excavator bucket
CT	cable tool	DZ	dozer blade
HA	hand auger	R	ripper tooth
D	diatube		
B	blade / blank bit		
V	V-bit		
T	TC-bit		

* bit shown by suffix e.g. ADV

coring
NMLC, NQ, PQ, HQ

SUPPORT

borehole logs		*excavation logs*	
N	nil	N	nil
M	mud	S	shoring
C	casing	B	benched
NQ	NQ rods		

CORE—LIFT

casing installed

barrel withdrawn

NOTES, SAMPLES, TESTS

D	disturbed
B	bulk disturbed
U50	thin-walled sample, 50mm diameter
HP	hand penetrometer (kPa)
SV	shear vane test (kPa)
DCP	dynamic cone penetrometer (blows per 100mm penetration)
SPT	standard penetration test
N*	SPT value (blows per 300mm) * denotes sample taken
Nc	SPT with solid cone
R	refusal of DCP or SPT

USCS SYMBOLS

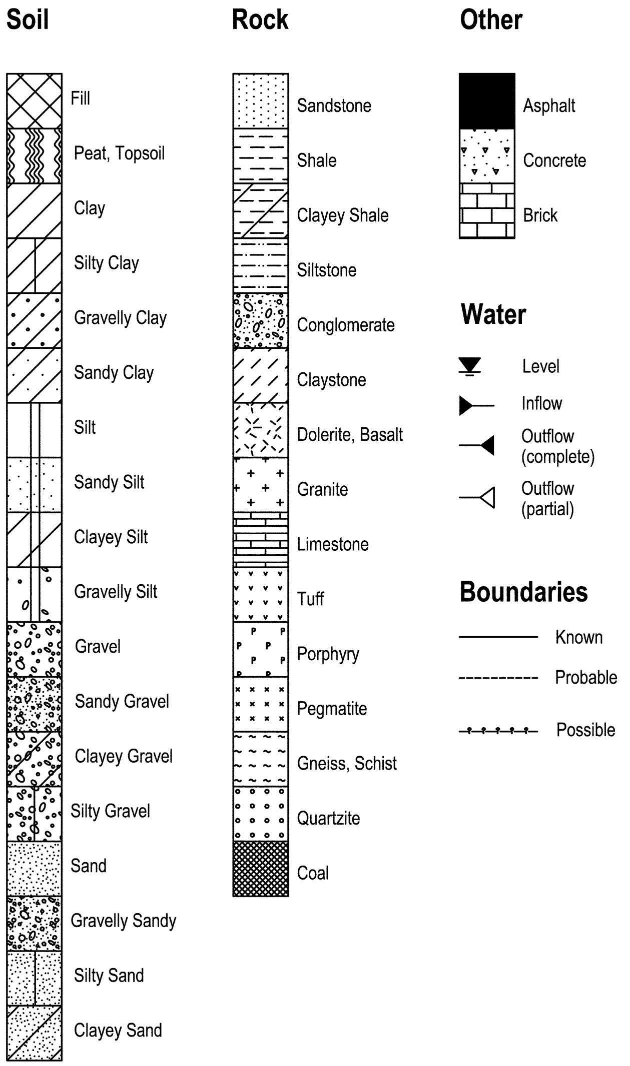
GW	Well graded gravels and gravel-sand mixtures, little or no fines.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines.
GM	Silty gravels, gravel-sand-silt mixtures.
GC	Clayey gravels, gravel-sand-clay mixtures.
SW	Well graded sands and gravelly sands, little or no fines.
SP	Poorly graded sands and gravelly sands, little or no fines.
SM	Silty sand, sand-silt mixtures.
SC	Clayey sand, sand-clay mixtures.
ML	Inorganic silts of low plasticity, very fine sands, rock flour, silty or clayey fine sands.
CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
OL	Organic silts and organic silty clays of low plasticity.
MH	Inorganic silts of high plasticity.
CH	Inorganic clays of high plasticity.
OH	Organic clays of medium to high plasticity.
PT	Peat muck and other highly organic soils.

MOISTURE CONDITION

D	dry
M	moist
W	wet
Wp	plastic limit
Wl	liquid limit

CONSISTENCY		**DENSITY INDEX**	
VS	very soft	VL	very loose
S	soft	L	loose
F	firm	MD	medium dense
St	stiff	D	dense
VSt	very stiff	VD	very dense
H	hard		
Fb	friable		

GRAPHIC LOG



WEATHERING		**STRENGTH**	
XW	extremely weathered	EL	extremely low
HW	highly weathered	VL	very low
MW	moderately weathered	L	low
SW	slightly weathered	M	medium
FR	fresh	H	high
		VH	very high
		EH	extremely high

RQD (%)

$$= \frac{\text{sum of intact core pieces} > 2 \times \text{diameter}}{\text{total length of section being evaluated}} \times 100$$

DEFECTS

type		*coating*	
JT	joint	cl	clean
PT	parting	st	stained
SZ	shear zone	ve	veneer
SM	seam	co	coating

shape		**roughness**	
pl	planar	po	polished
cu	curved	sl	slickensided
un	undulating	sm	smooth
st	stepped	ro	rough
ir	irregular	vr	very rough

inclination
measured above axis and perpendicular to core

Soil and Rock Explanation Sheets (2 of 2)

AS1726-1993

Soils and rock are described in the following terms, which are broadly in accordance with AS1726-1993.

SOIL

MOISTURE CONDITION

Term	Description
Dry	Looks and feels dry. Cohesive and cemented soils are hard, friable or powdery. Uncemented granular soils run freely through the hand.
Moist	Feels cool and darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet	As for moist, but with free water forming on hands when handled.

Moisture content of cohesive soils may also be described in relation to plastic limit (W_P) or liquid limit (W_L) [>> much greater than, > greater than, < less than, << much less than].

CONSISTENCY OF COHESIVE SOILS

Term	Su (kPa)	Term	Su (kPa)
Very soft	< 12	Very Stiff	100 – 200
Soft	12 – 25	Hard	> 200
Firm	25 – 50	Friable	–
Stiff	50 – 100		

DENSITY OF GRANULAR SOILS

Term	Density Index(%)	Term	Density Index (%)
Very Loose	< 15	Dense	65 – 85
Loose	15 – 35	Very Dense	>85
Medium Dense	35 – 65		

PARTICLE SIZE

Name	Subdivision	Size (mm)
Boulders		> 200
Cobbles		63 – 200
Gravel	coarse	20 – 63
	medium	6 – 20
	fine	2.36 – 6
Sand	coarse	0.6 – 2.36
	medium	0.2 – 0.6
	fine	0.075 – 0.2
Silt & Clay		< 0.075

MINOR COMPONENTS

Term	Proportion by Mass	
	coarse grained	fine grained
Trace	≤ 5%	≤ 15%
Some	5 – 2%	15 – 30%

SOIL ZONING

Layers	Continuous exposures.
Lenses	Discontinuous layers of lenticular shape.
Pockets	Irregular inclusions of different material.

SOIL CEMENTING

Weakly	Easily broken up by hand.
Moderately	Effort is required to break up the soil by hand.

USCS SYMBOLS

Symbol	Description
GW	Well graded gravels and gravel-sand mixtures, little or no fines.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines.
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GC	Clayey gravels, gravel-sand-clay mixtures.
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OH	Organic clays of medium to high plasticity.
PT	Peat muck and other highly organic soils.

ROCK

SEDIMENTARY ROCK TYPE DEFINITIONS

Rock Type	Definition (more than 50% of rock consists of .....)
Conglomerate	... gravel sized (>2mm) fragments.
Sandstone	... sand sized (0.06 to 2mm) grains.
Siltstone	... silt sized (<0.06mm) particles, rock is not laminated.
Claystone	... clay, rock is not laminated.
Shale	... silt or clay sized particles, rock is laminated.

LAYERING

Term	Description
Massive	No layering apparent.
Poorly Developed	Layering just visible. Little effect on properties.
Well Developed	Layering distinct. Rock breaks more easily parallel to layering.

STRUCTURE

Term	Spacing (mm)	Term	Spacing
Thinly laminated	<6	Medium bedded	200 – 600
Laminated	6 – 20	Thickly bedded	600 – 2,000
Very thinly bedded	20 – 60	Very thickly bedded	> 2,000
Thinly bedded	60 – 200		

STRENGTH

Term	Is50 (MPa)	Term	Is50 (MPa)
Extremely Low	<0.03	High	1.0 – 3.0
Very low	0.03 – 0.1	Very High	3.0 – 10.0
Low	0.1 – 0.3	Extremely High	>10.0
Medium	0.3 – 1.0		

NOTE: Is50 = Point Load Strength Index

WEATHERING

Term	Description
Residual Soil	Soil derived from weathering of rock; the mass structure and substance fabric are no longer evident.
Extremely	Rock is weathered to the extent that it has soil properties (either disintegrates or can be remoulded). Fabric of original rock is still visible.
Highly	Rock strength usually highly changed by weathering; rock may be highly discoloured.
Moderately	Rock strength usually moderately changed by weathering; rock may be moderately discoloured.
Slightly	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	Rock shows no signs of decomposition or staining.

DEFECT DESCRIPTION

Type

Joint	A surface or crack across which the rock has little or no tensile strength. May be open or closed.
Parting	A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering/ bedding. May be open or closed.
Sheared Zone	Zone of rock substance with roughly parallel, near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects.
Seam	Seam with deposited soil (infill), extremely weathered insitu rock (XW), or disoriented usually angular fragments of the host rock (crushed).

Shape

Planar	Consistent orientation.
Curved	Gradual change in orientation.
Undulating	Wavy surface.
Stepped	One or more well defined steps.
Irregular	Many sharp changes in orientation.

Roughness

Polished	Shiny smooth surface.
Slickensided	Grooved or striated surface, usually polished.
Smooth	Smooth to touch. Few or no surface irregularities.
Rough	Many small surface irregularities (amplitude generally <1mm). Feels like fine to coarse sandpaper.
Very Rough	Many large surface irregularities, amplitude generally >1mm. Feels like very coarse sandpaper.

Coating

Clean	No visible coating or discolouring.
Stained	No visible coating but surfaces are discolored.
Veneer	A visible coating of soil or mineral, too thin to measure; may be patchy
Coating	Visible coating ≤1mm thick. Thicker soil material described as seam.

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Borehole Log

BH no: BH1

job no.: 3315

client:	KDC Group	**started:**	9.9.2015
principal:		**finished:**	9.9.2015
project:	'Diamond' Apartment Building	**logged:**	MA
location:	7-9 Bent street, Gosford	**checked:**	MAG
equipment:	Comacchio MCT200 Ute Mounted	**RL surface:**	approx.
diameter:	100mm **inclination:** -90° **bearing:** --- **E:** **N:**	**datum:**	AHD

drilling information						material information						
method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material description soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	hand penetro-meter kPa 100 200 300 400	structure and additional observations
HA	N	None observed			0.0		OH	ORGANIC SOIL, fine grained, dark brown	W	VS		Topsoil
					0.1			CONCRETE	--	--		CONCRETE
					0.15		SM	Silty SAND/ sandy SILT, fine to medium grained, mottled red / brown	M	MD		FILL
ADT			SPT 3,5,8 N*=13		0.5–1.0							HA refusal
					1.2		SC	Clayey SAND, fine to medium grained, mottled light grey/brown, with layers of yellow Sand at depth 1.5-2 m	D	D		RESIDUAL
			SPT 10,14,16 N*=30		1.5–2.0							
					2.9			Borehole No: BH1 continued as cored hole from 2.9m				TC refusal

REFER TO EXPLANATION SHEETS FOR DESCRIPTION OF TERMS AND SYMBOLS USED

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Cored Borehole Log

BH no:	**BH1**
sheet:	2 of 3
job no.:	3315

client:	KDC Group	**started:**	9.9.2015
principal:		**finished:**	9.9.2015
project:	'Diamond' Apartment Building	**logged:**	MA
location:	7-9 Bent street, Gosford	**checked:**	MAG
equipment:	Comacchio MCT200 Ute Mounted	**RL surface:**	
diameter:	100mm **inclination:** -90° **bearing:** --- **E:** **N:**	**datum:**	AHD

drilling information | **material information** | **rock mass defects**

method	support & core-lift	water	RL	depth metres	graphic log / core recovery	rock substance description (rock type; grain characteristics, colour, structure, minor components)	weathering	estimated strength (MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH)	$Is_{(50)}$ MPa (D=diametral × A=axial ○)	RQD %	defect spacing mm (20 60 200 600 2000)	defect description (type, inclination, thickness, shape, roughness, coating) specific / general
		None observed		2.5		Continued from non-cored borehole from 2.9m						
NMLC				2.9 – 3.0		SAND STONE / Mudstone, mottled orange brown to red brown / grey with layer of Claystone at depth of 4.0-4.15 m	MW - SW		D=0.04 A=0.31			drilling break
												Clay SM
				4.0					D=0.24 A=0.15			Clay SM
												JT 45°st ro ve
				4.5								Clay SM
												Clay SM
				5.0					D=0.51 A=0.13			JT, 30°, un, ro, cl (general)
				5.7		SANDSTONE with Carbonaceous lamination, grey	SW					
				6.0					D=0.21 A=0.95			Clay SM
				6.3		SANDSTONE, light to dark grey, coarse grained, with caoglomera layer between depth of 8.66-8.80 m	SW - FR					
		None observed		6.5 – 7.0								Clay SM

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Cored Borehole Log

BH no:	BH1
sheet:	3 of 3
job no.:	3315

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principal:		finished:	9.9.2015
project:	'Diamond' Apartment Building	logged:	MA
location:	7-9 Bent street, Gosford	checked:	MAG
equipment:	Comacchio MCT200 Ute Mounted	RL surface:	
diameter:	100mm inclination: -90° bearing: --- E: N:	datum:	AHD

drilling information | **material information** | **rock mass defects**

method	support & core-lift	water	RL	depth metres	graphic log core recovery	rock substance description (rock type; grain characteristics, colour, structure, minor components)	weathering	estimated strength (MPa: EL 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH)	$Is_{(50)}$ MPa (D=diametral × A=axial ○)	RQD %	defect spacing mm (20 60 200 600 2000)	defect description (type, inclination, thickness, shape, roughness, coating) specific	general
NMLC						SANDSTONE, light to dark grey, coarse grained, with caoglomera layer between depth of 8.66-8.80 m *(continued)*	SW - FR		D=1.04 A=1.1				
				7.5									
				8.0					D=0.86 A=1.04				
				8.5								PT ir vr st	
				9.0					D=0.98 A=0.71				JT, 30°, un, ro, cl
				9.5									
				10.0					D=0.73 A=1.12				
				10.5									
			10.9	11.0		SANDSTONE, dark grey, fine grained			D=0.27 A=0.67				
				11.5									
			11.9	12.0		BH1 terminated at 11.9m							

issue	date	description
A	14.09.15	INITIAL ISSUE

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PROPOSED "DIAMOND" APARTMENT
7–9 BENT STREET, GOSFORD
for
KDC GROUP

CORE PHOTOS – BH1

drawn: MA	**job no.:** 3315
date: 14.9.15	
checked: MAB	**fig:** —
scale: 1:4 A4	**issue:** A

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Borehole Log

BH no:	**BH2**
sheet:	1 of 1
job no.:	3315

client:	KDC Group	**started:**	9.9.2015
principal:		**finished:**	9.9.2015
project:	'Diamond' Apartment Building	**logged:**	MA
location:	7-9 Bent street, Gosford	**checked:**	MAG
equipment:	Comacchio MCT200 Ute Mounted	**RL surface:**	approx.
diameter:	100mm **inclination:** -90° **bearing:** --- **E:** **N:**	**datum:**	AHD

drilling information / **material information**

method	support	water	notes samples, tests, etc	RL	depth metres	graphic log	USCS symbol	material description (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency/ density index	hand penetrometer kPa (100 200 300 400)	structure and additional observations
HA	N	None observed					OH	ORGANIC SOIL, fine to medium grained, dark brown	W	S		TOPSOIL
					0.1		SM	SILTY SAND, fine to medium grained, mottled brown/red	M	D		RESIDUAL
					0.5							HA refusal
ADT			SPT 11,Rs N*=Rs		0.7		SP-SC	Clayey SAND, fine to medium grained, light grey	D	VD		RESIDUAL
					1.0							
					1.3			Borehole No: BH2 terminated at 1.3m				TC refusal
					1.5							
					2.0							
					2.5							
					3.0							
					3.5							
					4.0							
					4.5							
					5.0							

APPENDIX C

Laboratory Test Results

POINT LOAD STRENGTH INDEX REPORT

Client:	Asset Geotechnical	**Moisture Content Condition:**	As Received
Address:	Suite 2.05, 56 Delhi Road, North Ryde, NSW 2113	**Storage History:**	Core Box
Project:	Gosford (3315)	**Report No:**	S6226-PL
Job No:	S15262	**Date Tested:**	18/09/2015

Test Procedure: ☑ AS4133 4.1 Rock strength tests - Determination of point load strength index

Sampling: Sampled by Client **Date Sampled:** 09.09.15

Preparation: Prepared in accordance with the test method

Sample Number	Sample Source	Sample Description	Test Type	Average Width (mm)	Platen Separation (mm)	Failure Load (kN)	Point Load Index Is (MPa)	Point Load Index $Is_{(50)}$ (MPa)	Notes
S6226	BH1 3.05m	Sandstone	Diametral	-	51.0	0.10	0.04	0.04	
			Axial	52.0	19.0	0.46	0.37	0.31	
S6227	BH1 4.17m	Sandstone	Diametral	-	49.0	0.57	0.24	0.24	
			Axial	52.0	42.0	0.41	0.15	0.15	
S6228	BH1 5.10m	Sandstone	Diametral	-	50.0	1.28	0.51	0.51	
			Axial	52.0	36.0	0.31	0.13	0.13	
S6229	BH1 6.05m	Sandstone	Diametral	-	51.0	0.55	0.21	0.21	
			Axial	52.0	38.0	2.39	0.95	0.95	
S6230	BH1 7.10 m	Sandstone	Diametral	-	50.0	2.59	1.04	1.04	
			Axial	52.0	36.0	2.64	1.11	1.10	
S6231	BH1 8.10m	Sandstone	Diametral	-	50.0	2.16	0.86	0.86	
			Axial	52.0	39.0	2.67	1.03	1.04	
S6232	BH1 9.10m	Sandstone	Diametral	-	50.0	2.46	0.98	0.98	
			Axial	52.0	36.0	1.72	0.72	0.71	
S6233	BH1 10.10m	Sandstone	Diametral	-	51.0	1.89	0.73	0.73	
			Axial	52.0	39.0	2.86	1.11	1.12	
S6234	BH1 11.10m	Sandstone	Diametral	-	51.0	0.69	0.27	0.27	
			Axial	52.0	41.0	1.79	0.66	0.67	

Comments:

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced, except in full.

NATA Accredited Laboratory Number: 14874

Authorised Signatory:

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21/09/2015

Date:

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APPENDIX D

Table R3	Geotechnical Data
Table A	Preliminary Landslide Risk Assessment (Risk to Property)
Table B	Preliminary Landslide Risk Assessment (Risk to Life)

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Table R3 - Geotechnical Report Data
7-9 Bent Street, Gosford

Assessed by: Mark Bartel		**Assessment date:** 9 October 2015		
Lot No:	**Street No:** 7-9	**Street:** Bent Street	**Suburb:** Gosford	
SITE DATA		**Land Area 1 (entire site)**		
Site Classification (AS2870-2011):		P (Problem) site - due to slope instability risk		
Land Slope (degrees):		15°		
Geological abbreviation of underlying bedrock type:		Rnt		
Description of surficial soil:		Topsoil over Silty SAND (fill and residual)		
Type of Stability Risk:		Slump of steep excavation in soils, and rock wedge failure within rock excavation		
Risk Assessment (with respect to property):				
Hazard 1		Very High (Very Low after mitigation)		
Hazard 2		High (Low after mitigation)		
Risk Assessment (with respect to life):				
Hazard 1		Not Tolerable (Acceptable after mitigation)		
Hazard 2		Not Tolerable (Acceptable after mitigation)		
Geotechnical Inspections required during construction?		Yes		
Risks from adjoining land:		Not applicable		

Notes:

1. Refer Figure 3 Rev B in Report 3315-R1 for identification of Land Areas.
2. This table to be read in conjunction with Tables A and B of Report 3315-R1, which defines Hazards 1 and 2.

Table A - Landslide Risk Assessment (Risk to Property)
7-9 Bent Street, Gosford

Possible Hazards			Consequences (Note 2)	Assessed Likelihood	Risk (Note 1)	Risk Treatment and Comments
Failure Envisaged	**Failure Mode**	**Initiating Circumstances**				
Hazard 1 - Slump in steep excavation in soils	Slump	Rainfall, erosion, steep cut	Major	Likely (without mitigation)	**Very High**	Tempoary batter at no steeper than 1H:1V, or install temporary shoring
				Barely credible (with mitigation)	Very Low	
Hazard 2 - Rock wedge failure within rock excavation	Topple	Adversely oriented joints and defects	Major	Possible (without mitigation)	**High**	Inspect rock excavation at every 2m vertical lift and install temporary support as directed by geotechnical engineer
				Rare (with mitigation)	Low	

Notes:
1. The risk assessment addresses only the consequences to property from potential landslide events considered relevant to the subject site. Injury to persons or potential for fatality from land sliding is not assessed in this table (refer Table B). The risk assessment is based on a preliminary appraisal only, carried out by inspection. Further assessment or quantification of the assessed geotechnical risks for the subject property would require additional data and/or investigation.
2. The consequences are for a development that is designed to accomodate the potential landslide risk or has demonstrated adequate performance over many years.
3. Refer to report and associated figures for illustration of possible hazards / slope failure mechanisms.
4. Refer to attachments for definitions and explanations of terms used in the risk assessment.

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Table B - Landslide Risk Assessment (Risk to Life)
7-9 Bent Street, Gosford

Possible Hazard	**Use of Affected Structure**	**Likelihood**	**Indicative Annual Probability P (H)**	**Probability of Spatial Impact P (S:H)**	**Temporal Probability P (T:S)**	**Vulner-ability V (D:T)**	**Probability of becoming Trapped**	**Risk for Person Most at Risk [Risk Evaluation]**	**Risk Outcome: A = Acceptable T = Tolerable NT = Not Tolerable**
Hazard 1 - Slump in steep excavation in soils (during construction)	Base of excavation	Likely (without mitigation)	1.0E-02	1.00	0.33	1.00	1.00	3.30E-03	NT
		Barely credible (with mitigation)	1.0E-06	1.00	0.33	1.00	1.00	3.30E-07	A
Hazard 2 - Rock wedge failure within rock excavation (during construction critical)	Base of excavation	Possible (without mitigation)	1.0E-03	1.00	0.33	0.50	1.00	1.65E-04	NT
		Rare (with mitigation)	1.0E-04	1.00	0.33	0.05	0.10	1.65E-07	A

Notes:

1. The appraisal of the assessed risk relative to acceptable and tolerable risks is based on Table 1 of AGS (2007) – Reference 1, for a new development.
2. Risk mitigation will be required to ensure that the assessed risk outcome during and after the proposed development is acceptable. Referred to report for further details.
3. This table must be read in conunction with Table A.
4. Risk Outcome:

   A = Acceptable $\leq 10^{-6}$

   T = Tolerable $\leq 10^{-5}$

   NT = Not Tolerable - treatment options to be assessed and implemented