CIVIL TEST PTY LTD
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LAND STABILITY ASSESSMENT

AT

14-16 VIEW POINT ROAD

McCRAE

Report No: 1140220C

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REPORT No	:	1140220C
CLIENT	:	David Norman Design & Construction P O Box 321 MOUNT MARTHA VIC 3934
PROJECT LOCATION	:	14-16 View Point Road MCCRAE
PROPOSAL	:	It is proposed to develop this site with a double storey articulated masonry veneer and clad dwelling with a lower floor garage.
COMMISSION	:	To determine the slope stability of the existing site and whether the proposed works will be detrimental to the slope stability of the site and surrounding areas.

1. INTRODUCTION:

A site investigation has been undertaken to assess the stability of the slope at 14-16 View Point Road, MCCRAE to determine the implications of the above mentioned development on the site. Civiltest Pty Ltd carried out the field work aspect of the investigation on 24 March 2014.

The site investigation for the land stability assessment included:

- A site inspection of the existing land and topography
- Interpretation of the proposed development and magnitude of the proposed earthworks
- Bore holes to determine the soil profile and to confirm the geology of the site
- Assessment of the likely groundwater levels
- Modelling of the slope's stability
- Risk assessment in accordance with AGS 2007 guidelines on landslide risk management
- Assessment of the implications of the proposed development and recommendations with regard to slope stability.

This amended report is provided in response to the queries raised in the peer review by Intrax Consulting Engineers Pty Ltd (Mr Scott Emmett).

2. INFORMATION PROVIDED:

The information provided to Civiltest Pty Ltd consisted of the proposed site plan, floor plan and elevations for 14-16 View Point Road MCCRAE prepared by David Norman Design & Construction Pty Ltd. Surface contours are also shown on the site plan.

Further drawings for the above site, Project No CGR 6391 (details below), were provided to Civiltest Pty Ltd on 12 December 2014.

Drawing No.	Details	Rev.	Date
C1	Driveway Plan & Cross Section	A	Aug. 2014
S1	Note Sheet & Drawing list	-	Nov. 2014
S2	Slab & Footing, Floor Framing & Roof Framing Plans	-	Nov. 2014
S3	Elevations & Cross Sections	-	Nov. 2014
S4	Slab & Footing details – Sheet 1	-	Nov. 2014
S5	Slab & Footing details – Sheet 2	-	Nov. 2014
S6	Slab & Footing details – Sheet 3	-	Nov. 2014

3. SITE GEOLOGY:

Geological maps of the area suggest that the site is in an area of Devonian Granodiorite & Granites overlain by Quaternary Aeolian. The site investigation confirmed this. A copy of the site geology is shown in Figure 1 below.

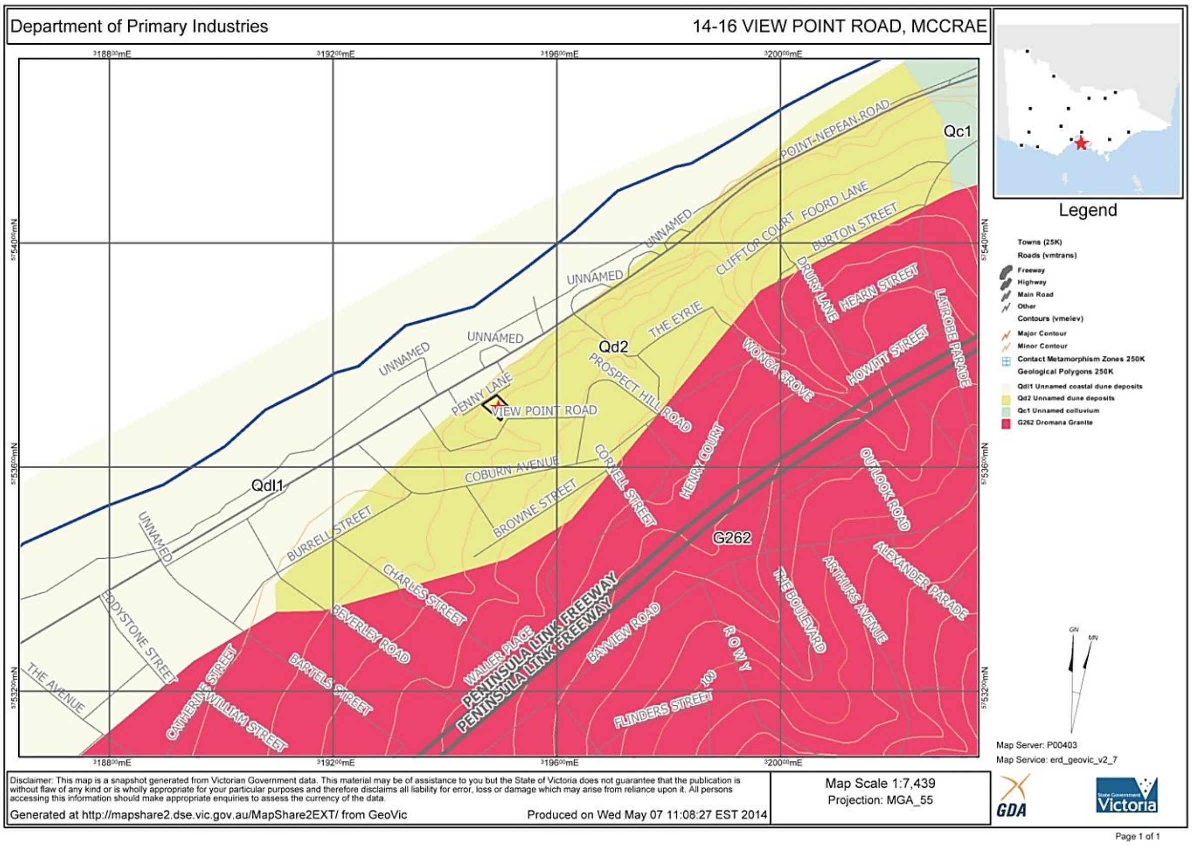


Figure 1: Site Geology from GeoVic

4. Existing Site Conditions:

The subject site is located between Penny Lane to the northwest and View Point Road to the southeast. The natural ground surface slopes can generally be described as steep to very steep, with slopes varying between approximately 46° near View Point Road down to approximately 26° near Penny Lane. The ground cover consists of natural grasses, native trees and introduced trees. Most of the trees noted were inclined towards the downslope. The leaning of the trees are due to the shallow (up to 1m depth) creep near areas that had been disturbed by excavations for the access steps, road and existing dwellings.

There is an existing single storey timber and fibro sheet clad dwelling near the upper slope end of the allotment and a timber cottage at the downslope end of the allotment – see Figure 2. The existing dwelling is on steel H columns that are founded on what appears to be shallow concrete piles. It is understood the existing structures will be demolished to give way to the construction of the proposed building. No visible defects were observed on the existing dwelling.

Figure 2: Google Aerial View of 14-16 View Point Road, MCCRAE

There is a timber step leading down to the existing dwelling from View Point Road. A further step formed from the side cut of the hillside material and supported by sleepers was noted leading down to the centre of the site. The earth constructed steps where noted to be gently inclined towards the downslope. This inclination is due to the creep movement that has taken place, as well as some scouring and erosion from surface runoff.

A stone/rock retaining wall approximately 1.0 metre high was noted just upslope of the timber cottage.

5. SITE INVESTIGATION:

5.1 Soil Profile

Seven bore holes were drilled by mechanical and hand auger at the approximate locations shown on the attached site plan (Appendix A).

Borehole 1 was drilled by mechanical auger to 15.0 metres depth at the top of the steepest section and this borehole indicated that the natural soil profile mainly consisted of silty SAND underlain by clayey SAND, with CLAY dominated layers at depths of 8.0 to 9.0 metres and 13.0 to 14.0 metres. Assessment of the material encountered as silty SAND with clay and gravels below 5.0 metres depth is the initial part of the weathered ROCK – residual soil. The clayey SAND and sandy CLAY form the extremely weathered ROCK layer.

Boreholes 2, 3 and 4 were drilled by mechanical auger at the downslope end, near the existing timber cottage. The boreholes revealed that the existing soil profile consisted of up to 500mm of SAND FILL underlain by natural silty SAND. Auger refusal was encountered on weathered granitic ROCK at depths between 2.2 metres and 2.5 metres.

Borehole 5 was drilled by hand auger approximately within the mid-section of the site. This borehole revealed the natural soil profile consisted of silty SAND overlying clayey SAND, followed by silty CLAY with sand, which in turn lies over clayey SAND.

Boreholes 6 and 7 were drilled by hand auger approximately within the mid-section of the site. These boreholes revealed that the existing soil profile consisted of site derived silty SAND FILL of up to 600mm underlain by natural silty SAND in borehole 6, and in borehole 7 the FILL is underlain by natural clayey SAND. Hand auger refusal was encountered at 750mm on dense SAND and gravels in these boreholes.

Free ground water was not encountered in the boreholes and it is expected that the ground water level is below 15.0 metres depth.

5.2 Laboratory Results

5.2.1 Moisture Contents

Bore Hole No.	Depth (m)	Material	Moisture Content (%)
1	3.0	Silty SAND	4.9
1	5.5	Silty SAND	7.0
1	8.5	Sandy CLAY	11.4
1	13.0	Sandy CLAY	14.9
1	14.5	Clayey SAND	14.0
2	1.0	Silty SAND	7.6

5.2.2 Atterberg Limits Testing

Bore Hole No.	Depth (m)	Material	Liquid Limit %	Plastic Limit %	Plasticity Index
BH1	5.0	Clayey SAND	21	15	6
BH1	7.0	Clayey SAND	22	14	8
BH1	8.0	Sandy CLAY	32	10	22
BH1	13.0	Sandy CLAY	40	11	29

The above results indicate that the natural soils encountered are of low to medium plasticity, consistent with the geology. The moisture contents are as would be expected for CLAY and SAND dominated materials.

6. SLOPE STABILITY MODELLING

The following slope stability models utilise the software program SLIDE 5.0. A number of analyses have been used to calculate the factor of safety with respect to the slope at this site and include: Bishop simplified, Janbu simplified, GLE/Morgenstern Price and Spencer methods. The resultant factor of safety with respect to each analysis is indicated on the models.

As a guide, a factor of safety (FOS) less than 1 would indicate that the slope should have failed. A factor of safety between 1.0 and 1.5 would be indicative of a slope at risk of failure. A factor of safety between 1.5 and 2.0 would be regarded as tolerable, however the slope may require some form of remediation to lower the risk. A factor of safety greater than 2.0 would be regarded as acceptable and safe.

The analysis assumes a circular type of failure. A circular failure assumes the slip surface occurs as an arc through the slope. A circular failure surface has been adopted in the slope modelling at this site due to near uniformity of the soil materials in the lower soil profile.

The cross section drawn in all slope stability models are taken through section ‘A-A’ as shown on the attached site plan, Appendix A. Due to the number of models produced in this report, the entire test results file for each model will not be reproduced. If further information is required about the models used in this report, these can be supplied upon request.

The following parameters have been adopted for the units represented in the following models. These effective shear strength parameters have been assumed based on Civiltest’s previous experience, from our knowledge of similar sites.

All the models represented below consider the effects of earthquake acceleration on the slope in question. Groundwater level is not considered in the models. Due to the steep slope at this site and the sandy nature of the soils, it is expected that drainage at this site will be good.

6.1 Material Properties

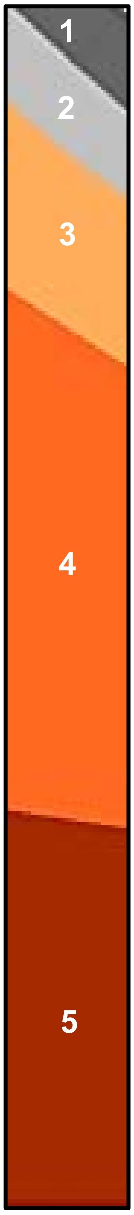
Material 1: Silty SAND & Gravels
Strength Type: Mohr-Coulomb
Unit Weight: 18 kN/m^3
Cohesion: 1 kPa
Friction Angle: 32 degrees
Water Surface: None

Material 2: Silty SAND - Med Dense
Strength Type: Mohr-Coulomb
Unit Weight: 19 kN/m^3
Cohesion: 2 kPa
Friction Angle: 35 degrees
Water Surface: None

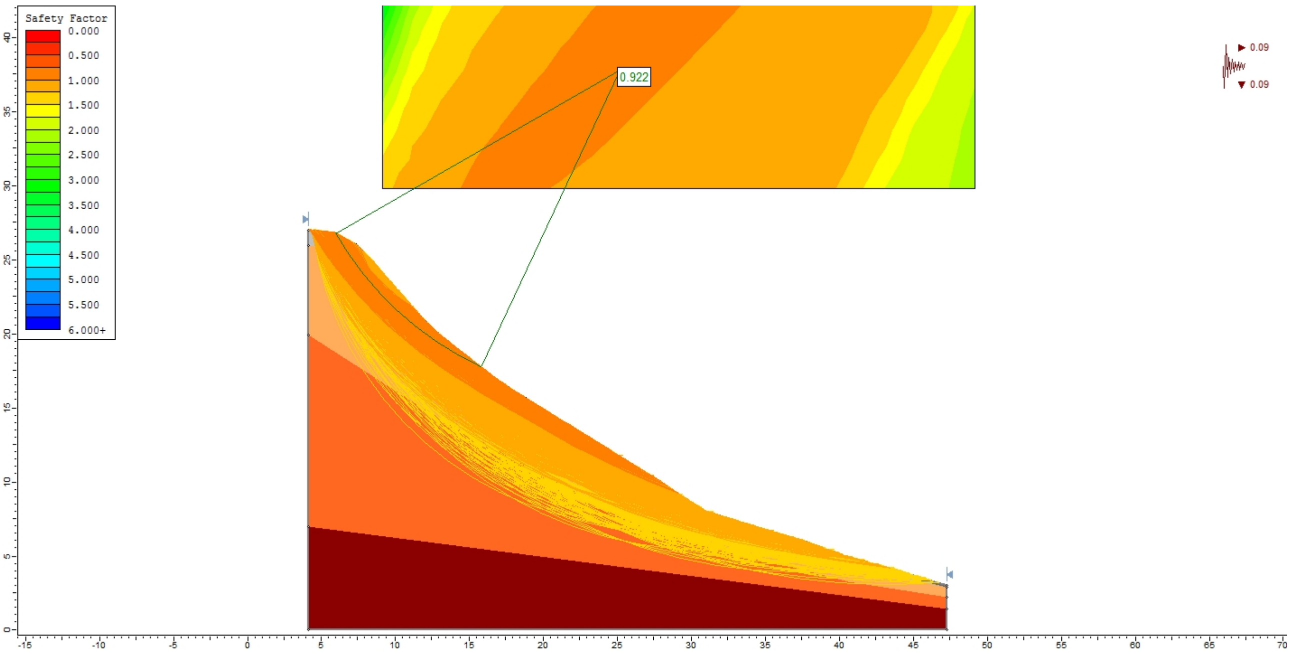
Material 3: Silty SAND- Dense
Strength Type: Mohr-Coulomb
Unit Weight: 20 kN/m^3
Cohesion: 2 kPa
Friction Angle: 40 degrees
Water Surface: None

Material 4: Clayey SAND
Strength Type: Mohr-Coulomb
Unit Weight: 21 kN/m^3
Cohesion: 5 kPa
Friction Angle: 40 degrees
Water Surface: None

Material 5: Extremely Weathered ROCK
Strength Type: Mohr-Coulomb
Unit Weight: 22 kN/m^3
Cohesion: 20 kPa
Friction Angle: 45 degrees
Water Surface: None



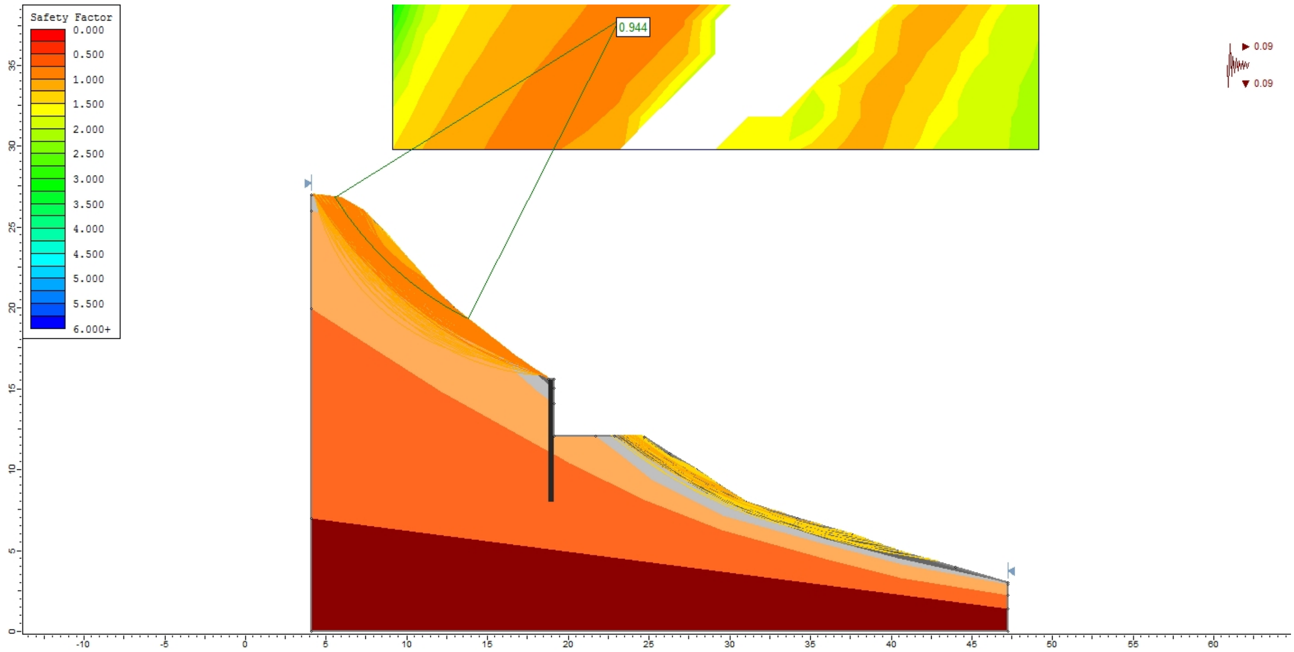
6.2 Model - Existing Site Conditions with Seismic Loading



Model 6.2 shows the present soil stratigraphy based on the site investigation and the latest contour map provided to Civiltest. This model considers the effects of earthquake loading. It shows a minimum Factor of Safety (FOS) equalling 0.922 for a failure surface. This would indicate that the slope would have collapsed under earthquake loading. The existing slope has been stable for at least the age of the existing dwelling on site. The model does not consider the effect of vegetation. The roots of existing vegetation over the site are contributing to the stability of the upper SAND. In addition, it is the author's opinion that the shear strength of the indurated SAND applied in the stability analysis for this site could be conservative.

All possible failure circles with a FOS of less than 1.5 are also shown in the above model. These failure circles are within the loose colluvium materials and the upper silty SAND layers. The depth of the failure circle is shown to be 5.0 metres from the existing surface level and this is highly unlikely. The failure surface would be shallow as the underlying SANDS are indurated. Collins, B.D. and Sitar, N. (2009) in an ASCE publication report cohesion values of 25kPa for indurated SAND. The modelling has adopted a cohesion of 1kPa because of the unknown depth of soil disturbance and weathering.

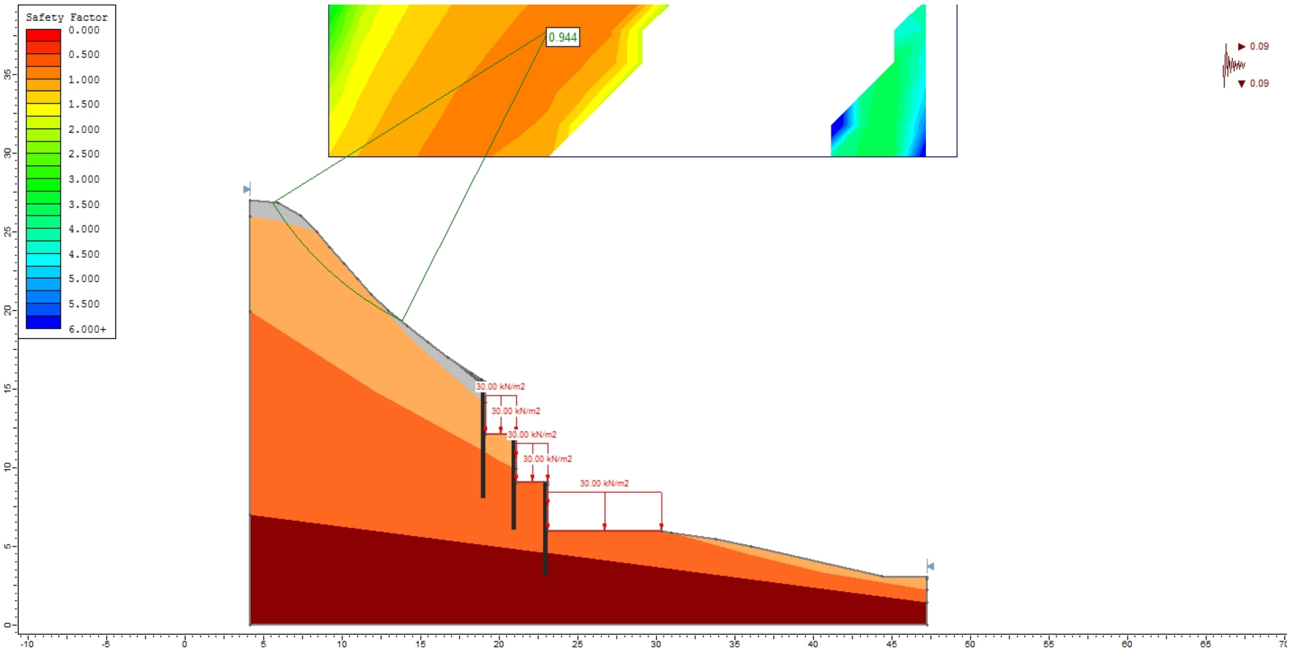
6.3 Model – Stage 1 Including the Installation of the Upper Line of Piers as a Retaining Structure



Model 6.3 demonstrates the effect of the proposed installation of the upper row of piers as a retaining wall. The modelling assumes that the proposed construction will entail constructing the upper row of piles followed by excavation of benches on the downslope side. This mode of construction is believed to minimise and stop any upslope disturbed material fall-out and movement of the disturbed material down slope. Including the earthquake loading, the minimum FOS is 0.944. The location of the failure surface with the minimum FOS is at the steepest section of the site. Again the failure surface is within the indurated SAND layer and the depth is depicted to be a couple of metres at the most. The existing good vegetation cover and the indurated SAND soils at the exposed escarpment are contributing to the stability of the steep slope face.

The retaining wall, assumed to be steel and concrete, was added to the model at the vertical cut locations. It has been assumed that the retaining walls will consist of closely spaced piles no more than a horizontal distance of 2.5d centre to centre spacing. (Where d = diameter of the pier). The piers and wall will be structurally engineered and have sufficient strength to resist the lateral earth pressures, as well as static and dynamic design actions.

6.4 Model – Proposed Building Loads with the Retaining Walls where Cuts are Proposed.



Model 6.4 demonstrates the effect of the proposed dwelling and the soil retaining walls as benched construction along the hillside. The minimum FOS is noted to remain at approximately the same location and the same value of 0.944 as per Model 6.3. Again the failure surface is within the indurated SAND layer and the depth is depicted to be a couple of metres at most. The existing good vegetation cover and the indurated SAND soils at the exposed escarpment are contributing to the stability of the steep slope face. To verify the existing stable conditions at this site based on the soil's material properties is made difficult because undisturbed sampling in sands is near to impossible.

It is the author's opinion that the shear strength of the indurated SAND used in the stability analysis for this site is conservative. Stability analysis with a cohesion of 10kPa in the silty/clayey SAND (indurated) would provide a minimum FOS of over 1.5. Given the sandy nature of the exposed material, shallow surface erosion and ravelling can be expected as well creep movements. The depth of these failures is unlikely to be more than 2.0 metres.

6.5 Discussion

The failure surfaces (circles) with a minimum FOS of 1.082 indicated in models 6.3 and 6.4 at the steeper section of the slope (escarpment) indicate that the stability of the site is not altered significantly and also the risk of any fall-out of material is minimised if the site works are undertaken commencing at the centre of the site and working downslope.

The good vegetation cover over the existing surface material should be maintained and any barren areas should be allowed to have vegetation regrowth in order to minimise shallow surface erosion and ravelling. Chicken wire mesh pinned in by star pickets or soil nails at selected strategic locations would provide added stability.

Model 6.2 indicates that under existing conditions, the possible failure surfaces with a FOS less than 1.5, could extend to a depth of up to 5.0 metres from the existing ground surface and this is very dependent on the degree of weathering and disturbance of the surface soils.

Model 6.3 and 6.4 indicate that if the upslope retaining walls at the proposed cuts are engineered and constructed properly, the stability of the slope in general would be maintained. It is recommended that a bored pier wall with capping beam should be provided at the upslope side of the proposed building before any construction procedures commence. Measures for stabilisation against shallow surface ravelling and erosion can be done together with bored pier wall or immediately after.

Overflow from the roadside kerb should be captured and diverted to the street drainage system such that there is minimal water cascading over the steep slope surface.

The subsurface soil profile may vary compared to the models due to inevitable variability in interpolation between the boreholes, and thus it is possible that the underlying granitic ROCK layer could be encountered at a more shallow depth in comparison to the interpolations made in the models.

At the downslope end of the site, weathered ROCK is expected below approximately 2.0 metres depth. At the proposed building location, weathered ROCK is expected between 5.0 metres to 10.0 metres depth whereby the footings at the downslope side of the building could intersect weathered rock at less than 5.0 metres depth. All load bearing footings should be founded at least 2000mm into the distinctly weathered ROCK.

The upslope bored piers should penetrate the weathered ROCK sufficiently and should be designed to support the lateral load expected on the proposed building wall. The piers should form the foundations for the retaining wall to the building. The above retaining wall should extend above the ground surface to stop the impact on the building of any material moving down the slope.

**Note: Distinctly weathered ROCK is assumed at depth of auger refusal.*

7. RISK ANALYSIS/ASSESSMENT

7.1 Risk Management Terminology

Risk is defined as a measure of the probability and severity of an adverse effect to health, property or the environment. (Australian Geomechanics Society Landslide Taskforce 2007).

Risk = the chance of an event times the consequences.

A comprehensive list of terms from AGS Appendices A and B (2007) are included in APPENDIX E of this report.

7.2 Landslip Terminology

The terms landslip and landslide will have the same meaning. There are five types of landslip: 1 Fall, 2 Topple, 3 Slide, 4 Spread and 5 Flow. Figure B1 AGS Mar 2007 describes each type with a diagram. To each term may be attached an AGS modifier. For example, *Rock Fall.* The term *active* will be used to describe landslip areas which, display bare silt, sand, gravel and/or clay. *Inactive* will be used to describe landslips without bare ground but with distinct edges. An inactive landslip may become active under the influence of one or more *triggers*. *Relic* will be used to describe land forms that were formed by ancient landslips and/or possible landslips. Relic land slips are considered stable due to the passage of time and/or successful remedial action.

At present there are two types of slope instability that could potentially occur at this site. These are: (a) Potential shallow rotational/translational landslide in the upper sand and colluvial units; (b) Potential earth debris slide in the soils.

a) A potential shallow rotational/translational Earth/Debris SLIDE/FLOW is thought to be possible within upper SAND and possible colluvial materials at the upslope and downslope of the proposed building.

b) A potential Earth/Debris SLIDE or FLOW could potentially initiate along the upper steep portion of the property as indicated by the existing slope stability modelling under 6.3. This could be triggered by earthquakes or following prolonged wet weather after penetration of water into the underlying soils.

7.3 Frequency Analysis

A qualitative assessment is being used to determine specific frequencies of hazards described above. This qualitative assessment uses the terminology as set out in table *Qualitative Measures of Likelihood* of Appendix C of AGS 2007. Based on the previous knowledge of the area the likelihood of landslides on steeper slopes is generally POSSIBLE. As the present slopes on the site are greater than 30% the likelihood of instability is as follows:

A. LIKELY given the depth of the upper silty SAND and possible colluvial materials as well as the level and depth of disturbed indurated SAND soils.
B. POSSIBLE given the soil profile and natural slope of the site and evidence shown on sites within the area.

7.4 Consequences to Property

Using the table *Qualitative Measures of Consequences to Property* of Appendix C AGS (2007) and taking into account the proposed development the consequences are assessed as follows

- Hazard A: Based on the potential hazards, small to moderate damage to some of the proposed structure and site requiring some stabilisation works is thought possible thus giving a descriptor of MINOR.
- Hazard B: Based on the proposed construction and the potential hazards, moderate damage to parts of the proposed structure, and/or extending beyond site boundaries requiring significant stabilisation works is thought possible, thus giving a descriptor of MEDIUM.

7.5 Risk Assessment For Property

The *Qualitative Risk Analysis Matrix* as in Appendix C AGS (2007) has been used to assess the level of risk to the proposed property and is represented in the following table.

Hazard		Likelihood	Consequence	Risk
A	Shallow Earth/Debris SLIDE/FLOW	LIKELY	Minor	**Moderate**
B	Earth/Debris FLOW/SLIDE	POSSIBLE	Medium	**Low to Moderate**

Table 7.5.1

Table 7.5.1 shows the identified hazards to have a Moderate risk level with respect to the proposed development and the practice note guidelines for landslide risk management. THE AGS guidelines suggest areas with a moderate risk level may be tolerated in certain circumstances (subject to regulatory approval) but require investigation, planning and implementation of treatment options to reduce the risk to Low. Detailed investigation, planning and implementation of treatment options are required to reduce the risk level to Low.

7.6 Risk Assessment for Life

Hazards A and B require a probabilistic approach to determine the risk assessment for life and this approach is as detailed below.

The risk to life in the event of an earth slide is considered as follows:

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

Where

$P_{(H)}$ is the annual probability of the hazardous event (e.g. Landslide)

$P_{(S:H)}$ is the probability of spatial impact multiplied by the hazard (e.g. of the landslide impacting a building (location) taking into account the travel distance) given the event

$P_{(T:S)}$ is the temporal probability (e.g. the occupation of the building at the time of the event) given the spatial impact

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

For each conceivable event as described above, the risk to life is calculated using the formula stated above.

$P_{(H)}$ and $P_{(S:H)}$ have been calculated using AGS Appendix C (2007), using indicative probabilities.

$P_{(T:S)}$ is calculated as 1.0 assuming that the house is always occupied.

Hazard	$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	$R_{(DI)}$
A. Shallow Earth/Debris FLOW/SLIDE	*2.0 x10^{-3}*	*0.50*	*1.0*	*0.1*	***1 x 10^{-4}***
B. Deep seated Earth/Debris FLOW/SLIDE	*2 x 10^{-4}*	*0.40*	*1.0*	*0.3*	***2.4 x 10^{-5}***

Table 7.6.1:

The risk to life is considered acceptable for Hazards A and B under existing conditions, but is determined to be a moderate risk for the proposed development and surface profile. This assessment is based on the AGS tolerable risk criteria under section 8.2 (Australian Geomechanics Society Landslide Taskforce. 2007).

Foundations for the proposed development should all be embedded in the weathered ROCK.

8. RISK MANAGEMENT AND TREATMENT

The risk assessment revealed moderate risk to life and of damage to the proposed property due to potential earth/debris slide/flow and potential earth/debris topple. These hazards will require management and treatment to reduce the risk level to preferably acceptable levels. With respect to the proposed development a number of risk treatment measures are listed below.

To mitigate the risk of the above failure hazards, the following measures would need to be incorporated into the proposed development.

- Foundations for the proposed structure should be founded at least 2000mm into the distinctly weathered ROCK and an allowable bearing pressure of 1200kPa can be assumed at this depth.

- Retention systems must be constructed prior to making any cuts for the proposed building. The upslope wall for the proposed building should also be designed as a retaining wall. The retaining wall founded on the bored piers at the upslope side of the proposed building should extend further above the existing ground surface to catch any dislodged or washed-out material travelling downslope.

- The area below View Point Road is relatively steep and is currently partly covered by vegetation. The slope appears stable largely because of the indurated SANDS near the upper layer and also due to the roots of existing vegetation. To minimise surface scouring and erosion that is expected during prolonged wet weather, the exposed and barren areas should be covered by geotextile, or vegetation regrowth encouraged. To further improve stability of the escarpment, the factor of safety can be increased by placing a wire mesh and pinning it down with soil nails or star pickets.

- No fill should be placed on this site except for a small amount of levelling fill. Excess material from any cuts should be taken down to lower, stable ground.

- Control surface water and sub-surface groundwater and direct the water collected, in addition to the roof and pavement runoff, into pipes connected to the stormwater system. The pipes should be flexible to accommodate creep or ground movements and be designed to prevent blockage. Energy dissipaters may be required.

- The surface of the exposed cut pad area should be graded to shed surface water towards open surface drains and in turn to the appropriate collection points.

- Revegetation should be encouraged at the existing slope face and on any uncovered soil surface. Revegetation using deep rooted vegetation is also a suitable option over certain areas that have been left barren. The aim of this is to prevent impact from rainfall by utilising the vegetation to take up excess moisture from the surface soils, rather than permitting surface infiltration.

The above treatment options will guard against the identified hazards impacting the dwelling.

Note: Good hillside practices should be adopted at all times when building on sites that may become unstable. Appendix G of AGS (2007) outlines good hillside practices and can be found attached to this document.

9. RECOMMENDATIONS:

9.1 Site Clearing

All natural vegetation should be retained whenever and wherever possible.

9.2 Earthworks – Cuts

Cut batters (unretained) may be up to 1.0 metre in height on this site with batters not steeper than 1V:2H. Retaining walls will be inevitable where cuts are required for the proposed dwelling area. A proper retention system must be constructed before any deep cut (more than 1.0m) has been made. The retention system will need to be structurally engineered and constructed by an experienced builder who has previous experience building on sites of this nature.

9.3 Earthworks - Fill

No fill has been allowed for on this site, except for very minimal fill of less than 400mm where required for leveling or on the proposed access driveway at the downslope end.

9.4 Retaining Walls

Where cut batters steeper than 35° are required in the clayey SAND and steeper than 60° in extremely weathered ROCK, these should be retained by engineer designed retaining walls. These retaining walls should be founded on deep piles founded at a minimum depth of 1000mm into the distinctly weathered ROCK. The retaining walls should be constructed before any earthworks start.

The retaining walls must have an agricultural type drain surrounded by a drainage sock placed behind them. This agricultural drain must be surrounded by a granular material which extends to the top of the wall. Sufficient weep holes should be made to reduce the pore water pressure on the wall.

The upslope walls of the proposed dwelling should be designed as part of the soil retaining wall if there is no separate retaining wall structure. Design of the upper retaining wall can be undertaken as normal by a qualified engineer with experience in slope stability.

Design of permanent earth retaining structures that will support earth pressures, can adopt the following parameters:

Material	Unit weight (kN/m^3)	K_a	K_o	c'(kPa)
Silty SAND	18.5	0.32	0.49	0
Sandy CLAY	21	0.41	0.58	4
Clayey SAND	20	0.27	0.43	2

Where c'= effective cohesion
K_a = active earth pressure coefficient
K_o = at-rest earth pressure coefficient

The above parameters assume there is sufficient drainage at the back of the retaining wall and no hydrostatic conditions are set up at the back of the wall.

9.5 Drainage

The proposed development, including the dwelling, will involve excavation cut and benching along the side of the hill. The upper cuts must have a catch drain constructed at the top to prevent any run-off water flow from running down the lower benches. Storm water collected in the lower benches should be directed to suitable drainage pits. The water collected in these drains should ideally be discharged into street drainage and/or a council easement drain.

Owners of the property must take responsibility of the ongoing maintenance of the drainage to ensure the drains are never blocked and to ensure the repair of any damaged drains.

9.6 Footings for Proposed Dwelling

Bored piers should be founded not less than 2000mm into the distinctly weathered ROCK and can be assumed to have an allowable bearing capacity of 1200kPa at this depth. At a depth of 1500mm into the distinctly weathered ROCK, a bearing capacity of 1500kPa can be assumed. A skin friction of 10kPa will exist between the piers and all clayey SAND soils, except for the soil within 1500mm of the surface and in FILL soils, where no skin friction will exist. An allowable skin friction of 150kPa can be adopted over the pier shaft embedded in distinctly weathered ROCK.

It is recommended that the founding materials be confirmed by Civiltest Pty Ltd at the time of excavation to ensure that suitable founding materials have been encountered.

9.7 Construction and access

Access for construction machinery to this site would be from Penny Lane. It is likely that an access track will have to be constructed leading to the proposed building location and will involve the demolition of the existing stone/rock retaining wall.

Access for the construction of the proposed bored piers at the upslope side will require some cut and fill. These shallow cuts and fill should be battered at no steeper than 30 degrees with the horizontal.

Short term stability and risk assessments would be required when location and loading for the proposed construction equipment are known.

10. CONDITIONS OF THE RECOMMENDATIONS:

a) The recommendations made in this report may need to be reviewed should any site works disturb any soil 300mm below the founding depth of the structure.

b) Since the soil horizons and layers can vary in depth and thickness over the site, the depths and bearing capacities given above are given as a guide only. If the footings are founded at the minimum depth, as stated and are in the soil as described in the logs of boring for this site, then the requirements of this report have been met.

c) The recommendations in this report do not consider any effects that climate change may have on the subject property.

d) The descriptions of the soils found in the bore holes closely follow those outlined in AS 1726-1993 (Geotechnical Site Investigations). Colour descriptions can vary with soil moisture content. It should be noted therefore, colour and shade descriptions mentioned in this report are made when the soil is in a moist condition.

e) This report has been compiled and recommendations made based on the information supplied in the brief to Civiltest Pty Ltd and from the field investigations and observations made including the extent of if any site filling. Every care has been taken within the terms of the brief to ensure that the field investigation is representative of the site. Therefore, if it is found that for any reason information received by Civiltest Pty Ltd is incorrect or conditions on site vary considerably during construction to those described in this report then the comments and recommendations made in this report may need to be amended.

f) Finally, no responsibility will be taken for this report if it is altered in any way or not reproduced in full.

This report consists of twenty one pages. Appendices A, B, C, D and E are attached.

REPORT PREPARED BY:

Irrelevant / Sensitive

Mr JINKE YU
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REF: MR/PB/jy/sv/po/sb/jg

23 October 2015

AMENDMENT: *This report was first issued on 19 May 2014. Sections of this report were amended on 15 September 2014, 19 December 2014 and 23 October 2015 and consequently this revised report now takes precedence over any previously dated report.*

Enc: Civiltest Pty Ltd Letter 1140220.3

11. REFERENCES

Australian Geomechanics Society Landslide Taskforce. (2007). "Practice Note Guidelines For Landslide Risk Management 2007." Journal and News of the Australian Geomechanics Society **42**(1): 63-158.

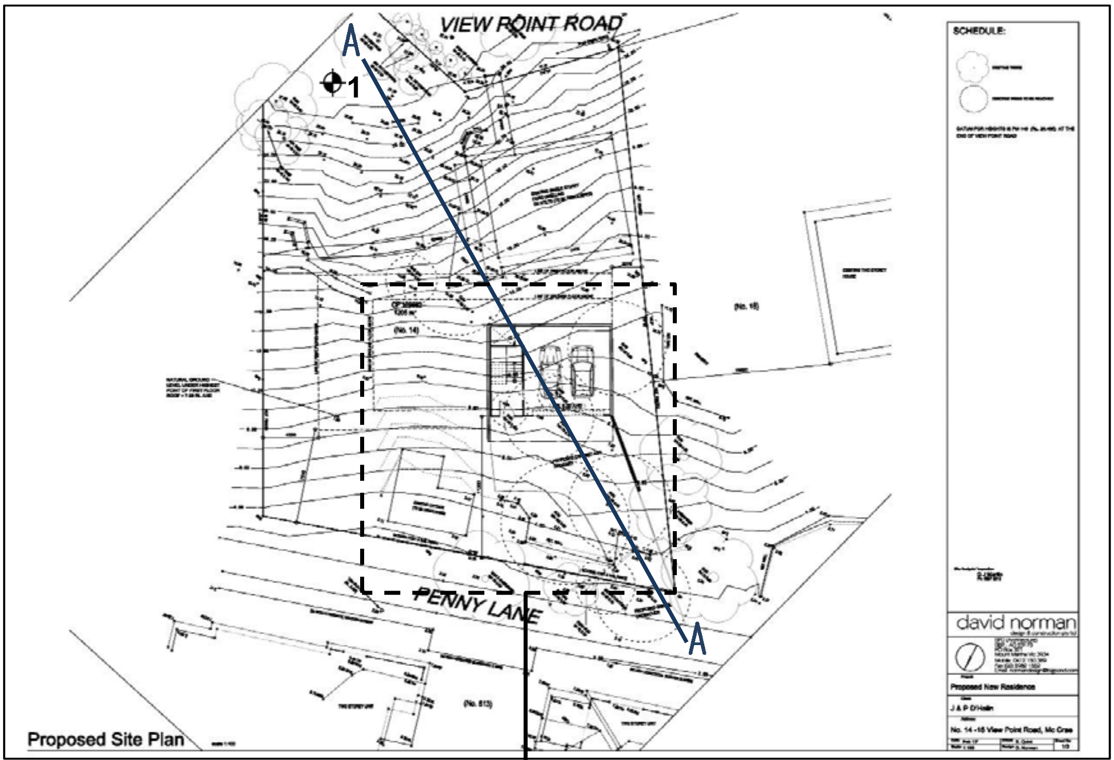
Australian Geomechanics Society, S. C. o. L. R. M. (2002). "Landslide Risk Management Concepts and Guidelines." Australian Geomechanics **35**(1): 51-90.

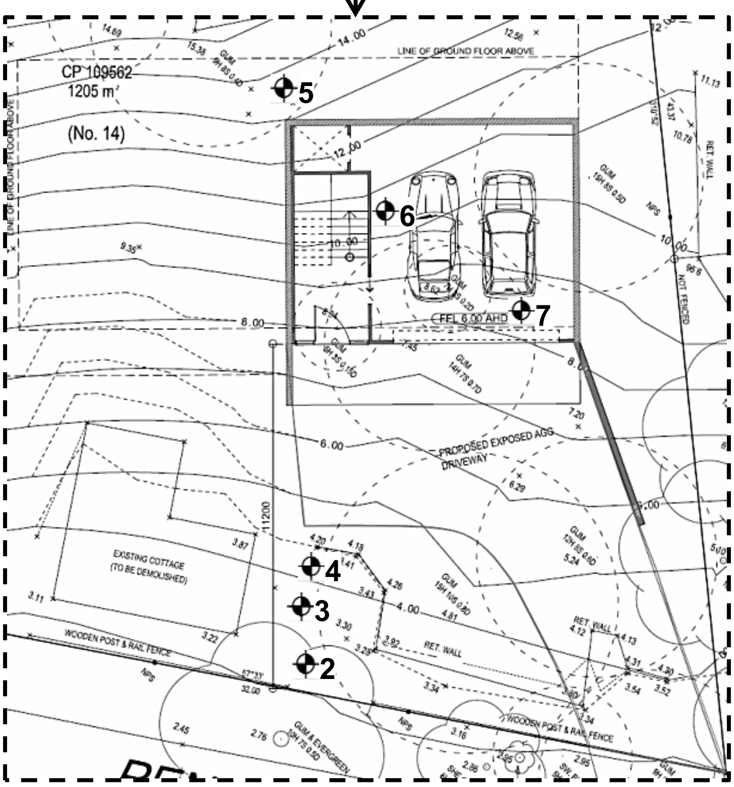
APPENDIX A

SITE PLAN - LOCATION OF TEST SITES

SITE PLAN – LOCATION OF TEST SITES

14-16 VIEW POINT ROAD, MCCRAE





Note:
Bore Hole 1 is on the plan above, Bore Holes 2-7 are on the plan at left.

Denotes Bore Holes

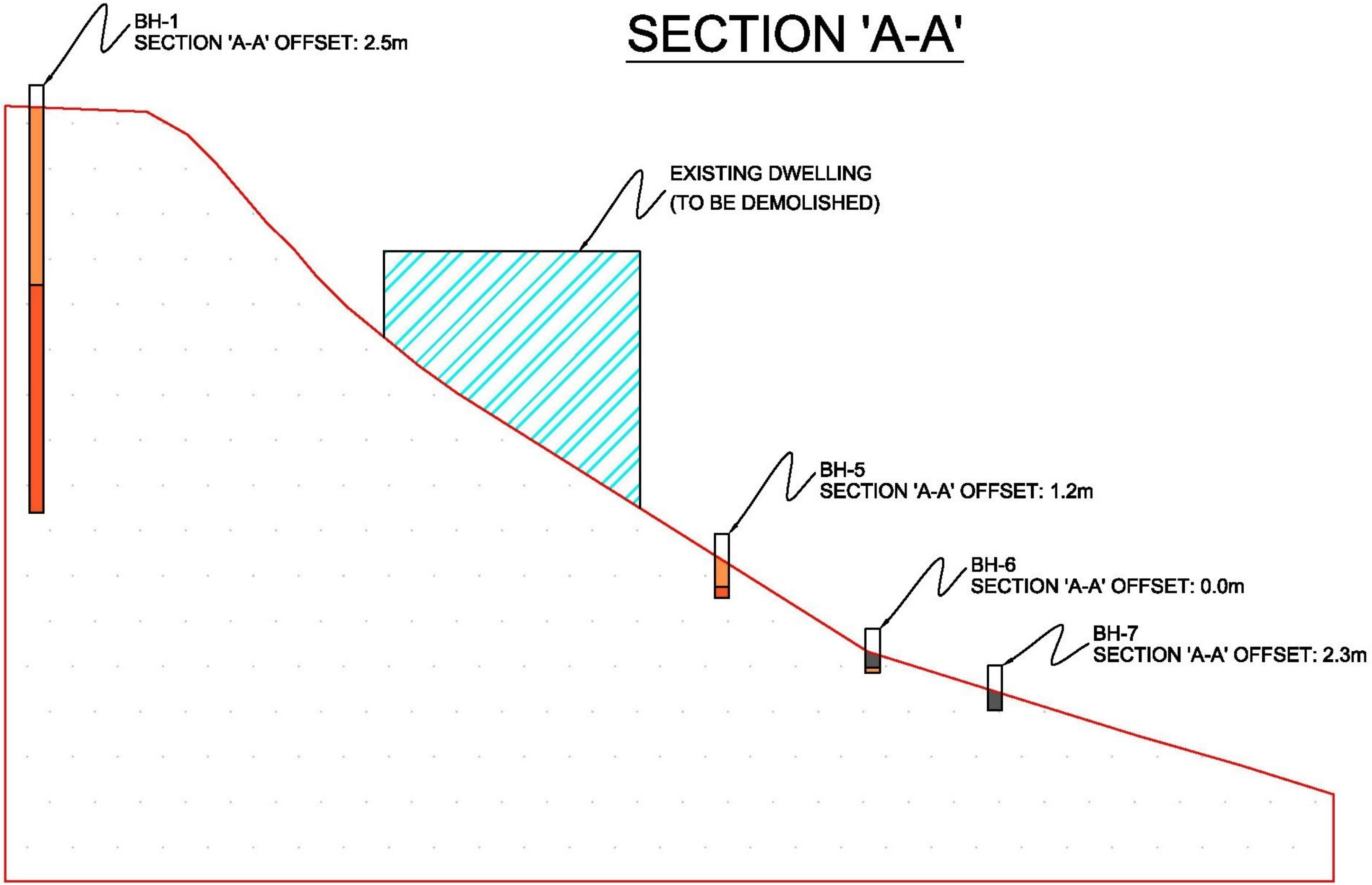
THIS SKETCH IS NOT INTENDED TO BE AN ACCURATE DEPICTION OF THE NUMBER, SIZE OR LOCATION OF TREES AND/OR SHRUBS

NOT TO SCALE

APPENDIX B

SECTION 'A-A'

SECTION 'A-A'


BH-1
SECTION 'A-A' OFFSET: 2.5m
EXISTING DWELLING
(TO BE DEMOLISHED)
BH-5
SECTION 'A-A' OFFSET: 1.2m
BH-6
SECTION 'A-A' OFFSET: 0.0m
BH-7
SECTION 'A-A' OFFSET: 2.3m

APPENDIX C

LOGS OF BORING

Test Hole No 1 Depth (m)	Classification	Moisture Content %	**Engineering Log**
3.000 5.500 7.000		4.9 7.0	SAND silty Grey Dry, Medium dense Dense and fine gravels throughout at 1.000 Pales with depth Becomes pale brown and moist at 2.000 Very dense at 3.400 Becomes clayey at 5.000
8.000			Extremely weathered ROCK, Low strength Excavated as clayey SAND Grey Moist, Dense
8.500 9.000		11.4	Extremely weathered ROCK, Low strength Excavated as sandy CLAY Grey brown Moist, Very stiff Occasional gravels present
13.000		14.9	Extremely weathered ROCK, Low strength Excavated as clayey SAND Pale grey brown Moist, Very dense
14.000			Extremely weathered ROCK, Low strength Excavated as sandy CLAY Brown grey Moist, Stiff Occasional gravels present
14.500 15.000		14.0	Extremely weathered ROCK, Low strength Excavated as clayey SAND Brown grey Moist, Stiff
			END OF BORE (24-03-14)

Test Hole No 2 Depth (m)	Classifi-cation	Moisture Content %	**Engineering Log**	
0.100	x . . . x . . . x . . .		SAND silty FILL Grey Dry to moist Medium dense Crushed rock throughout	**FILL**
1.000 2.500	x . . . x . . . x . . . x . . . x . . . x . . . x . . . x . . . x . . . x	7.6	SAND silty Grey brown Dry Very dense Occasional gravels present Dense and gravels present at 1.000 Becoming brown and a trace of clay present at 2.100 Granitic rock pieces at 2.200 **REFUSAL ON ROCK PIECES**	
			END OF BORE (24-03-14)	

Test Hole No 3 Depth (m)	Classifi-cation	Moisture Content %	**Engineering Log**	
0.400	x . . . x . . . x . . .		SAND silty FILL Grey Dry to moist Medium dense Crushed rock throughout	**FILL**
2.300	x . . . x . . . x . . . x . . . x . . . x . . . x . . . x . . . x		SAND silty Grey brown Dry Very dense Occasional gravels present Dense and gravels present at 1.000 Granitic rock pieces at 1.900 **REFUSAL ON ROCK PIECES**	
			END OF BORE (24-03-14)	

Test Hole No 4 Depth (m)	Classifi-cation	Moisture Content %	**Engineering Log**	
0.500	x . . . x . . . x . . .		SAND silty FILL Grey Dry to moist Medium dense Crushed rock throughout	**FILL**
2.200	x . . . x . . . x . . . x . . . x . . . x . . . x . . . x		SAND silty Grey brown Dry Very dense Occasional gravels present Dense and gravels present at 1.000 Granitic rock pieces at 1.800 **REFUSAL ON ROCK PIECES**	
			END OF BORE (24-03-14)	

Test Hole No 5 Depth (m)	Classifi-cation	Moisture Content %	**Engineering Log**
0.800	x . . . x . . . x . . . x . . . x . . .		SAND silty Grey Dry Medium dense Large gravel pieces at 0.600
1.100	__ . . . _ _ . . . _ _ . . .		SAND clayey Brown Dry to moist Medium dense
1.400	x ∴ ____ _ ∴ x _ ____ x ∴		CLAY silty, with sand Yellow mottled pale grey Moist Stiff
1.500	__ . . . _ _ . . . _ _ . . .		SAND clayey Yellow mottled pale grey Moist Medium dense to dense
			END OF BORE (24-03-14)

Test Hole No 6 Depth (m)	Classifi-cation	Moisture Content %	**Engineering Log**	
0.600	x . . . x . . . x . . .		SAND silty FILL Grey Dry Dense	**FILL**
0.750	x . . . x . . . x . . .		SAND silty Grey Dry Very dense Occasional gravels present **REFUSAL ON DENSE GRANITIC SAND & FINE GRAVELS**	
			END OF BORE (24-03-14)	

Test Hole No 7 Depth (m)	Classification	Moisture Content %	**Engineering Log**
0.400	x . . . x . . . x		SAND silty FILL Grey Dry Dense **FILL**
0.750	— . . . _ _ . . . _ _ . . .		SAND clayey Brown grey Dry to moist Medium dense Occasional gravels present **REFUSAL ON DENSE GRANITIC SAND & FINE GRAVELS**
			END OF BORE (24-03-14)

APPENDIX D

LABORATORY TEST RESULTS

CIVIL TEST PTY LTD
ABN 91 006 855 689 SOIL TESTING & GEOTECHNICAL CONSULTANTS ACN 006 855 689
10 Latham Street (P O Box 537) MORNINGTON Tel: (03) 5975 6644 Fax: (03) 5975 9589
Also at: Mitcham (03) 9874 5844 Wonthaggi (03) 5672 3900 and Mildura Tel: (03) 5023 2870

Atterberg Limits Report

Client :	**DAVID NORMAN DESIGN & CONSTRUCTION PTY LTD**	Report Number:	**1140220 - 1**
Address :	**PO Box 321, MT MARTHA, VIC, 3934**	Report Date :	**7/04/2014**
Project Name :	**14-16 VIEW POINT RD**	Order Number :	**-**
Project Number :	**1140220**	Test Method :	**AS1289.3.1.2, 3.2.1,3.3.1, 3.4.1**
Location:	**McCRAE , VIC**	**Page 1 of 1**	

Sample Number :	141-1150	141-1151	141-1152	141-1153
Test Number :	1	2	3	4
Date Sampled :	24/03/2014	24/03/2014	24/03/2014	24/03/2014
Date Tested :	3/04/2014	3/04/2014	3/04/2014	3/04/2014
Sampled By :	Mitchell Ratten	Mitchell Ratten	Mitchell Ratten	Mitchell Ratten
Sampling Method :	AS1289.1.2.1 (6.5.3)	AS1289.1.2.1 (6.5.3)	AS1289.1.2.1 (6.5.3)	AS1289.1.2.1 (6.5.3)
Material Source :	SITE DERIVED	SITE DERIVED	SITE DERIVED	SITE DERIVED
Material Type :	VARIOUS	VARIOUS	VARIOUS	VARIOUS
Sample Location :	BORE HOLE 1 @ 5.0m	BORE HOLE 1 @ 7.0m	BORE HOLE 1 @ 8.0m	BORE HOLE 1 @ 13.0m
Lot Number :	-	-	-	-
Moisture Method :	AS1289.2.1.1	AS1289.2.1.1	AS1289.2.1.1	AS1289.2.1.1
Sample History :	Oven Dried	Oven Dried	Oven Dried	Oven Dried
Sample Preparation :	Dry	Dry	Dry	Dry
Notes :	No Cracking or Crumbling	No Cracking or Crumbling	Some Curling Occured	Some Curling Occured
Mould Length (mm) :	250.0	250.0	250.0	250.0
Liquid Limit (%) :	**21**	**22**	**32**	**40**
Plastic Limit (%) :	**15**	**14**	**10**	**11**
Plasticity Index (%) :	**6**	**8**	**22**	**29**
Linear Shrinkage (%) :	**2.5**	**3.5**	**9.0**	**12.0**
SPECIFICATION DETAILS				
Specification Number :				
Liquid Limit-Max:				
Plasticity Index-Max:				
Linear Shrinkage-Max:				
Remarks :	-			
Soil Description :	**SAND Clayey**	**SAND Clayey**	**CLAY Sandy**	**CLAY Sandy**

NATA WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025.

APPROVED SIGNATORY

Darren Ashdown - Lab Co-Ordinator
NATA Accreditation Number : 1407

APPENDIX E

LANDSLIDE RISK MANAGEMENT –
AGS SUB-COMMITTEE APPENDICES MARCH 2007

Picarellei, L., Oboni, F., Evans, S.G., Mostyn, G. and Fell, R., (2005) *"Hazard characterization and quantification"* Proc Int Conf on Landslide Risk Management, Vancouver, 31 May-3 June 2005, AA Balkema Publ, O. Hungr, R. Fell, R. Couture and E. Eberhardt eds., pp681

Varnes, D.J. and The International Association of Engineering Geology Commission on Landslides and other Mass Movements (1984). Landslide Hazard Zonation: A review of principles and practice. Natural Hazards, Vol 3, Paris,France. UNESCO, 63p.

Standards Australia (1996) *"Residential Slabs and Footings"* Australian Standard AS2870

Standards Australia (2001) *"Concrete Structures"* Australian Standard AS3600

Standards Australia (2001) *"Steel Structures"* Australian Standard AS4100

Standards Australia (2002) *"Earth Retaining Structures"* Australian Standard AS4678.

APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK

RISK TERMINOLOGY

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 (eg 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.

ASSOCIATED TERMINOLOGY

Importance Level – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason *per se* of the Importance Level.

Authority or **Council** having statutory responsibility for community activities, community safety and development approval or management of development within its defined area/region.

The **Regulator** will be the responsible body/authority for setting Acceptable/Tolerable Risk Criteria to be adopted for the community/region/activity, which will be the basis for setting levels for Acceptable and Tolerable Risk in the application of the risk assessment guidelines.

Importance Level of Structure	Explanation	Examples (Regulatory authorities may designate any structure to any classification type when local conditions make such desirable)
1	Buildings or structures generally presenting a low risk to life and property (including other property).	Farm buildings. Isolated minor storage facilities. Minor temporary facilities. Towers in rural situations.
2	Buildings and structures not covered by Importance Levels 1, 3 or 4.	Low-rise residential construction. Buildings and facilities below the limits set for Importance Level 3.
3	Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds.	Buildings and facilities where more than 300 people can congregate in one area. Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250. Buildings and facilities for colleges or adult education facilities with a capacity greater than 500. Health care facilities with a capacity of 50 or more residents but no having surgery or emergency treatment facilities. Jails and detention facilities. Any occupancy with an occupant load greater than 5,000. Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4. Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries.
4	Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials.	Buildings and facilities designated as essential facilities. Buildings and facilities with special post-disaster functions. Medical emergency or surgery facilities. Emergency service facilities: fire, rescue, police station and emergency vehicle garages. Utilities required as back-up for buildings and facilities of Importance Level 4. Designated emergency shelters. Designated emergency centres and ancillary facilities. Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries.

(from BCA Guidelines)

Practitioner – A specialist Geotechnical Engineer or Engineering Geologist who is degree qualified, is a member of a professional institute and who has achieved chartered professional status – being either Chartered Professional Engineer (CPEng) within the Institution of Engineers Australia, Chartered Professional Geologist (CPGeo) within the Australasian Institute of Mining & Metallurgy, or Registered Professional Geoscientist (RPGeo) within the Australian Institute of Geoscientists – specifically with Landslide Risk Management as a core competency.

A Practitioner will include persons qualified under the Institution of Engineers Australia NPER – LRM register.

It would normally be required that the Practitioner can demonstrate an appropriate minimum period of experience in the practice of landslide risk assessment and management in the geographic region, or can demonstrate relevant experience in similar geological settings.

Regulator – The regulatory authority [Federal Government/ State Government/ Instrumentality/ Regional/Local.

APPENDIX B - LANDSLIDE TERMINOLOGY

The following provides a summary of landslide terminology which should (for uniformity of practice) be adopted when classifying and describing a landslide. It has been based on Cruden & Varnes (1996) and the reader is recommended to refer to the original documents for a more detailed discussion, other terminology and further examples of landslide types and processes.

Landslide

The term ***landslide*** denotes "the movement of a mass of rock, debris or earth down a slope". The phenomena described as landslides are not limited to either the "land" or to "sliding", and usage of the word has implied a much more extensive meaning than its component parts suggest. Ground subsidence and collapse are excluded.

Classification of Landslides

Landslide classification is based on Varnes (1978) system which has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are ***Rock***, ***Earth*** and ***Debris***, being classified as follows:-

The material is either rock or soil.

Rock: is "a hard or firm mass that was intact and in its natural place before the initiation of movement."

Soil: is "an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil."

Earth: "describes material in which 80% or more of the particles are smaller than 2 mm, the upper limit of sand sized particles."

Debris: "contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2 mm and the remainder are less than 2 mm."

The terms used should describe the displaced material in the landslide before it was displaced.

The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence ***fall***, ***topple***, ***slide***, ***spread*** and ***flow***.

The following table shows how the two terms are combined to give the landslide type:

Table B1: Major types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

<table>
<tr><th colspan="2" rowspan="3">TYPE OF MOVEMENT</th><th colspan="3">TYPE OF MATERIAL</th></tr>
<tr><th rowspan="2">BEDROCK</th><th colspan="2">ENGINEERING SOILS</th></tr>
<tr><th>Predominantly Coarse</th><th>Predominantly Fine</th></tr>
<tr><td colspan="2">FALLS</td><td>Rock fall</td><td>Debris fall</td><td>Earth fall</td></tr>
<tr><td colspan="2">TOPPLES</td><td>Rock topple</td><td>Debris topple</td><td>Earth topple</td></tr>
<tr><td rowspan="2">SLIDES</td><td>ROTATIONAL</td><td rowspan="2">Rock slide</td><td rowspan="2">Debris slide</td><td rowspan="2">Earth slide</td></tr>
<tr><td>TRANSLATIONAL</td></tr>
<tr><td colspan="2">LATERAL SPREADS</td><td>Rock spread</td><td>Debris spread</td><td>Earth spread</td></tr>
<tr><td colspan="2" rowspan="2">FLOWS</td><td>Rock flow</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><td>(Deep creep)</td><td colspan="2">(Soil creep)</td></tr>
<tr><td colspan="2">COMPLEX</td><td colspan="3">Combination of two or more principle types of movement</td></tr>
</table>

Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at http://landslides.usgs.gov.

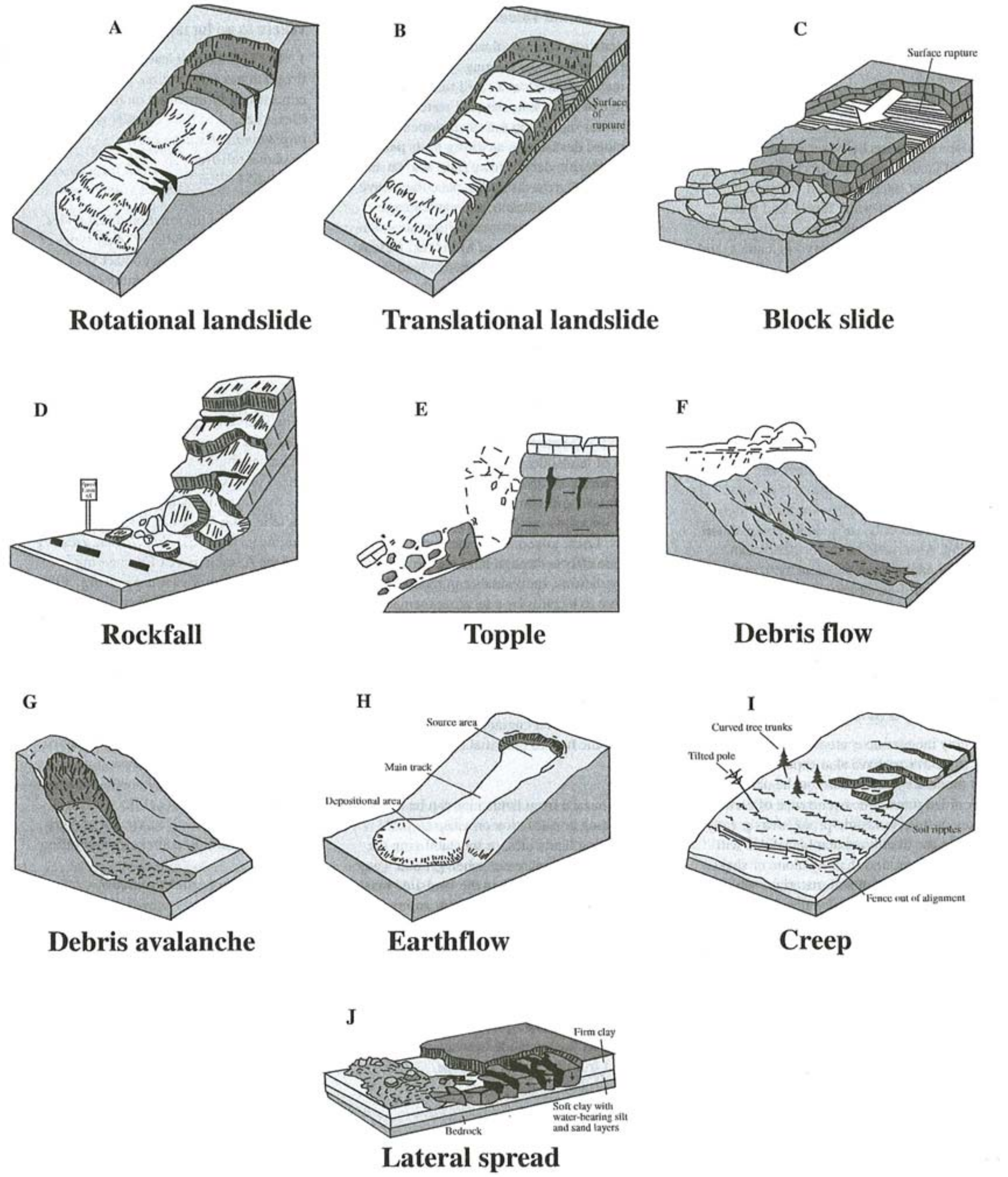


Figure B1: These schematics illustrate the major types of landslide movement.
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Second or subsequent movements in complex or composite landslides can be described by repeating, as many times as necessary, the descriptors used in Table B2. Descriptors that are the same as those for the first movement may then be dropped from the name.

For example, the very large and rapid slope movement that occurred near the town of Frank, Alberta, Canada, in 1903 was a *complex, extremely rapid, dry rock fall – debris flow*. From the full name of this landslide at Frank, one would know that both the debris flow and the rock fall were extremely rapid and dry because no other descriptors are used for the debris flow.

The full name of the landslide need only be given once; subsequent references should then be to the initial material and type of movement; for the above example, "the rock fall" or "the Frank rock fall" for the landslide at Frank, Alberta.

Table B2: Glossary for forming names of landslides.

Activity

State	**Distribution**	**Style**
Active Reactivated Suspended Inactive Dormant Abandoned Stabilised Relict	Advancing Retrogressive Widening Enlarging Confined Diminishing Moving	Complex Composite Multiple Successive Single

Description of First Movement

Rate	**Water Content**	**Material**	**Type**
Extremely rapid Very rapid Rapid Moderate Slow Very slow Extremely slow	Dry Moist Wet Very Wet	Rock Earth Debris	Fall Topple Slide Spread Flow

Note: Subsequent movements may be described by repeating the above descriptors as many times as necessary. These terms are described in more detail in Cruden & Varnes (1996) and examples are given.

Landslide Features

Varnes (1978, Figure 2.1t) provided an idealised diagram showing the features for a *complex earth slide – earth flow*, which has been reproduced here as Figure B2. Definitions of landslide dimensions are given in Cruden & Varnes (1996).

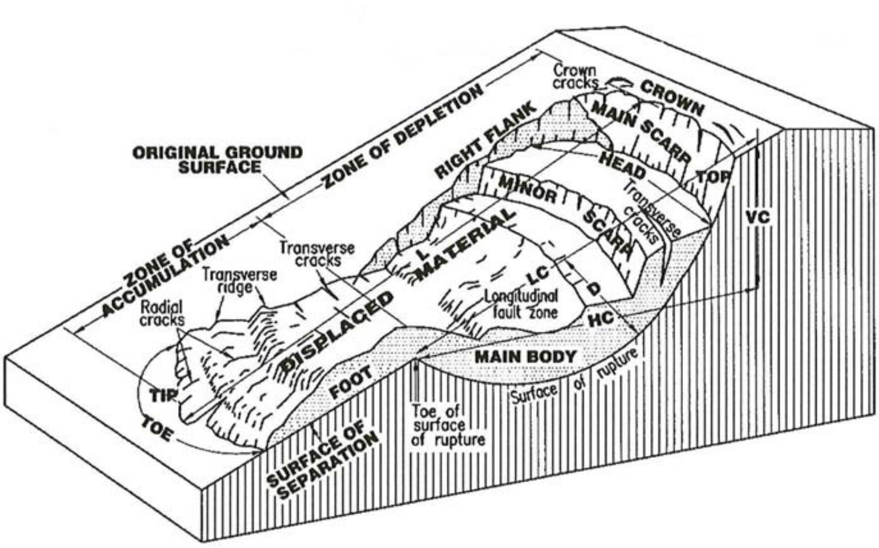


Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(*Varnes, D J (1978,)Slope Movement Types and Processes. In Special Report 176: Landslides: Analysis and Control(R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33).*

Rate of Movement

Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term "creep" has been omitted due to the many definitions and interpretations in the literature.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evaluation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
	Extremely **SLOW**			Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS**

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

REFERENCES AND ACKNOWLEDGEMENT

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IAEG (International Association of Engineering Geology) Commission on Landslides, (1990). Suggested nomenclature for landslides, Bulletin IAEG, No. 41, pp.13-16.

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PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

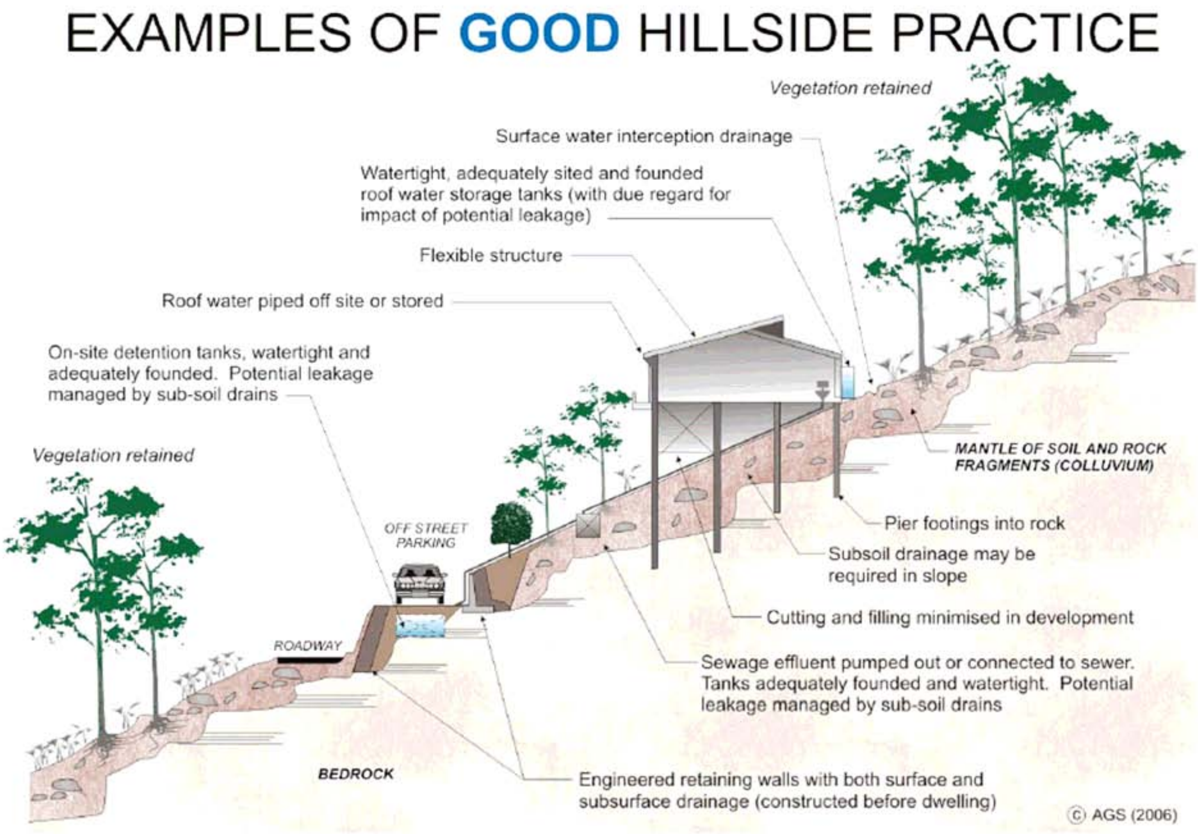
RISK LEVEL IMPLICATIONS

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

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

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner 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.	Indiscriminatory 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
ROADWAY
Cutting and filling minimised in development
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)
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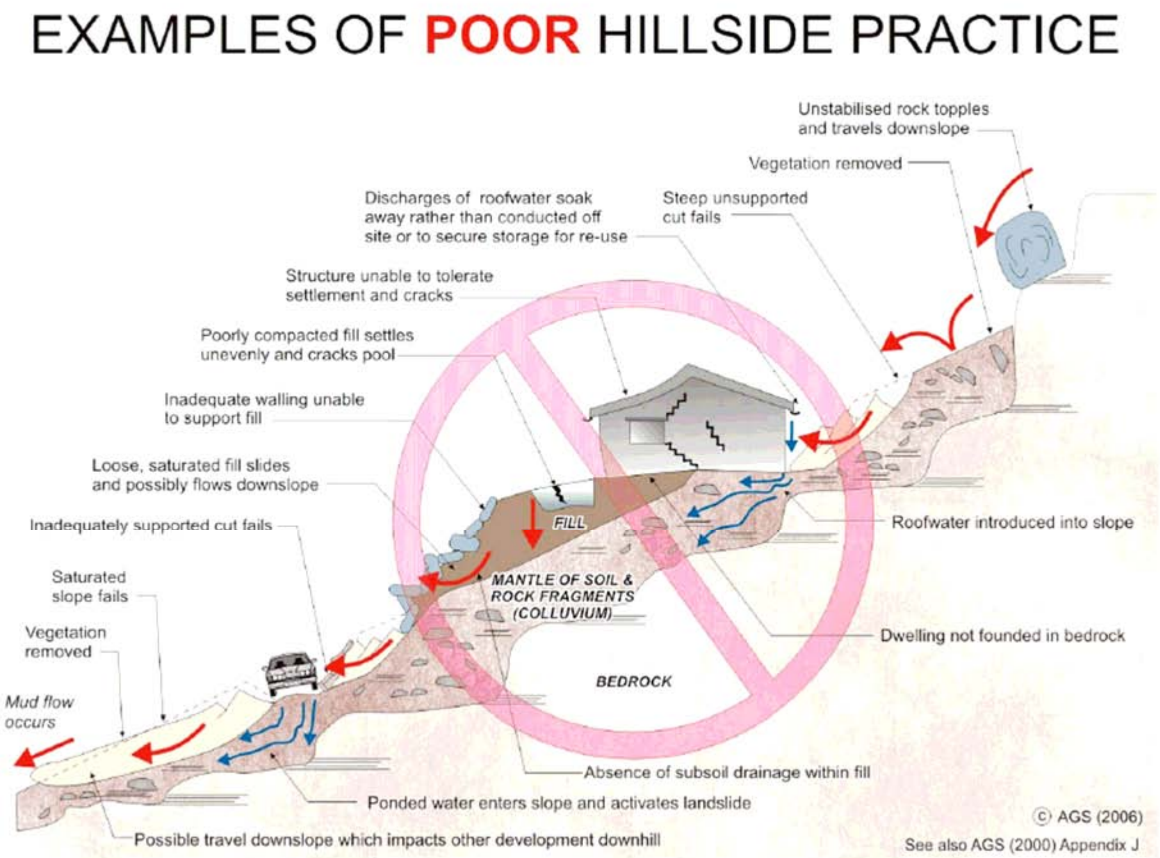
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
FILL
Roofwater introduced into slope
Inadequately supported cut fails
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
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J