GEOTECHNICS PTY LTD
CONSULTING GEOTECHNICAL ENGINEERS

GEOTECHNICAL ASSESSMENT

FOR

MR ANDREW DRY

30 Owen Stanley Avenue, Beacon Hill, New South Wales

Report No: 20/1320

Project No: 30458/3800D-G

May 2020

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1. INTRODUCTION

This report presents the results of a geotechnical assessment carried out by STS Geotechnics Pty Limited (STS) for a proposed residential development at 30 Owen Stanley Avenue, Beacon Hill. The assessment was undertaken at the request of Wincrest Group Pty Limited on behalf of Mr Andrew Dry.

We understand that it is proposed to demolish the existing dwelling on the site prior to construction of a new double storey residential dwelling. The dwelling includes a lower ground floor garage. Construction of the dwelling and garage will require excavating below the existing ground surface. The maximum depth of excavation will be in the order of 2.2 metres below existing surface levels.

Further details of the proposed development are provided in Section 2 of this report.

Further to the above we understand that the site is located in an area designated as "Zone B", by Northern Beaches Council. These areas typically comprise flanking slopes from 5° to 25°. As the proposed depth of excavation exceeds 2 metres, a geotechnical assessment is required by Northern Beaches Council.

The purpose of the investigation was to:

- Review available literature for the site,
- assess the subsurface conditions at the site,
- undertake a slope risk assessment of the site in accordance with the Landslide Risk Management guidelines set out by AGS, 2007,
- provide geotechnical recommendations regarding the outcomes of the slope risk assessment,

Our scope of works did not include a contamination assessment of the site.

It should be noted that this assessment is based on visual observations alone and that no intrusive boreholes have been drilled on the site by STS.

At the time of preparing the report STS were provided with a Lot Classification report prepared by Ideal Geotech. The previous report is referenced as 38494, dated 4th March 2019.

2. SITE DESCRIPTION

The A summary of the observations made by one of our Principal Engineering Geologists during our site visit on the 14th May 2020 are outlined below:

- The regional topography within this part of Beacon Hill slopes downwards to the south, towards Allenby Park.
- No 30 Owen Stanley Avenue, Beacon Hill comprises a roughly rectangular residential lot of 618m^2 in area. The site itself slopes to the south with a fall over the total site of approximately 2.5 metres from RL 114.2m to RL 111.7m.
- The lot is currently occupied by a single level brick and weatherboard clad residential dwelling with metal roof. The dwelling has a subfloor laundry and storage area at the front of the site together with a subfloor car port / garage.
- The garage and subfloor laundry/storage area have been constructed by cutting into the natural ground surface. The excavations at the northern end of the garage are supported by a combination of timber post and panel wall and rendered concrete/brick wall. The rendered wall has some cracking and displacement.
- The front of the site is demarked by a brick wall. Immediately in front of the wall is a grassed nature strip. Sandstone bedrock was observed outcropping in the nature strip. The exposed sandstone bedrock comprises fine to medium grained medium to high strength Hawkesbury Sandstone.
- There is an existing in-ground concrete swimming pool in the rear garden.
- The existing structures on the subject site appear in reasonable condition with no obvious signs of slope movement or distress. The cracking in the render of the retaining wall in the rear garden area is likely to be localised, and due to the method of construction.
- The vegetation on the site comprises grass and shrubs.
- To the north, east and west of the subject site are mixture of single and double storey residential dwellings. The adjoining buildings are located close to the site boundary.
- To the south of the site is Owen Stanley Avenue, beyond which is an area of bushland that leads to Allenby Park. The bushland slopes moderately to the south.

The details of the proposed development are shown on the following drawings:

Architectural: Wincrest Homes, Ref No. 17386, Drawing No.s 1 to 7 (inclusive)

The proposed dwelling comprises a double level residence with subfloor garage. The finished floor level of the garage area is RL 111.42m, and the finished floor level of the ground floor is RL 114.32m. Construction of the garage will require excavating up to 2.2 metres below the existing ground surface, and constriction of the ground floor level will require excavating up to 0.8 metres below the existing ground surface.

3. GEOLOGY AND SUBSURFACE CONDITIONS

The Sydney geological series sheet at a scale of 1:100,000 shows Triassic Age Hawkesbury Sandstone underlies the site. The Hawkesbury Sandstone comprises medium to coarse grained quartz sandstone.

Onsite there are rock outcrops consistent with the geological setting. There are other sandstone outcrops in the street and general area. The previous investigation undertaken by Ideal Geotech included the drilling of a single borehole in the front garden area. The borehole encountered bedrock at a depth of 0.4 metres and was terminated on sandstone bedrock at a depth of 1.0 metre.

The thickness of the overlying soils is not expected to exceed 1 metre.

Groundwater seepage was not observed during the site inspection.

4. LANDSLIDE RISK ASSESSMENT

4.1. Introduction

A landslide risk assessment has been undertaken for 30 Owen Stanley Avenue, Beacon Hill. It is not technically feasible to assess the stability of a particular site in absolute terms such as stable or unstable, and it must be recognised by the reader that all sites have a risk of land sliding, however small. However, a risk assessment can be undertaken by the recognition of surface features supplemented by limited information on the regional and local subsurface profile, and with the benefit of experience gained in similar geological environments.

Natural hill slopes are formed by processes that reflect the site geology, environment and climate. These processes include down slope movement of the near surface soil and rock. In geological time all slopes are 'unstable'. The area of influence of these down slope movements may range from local to regional and are rarely related to property boundaries. The natural processes may be affected by human intervention in the form of construction, drainage, fill placement and other activities.

4.2. Purpose of the Assessment

The purpose of this assessment is to enable the owner, potential owner or other parties interested in the site in question, to be aware of the level of risk associated with potential slope movements within the property, and within the area immediately surrounding the property. The risk is assessed considering the existing development of the property and proposed developments of which we have been informed of and which are summarised in this report. The onus is on the owner, potential owner or other party to decide whether the level of risk presented in this report is acceptable in the light of the possible economic consequence of such risk.

4.3. Risk Assessment Methodology

The risk assessment in this report is based on the guidelines on Landslide Risk Management (LRM) as presented in the Australian Geomechanics publication, Volume 42, Number 1, dated March 2007. This issue presents a series of LRM guidelines and further understanding on the application of the risk assessments for the recommended use by all practitioners nationwide.

Definition of the terms used in this report with respect to the slope risk assessment and management are given in Attachment 2.

It must be accepted that the risks associated with hillside construction are greater than construction on level ground in the same geological environment. The impact of development may be adverse, and imprudent construction techniques can increase the potential for movement. Areas of instability rarely respect property boundaries and poor practices on one property can trigger instability in the surrounding area.

4.4. Hazard Identification

A landslide is defined as "the movement of a mass of rock, debris or earth down a slope". Apart from ground subsidence and collapse, this definition is open to the movement of material types including rock, earth and debris down slope. The causes of landslides can be complex. However, two common factors include the occurrence of a failure of part of the soil or rock material on a slope and the resulting movement is driven by gravity. The actual motion of a landslide is subdivided into the five kinematically distinctive types of material movement including fall, topple, slide, spread, and flow. For further information regarding types of landslides please refer to Appendix B – Landslide Terminology from Australian Geomechanics Practice Note Guidelines For Landslide Risk Management 2007.

The frequency of landslides are difficult to quantify and typically dependant on the inter-relationship between the factors influencing the stability of the slope. Some of the common factors affecting the stability of slopes include the weather (prolonged rainfall with water percolating into rock mass defects can cause washout of fines and reduction of rock mass strength), land development, vegetation removal, changes in drainage and earthquakes. One or a combination of these conditions could result in a landslide failure event.

Table 4.1 below outlines the landslide hazards that have been identified 30 Owen Stanley Avenue, Beacon Hill.

Table 4.1: Landslide Hazard Identification

Hazard Description	Estimated Volume (m^3)	Justification
Failure of a cut face during bulk excavation	5	Construction of the garage area will require excavating up to 2.2 metres below the existing ground surface. The soils overlying the bedrock are susceptible to collapse if excavations are over steepened, and the underlying bedrock could include joints or seams which may cause instability both during excavation, and in the long term.

4.5. Risk Assessment to Property

Risk to property has been estimated by assessing the likelihood of an event and the consequences if such an event takes place. The relationship between likelihood, consequence and risk is determined by a risk matrix. The risk categories and implications are shown in Attachment 3 (taken from Practice Note Guidelines for Landslide Risk Management 2007, Appendix C). The terms used in risk assessments as defined in the above paper are presented in Attachment 1 (reproduced from AGS 2007 Appendix A).

The assessment process involved the following:

- Risk estimation (comparative analysis of likelihood of a slope failure versus consequence of the failure).
- Evaluation of the estimated (assessed) risk by comparing against acceptance criteria.

The following factors observed during the site walkover were taken into consideration when undertaking the slope risk assessment:

- Topography: The site is located on gently sloping terrain, however cuts up to 2.2 metres are proposed.

- Geology: The surface soils comprise minor amounts of topsoil, fill and residual soils overlying weathered sandstone bedrock.

- Drainage: The site in general is reasonably drained. Water runoff was observed from the upper cliff face.

- Slope stability: There were no signs of active slope instability noted during the site walkover.

Based on the above factors and site observations, an assessment of risk to property have been carried out as shown in Table 4.1 below:

Table 4.1: Risk to Property

Hazard		Failure of a cut slope (5m^3)
Likelihood	Descriptor	Unlikely
	Approximate Annual Probability	1 x 10^{-5}
Consequence		Medium
Risk Category		Low

The assessed risk to property is assessed to be Low risk. Based on the information provided by the AGS and presented in Attachment 1, the implications for a risk level of low is that it is usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.

4.6. Risk Assessment to Loss of Life

During A risk assessment for the loss of life was undertaken for the identified geotechnical hazards for the site. The risk assessment and management process adopted for this study was carried out in general accordance with AGS (2007a).

In accordance with the AGS 2007 Landslide Risk Management Guidelines for loss of life, the individual risk for loss of life can be calculated from:

$$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where

- $R_{(LoL)}$ is the risk - annual probability of loss of life (death) - of an individual.

- $P_{(H)}$ is the annual probability of the landslide.

- $P_{(S:H)}$ is the probability of spatial impact of the landslide impacting on a location potentially occupied by a person.

- $P_{(T:S)}$ is the temporal spatial probability (e.g. of the location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.

- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

In accordance with AGS 2007, the regulator should set risk acceptance criteria. In this case, Northern Beaches Council is the regulator, and requires the risk to life post development to be 'Tolerable' for existing areas of residential subdivision, provided risk control measures are put in place to control the risk

The risk acceptance criteria consider the occurrence of the potential geotechnical hazards identified for the site and evaluate the risk against a Tolerable Risk Criteria for loss of life. In this instance, the individual risk is accepted due to being tolerable or risk mitigation measures are undertaken to reduce the risk to more tolerable levels.

The AGS 2007 guidelines indicate that the regulator, with assistance from the practitioner where required, is the appropriate authority to set the standards for risk relating to perceived safety in relation to other risks and government policy. The importance of the implementation of levels of the tolerable risk should not be understated due to the wide ranging implications, both in terms of the relative risks or safety to the community and the potential economic impact to the community. The AGS provide recommendations in relation to tolerable risk for loss of life as shown below in the table.

Situation	Suggested Tolerable Loss of Life Risk for Person Most at Risk
Existing Slope (1) / Existing Development (2)	10^{-4}/annum
New Constructed Slope (3) / New Development (4) / Existing Landslide	10^{-5}/annum

Notes:

1. "Existing Slopes" in this context are slopes that are not part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

2. “Existing Development” includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

3. “New Constructed Slope” includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).

4. “New Development” includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope/Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.

5. “Existing Landslides” have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of “public safety”.

Due to the depth of excavation proposed, the future development at 30 Owen Stanley Avenue must be considered a New Development. The AGS risk threshold provided in Table 5.2 for new developments suggests the ‘Tolerable Loss of Life for the person most at risk’ is 10-5 per annum.

The risk assessment has been based on observations made during the site visit by an experienced engineering geologist, and by reviewing available geotechnical data and the future geotechnical requirements for development as outlined elsewhere in this report. Departures from the recommendations in this report may change the quantification of the hazard risk. A risk assessment has been carried out for the identified geotechnical hazards and is presented in Section 4.4 of this report.

The annual probability of a failure occurring has been calculated based on engineering judgement and observations made during the site visit. The probability of spatial impact is calculated by dividing the size of the estimated landslide by the size of the building area, 200m2.

The temporal spatial probability has been calculated based on the assumption that someone will be present on the site during construction for 12 hours a day. This is then divided by the number of hours in a day. The vulnerability of an individual is based on values from Australian Geomechanics Vol. 42. If visitor numbers to the site were to increase then this would change the risk to loss of life. This could affect whether the risk is considered tolerable or otherwise.

Any changes to the site will affect the risk assessment outcome, making it necessary to carry out the risk assessment again.

From our quantitative risk to life assessment we have estimated the annual probability of risk to life to be in order of the range of 7.5×10^{-7}. This value is considered tolerable using the AGS risk acceptance criteria.

5. GEOTECHNICAL RECOMMENDATIONS

5.1. Excavation Conditions and Support

Any development on the site should follow good hillside building practices (refer to Attachment 4 for some examples).

Based on the conditions observed and general experience in this geological environment, it is expected that excavations on this site will likely encounter medium to high strength sandstone at relatively shallow depths. Typically, the Hawkesbury Sandstone is horizontally bedded with sub- vertical joints. This type of profile can be observed in many places in Sydney where Hawkesbury Sandstone is exposed.

Excavators alone without assistance will not be able to remove any significant amount of the rock. Hydraulic breakers mounted on an excavator or jack hammers will be required to break up the majority the rock before it can be removed using an excavator.

Particular care will be required to ensure that buildings or other developments on adjacent properties are not damaged when excavating the rock. The adjacent buildings may be founded directly on the underlying bedrock. Buildings founded directly on rock can often be very susceptible to damage from vibrations.

Excavations methods should be adopted which limit ground vibrations at the adjoining developments to not more than 10 mm/sec. Vibration monitoring will be required to verify that this is achieved. However, if the contractor adopts methods and/or equipment in accordance with the recommendations in Table 5.1 for a ground vibration limit of 5 mm/sec, vibration monitoring may not be required.

Table 5.1 – Recommendations for Rock Breaking Equipment

Distance from adjoining structure (m)	**Maximum Peak Particle Velocity 5 mm/sec**		**Maximum Peak Particle Velocity 10 mm/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 10 mm/sec vibration limit.

The limits of 5 mm/sec and 10 mm/sec are expected to be achievable if rock breaker equipment or other excavation methods are restricted as indicated in Table 5.1.

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. grinding, rock sawing), although less productive, would reduce or possibly eliminate risks of damage to property through vibration effects transmitted via the ground. Such techniques may be considered if an alternative to rock breaking is required.

It should be noted that vibrations that are below threshold levels for building damage may be experienced at adjoining developments.

It would be appropriate before commencing excavation to undertake a dilapidation survey of any adjacent structures that may potentially be damaged. This will provide a reasonable basis for assessing any future claims of damage.

Excavations in competent sandstone should remain stable unsupported, at least in the short term. In some areas, support using rock bolts, shotcrete and/or underpinning using brick piers or infill concrete may be necessary. The latter would only normally be required if blocks fall out near to the boundary lines.

Until the excavation is commenced and the actual conditions are exposed it is not practical to be more definitive. The site observations suggest there could be detached boulders and some included joints. If joints are continuous they could form wedges which may need to be supported with bolts. If boulders extend beyond excavation boundaries, then they will need to be trimmed and supported. As noted above particular care will be required when excavating close to boundaries. This work should be carried out in small sections so that the subsurface conditions can be identified and any appropriate shoring or support can be installed before too large an area is exposed.

It is recommended that an experienced engineering geologist or geotechnical engineer observes the excavation as it progresses. At that time, they will be able to recommend any support that is required for either temporary or permanent conditions and help to finalise the design of the final cut slopes and any retaining walls that may be required.

All loosened rocks should either be stabilised or removed from the sides of the excavation as it proceeds. If floaters are encountered care will be required as they can often be sizeable in this geological environment, appearing to be part of the "solid" rock profile.

Temporary slopes in the shallow soil cover of 1.5:1 (Horizontal : Vertical) should remain stable. In the long term this material must be retained. Retaining walls supporting any significant depth of soil can be designed assuming an earth pressure of 0.4.

As noted above, experience has demonstrated that near vertical cuts in the competent in-situ sandstone found in this area will normally remain stable for long lengths of time. If you are considering permanent unsupported vertical cuts it is essential that the excavation boundary lines are first cut using a rock saw to create a clean face. The use of hydraulic rock hammers to create final permanent cut faces is not recommended as the hammers may induce fractures in the rock that may require long term support.

An alternative to leaving the rock face exposed is to design perimeter walls to support the excavation in the long term. A nominal loading of 10 kPa on average, would be appropriate for permanent vertical sides rock cuts. The space between the rock face and the back of the walls could be filled with free draining hard igneous rock with an appropriate large agriculture drain installed at the toe. This may help to relieve the potential for damp penetrating the external walls.

A layer of geofabric would help to stop any long term clogging of the backfill. The retaining wall approach will significantly reduce the need for dowels and shotcrete.

5.2. Foundation Design

The allowable bearing pressures given below have been determined using the procedures given by Pells et al, in their paper titled "Design Loadings for Foundations on Shale and Sandstone in the Sydney Region," published in the Australian Geomechanics Journal, 1998. Pad and/or strip footings or piles should be founded on at least low to medium strength sandstone bedrock.

The onsite sandstone is assessed to be Class IV Sandstone or better. The pad/strip footings or piles founded Class IV sandstone bedrock may be proportioned using an allowable bearing pressure of 1000 kPa.

Due to their variable thickness and distribution across the site, the soils and any fill materials placed during bulk earthworks are not considered suitable for foundation support.

6. FINAL COMMENTS

Based on the observations made during the site walkover and the risk assessment undertaken, it has been determined that the site has a low risk of slope instability. The site is suitable for residential development provided good hillside building practices are followed. There are no geotechnical constraints for the proposed development of the site; however, Section 5 of this report provides some advice that should be taken into consideration and applied to any future development. Provided the recommendations given in Section 5 of this reports, in particular the inspection and management of cut slopes during construction and design of permanent retaining structures are incorporated into the design and construction of the project the risk to property would remain at least low.

Provided that the proposed development is undertaken in accordance with the recommendations provided in this report, we feel that the site is suitable for the proposed development.

During construction, should the subsurface conditions vary from those inferred above, we would be contacted to determine if any changes should be made to our recommendations.

The exposed bearing surfaces for footings should be inspected by a geotechnical engineer to ensure the allowable pressure given has been achieved.

Matt Green
Principal Engineering Geologist
STS Geotechnics Pty Limited

NOTES RELATING TO GEOTECHNICAL REPORTS

Introduction

These notes have been provided to outline the methodology and limitations inherent in geotechnical reporting. The issues discussed are not relevant to all reports and further advice should be sought if there are any queries regarding any advice or report.

When copies of reports are made, they should be reproduced in full.

Geotechnical Reports

Geotechnical reports are prepared by qualified personnel on the information supplied or obtained and are based on current engineering standards of interpretation and analysis.

Information may be gained from limited subsurface testing, surface observations, previous work and is supplemented by knowledge of the local geology and experience of the range of properties that may be exhibited by the materials present. For this reason, geotechnical reports should be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Where the report has been prepared for a specific purpose (eg. design of a three-storey building), the information and interpretation may not be appropriate if the design is changed (eg. a twenty storey building). In such cases, the report and the sufficiency of the existing work should be reviewed by STS Geotechnics Pty Limited in the light of the new proposal.

Every care is taken with the report content, however, it is not always possible to anticipate or assume responsibility for the following conditions:

- Unexpected variations in ground conditions. The potential for this depends on the amount of investigative work undertaken.
- Changes in policy or interpretation by statutory authorities.
- The actions of contractors responding to commercial pressures.

If these occur, STS Geotechnics Pty Limited would be pleased to resolve the matter through further investigation, analysis or advice.

Unforeseen Conditions

Should conditions encountered on site differ markedly from those anticipated from the information contained in the report, STS Geotechnics Pty Limited should be notified immediately. Early identification of site anomalies generally results in any problems being more readily resolved and allows re-interpretation and assessment of the implications for future work.

Subsurface Information

Logs of a borehole, recovered core, test pit, excavated face or cone penetration test are an engineering and/or geological interpretation of the subsurface conditions. The reliability of the logged information depends on the drilling/testing method, sampling and/or observation spacings and the ground conditions. It is not always possible or economic to obtain continuous high quality data. It should also be recognised that the volume or material observed or tested is only a fraction of the total subsurface profile.

Interpretation of subsurface information and application to design and construction must take into consideration the spacing of the test locations, the frequency of observations and testing, and the possibility that geological boundaries may vary between observation points.

Groundwater observations and measurements outside of specially designed and constructed piezometers should be treated with care for the following reasons:

- In low permeability soils groundwater may not seep into an excavation or bore in the short time it is left open.
- A localised perched water table may not represent the true water table.
- Groundwater levels vary according to rainfall events or season.
- Some drilling and testing procedures mask or prevent groundwater inflow.

The installation of piezometers and long term monitoring of groundwater levels may be required to adequately identify groundwater conditions.

Supply of Geotechnical Information or Tendering Purposes

It is recommended tenderers are provided with as much geological and geotechnical information that is available and that where there are uncertainties regarding the ground conditions, prospective tenders should be provided with comments discussing the range of likely conditions in addition to the investigation data.

APPENDIX A – SITE PHOTOGRAPHS

PROJECT: 30 OWEN STANLEY AVENUE, BEACON HILL
PROJECT No: 30458/3800D-G
REPORT No: 20/1320
TITLE: PHOTO 1 - FRONT OF DWELLING AND ROCK OUTCROP

GEOTECHNICS PTY LTD
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Sandstone Bedrock Outcrop

Existing Dwelling

PROJECT: 30 OWEN STANLEY AVENUE, BEACON HILL
PROJECT No: 30458/3800D-G
REPORT No: 20/1320
TITLE: PHOTO 2 - REAR GARDEN AREA

Deepest area of proposed cut

Existing cracked retaining wall

ATTACHMENTS 1, 2, 3, 4

ATTACHMENT 1 - DEFINITION OF TERMS AND LANDSLIDE RISK

(Australian Geomechanics Vol 42 No 1 March 2007)

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

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any year.

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

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

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

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

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

Landslide Activity – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (e.g. seasonal) or continuous (in which case the slide is “active”).

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

Landslide Risk – The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

Landslide Susceptibility – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

Likelihood – Used as a qualitative description of probability or frequency.

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an “objective” or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

Qualitative Risk Analysis – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative Risk Analysis – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

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

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

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

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

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

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

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

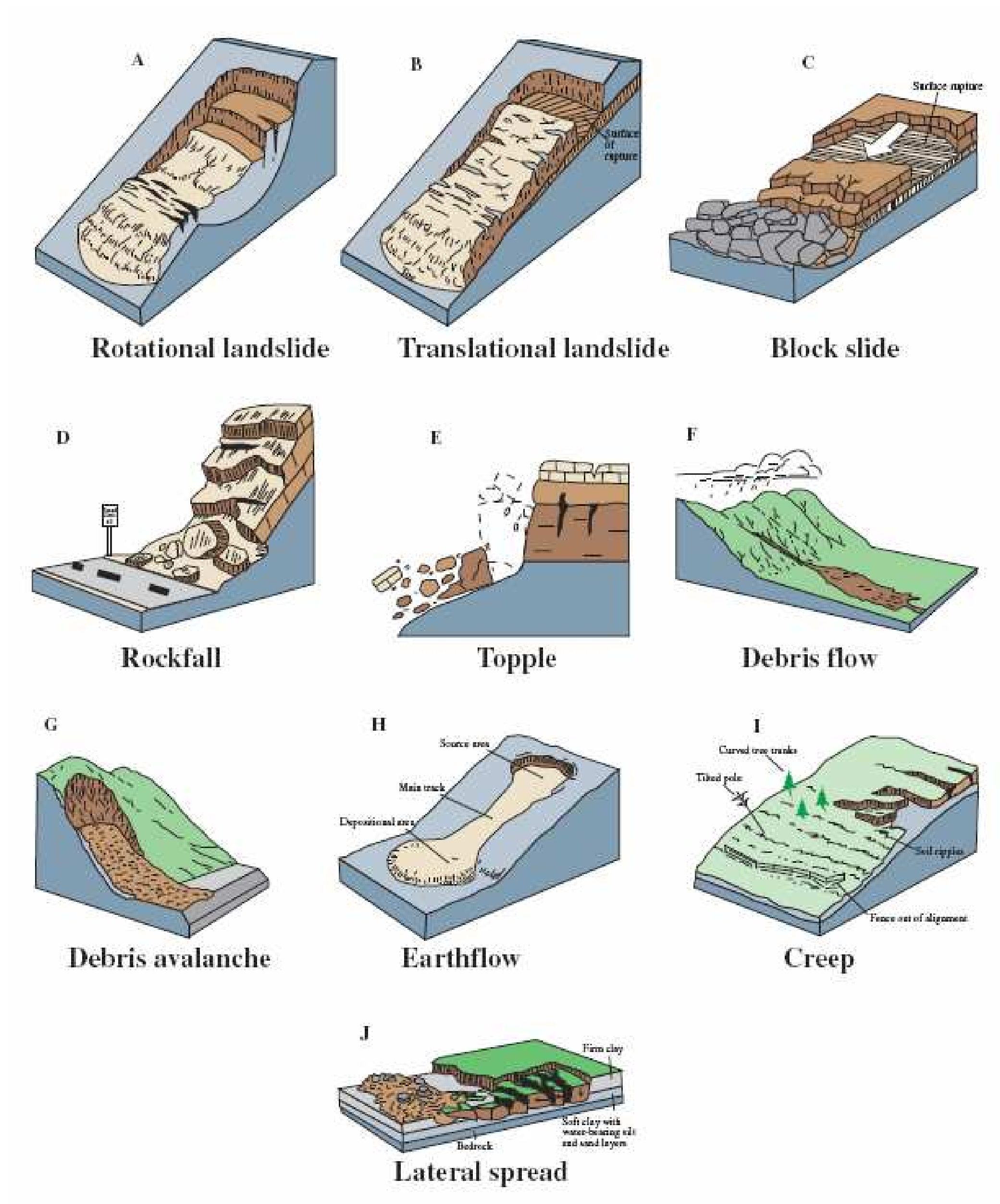
Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

Susceptibility – see Landslide Susceptibility

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

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

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



ATTACHMENT 2 MAJOR TYPES OF LANDSLIDES

ATTACHMENT 3: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		**Implied Indicative Landslide Recurrence Interval**		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**					
10^{-1}	5×10^{-2}	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	5×10^{-3}	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	5×10^{-4}	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	5×10^{-5}	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	5×10^{-6}	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		**Description**	**Descriptor**	**Level**
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

ATTACHMENT 3: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	1: CATASTROPHIC 200%	2: MAJOR 60%	3: MEDIUM 20%	4: MINOR 5%	5: INSIGNIFICANT 0.5%
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

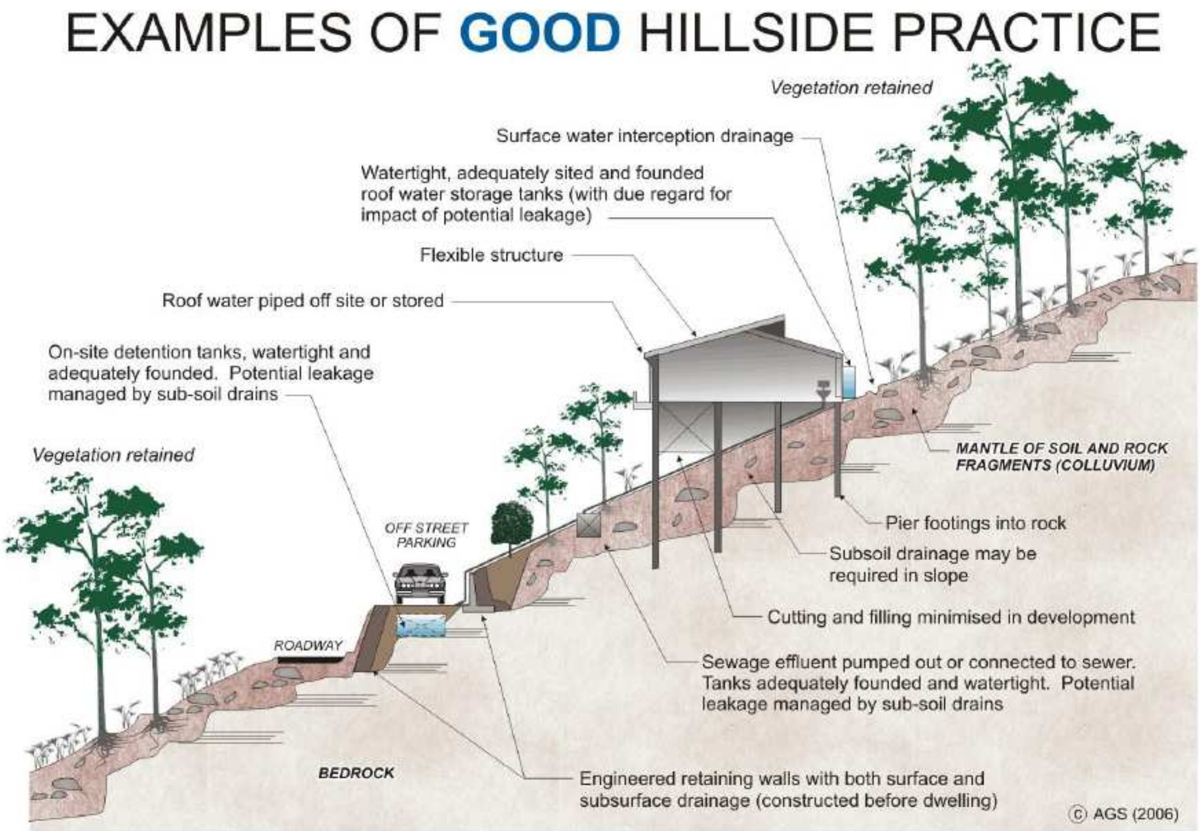
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

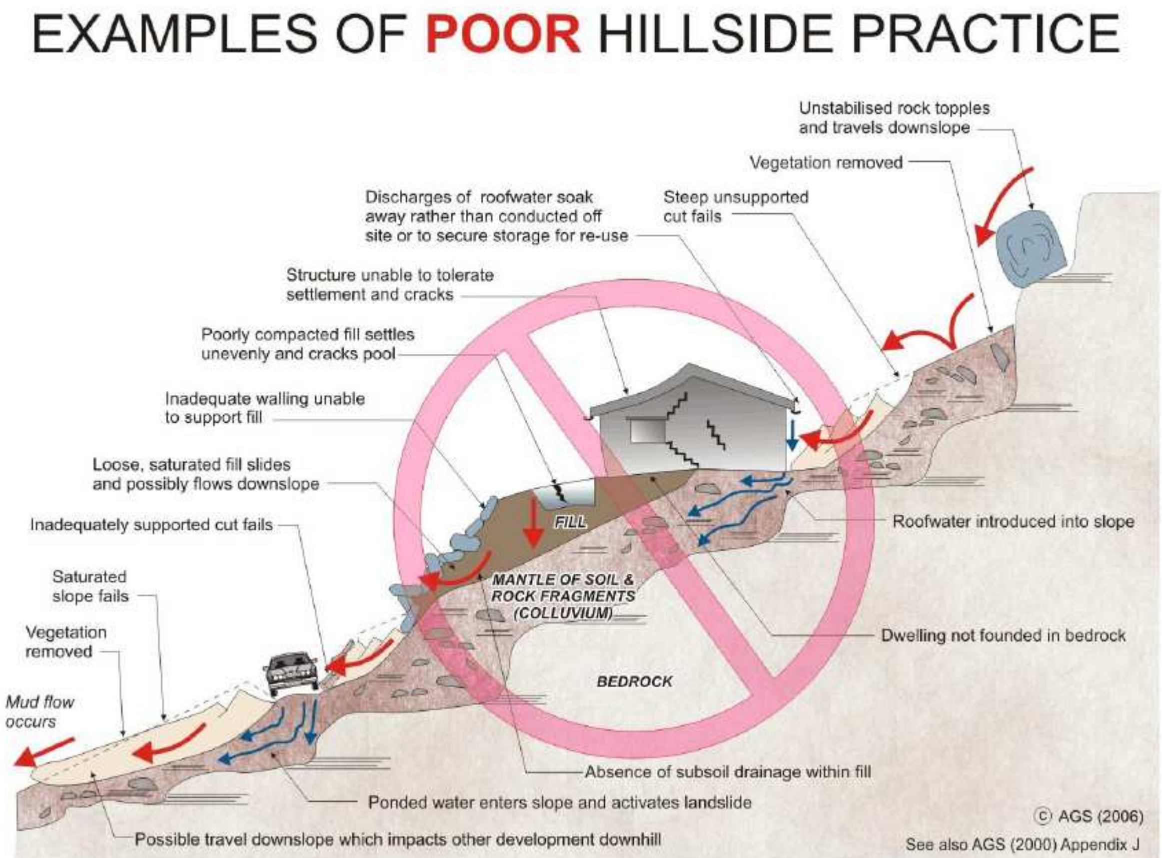
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

ATTACHMENT 4

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
FILL
Inadequately supported cut fails
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
Mud flow occurs
BEDROCK
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
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Possible travel downslope which impacts other development downhill
See also AGS (2000) Appendix J