GEO-ENVIRONMENTAL SOLUTIONS

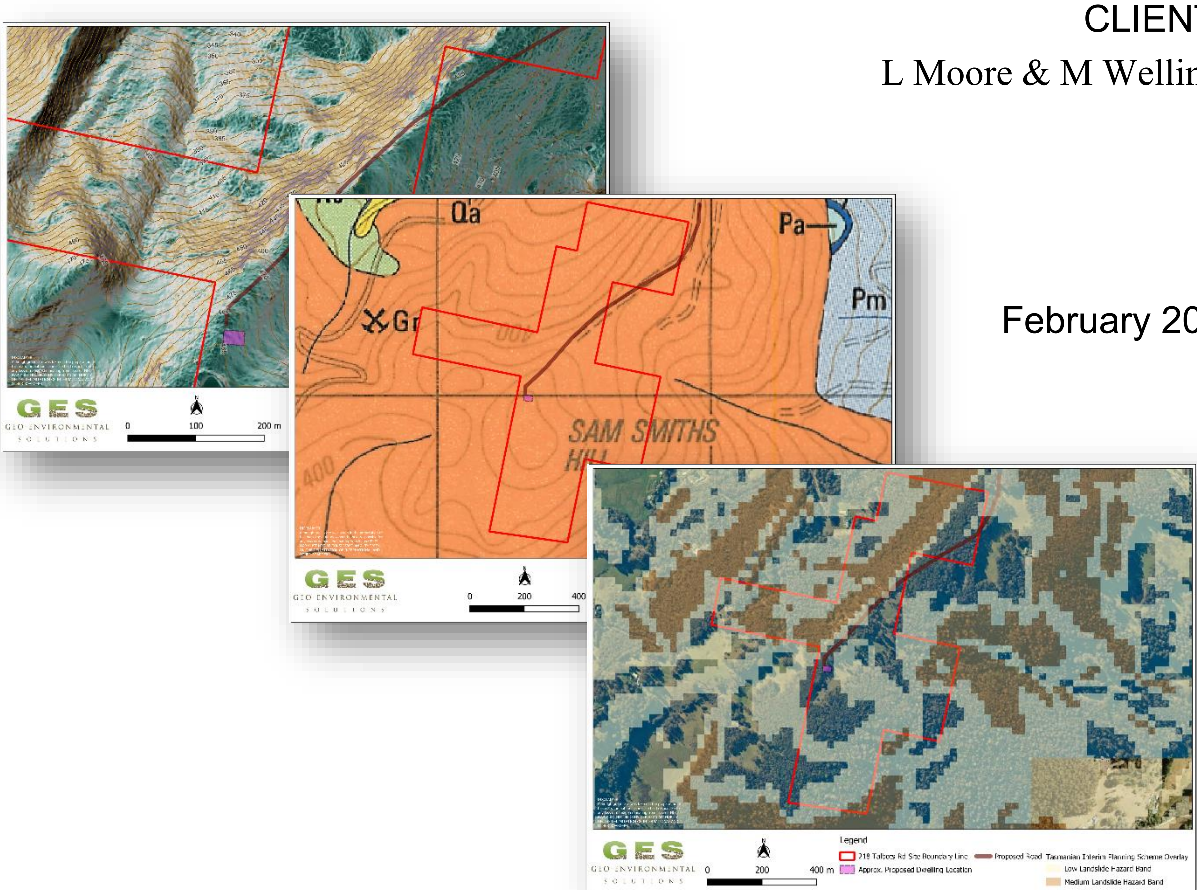
LANDSLIDE RISK ASSESSMENT

218 Talbots Road, Sandfly TAS 7150

CLIENT

L Moore & M Welling

February 2023



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Tables

Figures

1 Introduction

Geo-Environmental Solutions Pty Ltd (GES) were contracted by L Moore & M Welling, to provide a geotechnical assessment to assess landslide hazard management for a proposed works at Sandfly, which lays within the Kingborough Interim Planning Scheme. The proposed development is located at cadastral title (CT 240577/1) at 218 Talbots Road, Sandfly, TAS (The Site). GES are to undertake this geotechnical assessment relating to the proposed works conjunction with the requirements of the Landslide Hazard Code, part of the Tasmanian Interim Planning Scheme. GES have written this report in accordance with the Australian Geomechanics Guidelines (AGS 2007).

GES have undertaken this assessment using previous site observations and investigation, photographs and publicly available datasets in the construction of this report. Estimations are determined by approximation with regional information applied where appropriate to site specific information.

2 Objectives

The objective of the site investigation is to:

- Identify the requirements of the Landslide Hazard Code;
- Conduct a landslide risk assessment of the proposed development excavations with reference to the Australian Geomechanics Society (AGS) *Landslide Risk Management (2007) guidelines';*
- Identify which planning scheme codes need to be addressed in terms of landslip and identify the relevant performance criteria relevant to the project which need addressing;
- Conduct a site risk assessment for the proposed development ensuring relevant performance criteria are addressed; and
- Where applicable, provide preliminary recommendations on earthworks to ensure safe slope management.

3 Site Details

3.1 Project Area Land Title

The land studied in this report is defined by the following title reference:

- CT 240577/1

This parcel of land is referred to as the 'Site' and/or the 'Project Area' in this report (Figure 1 and Figure 2).

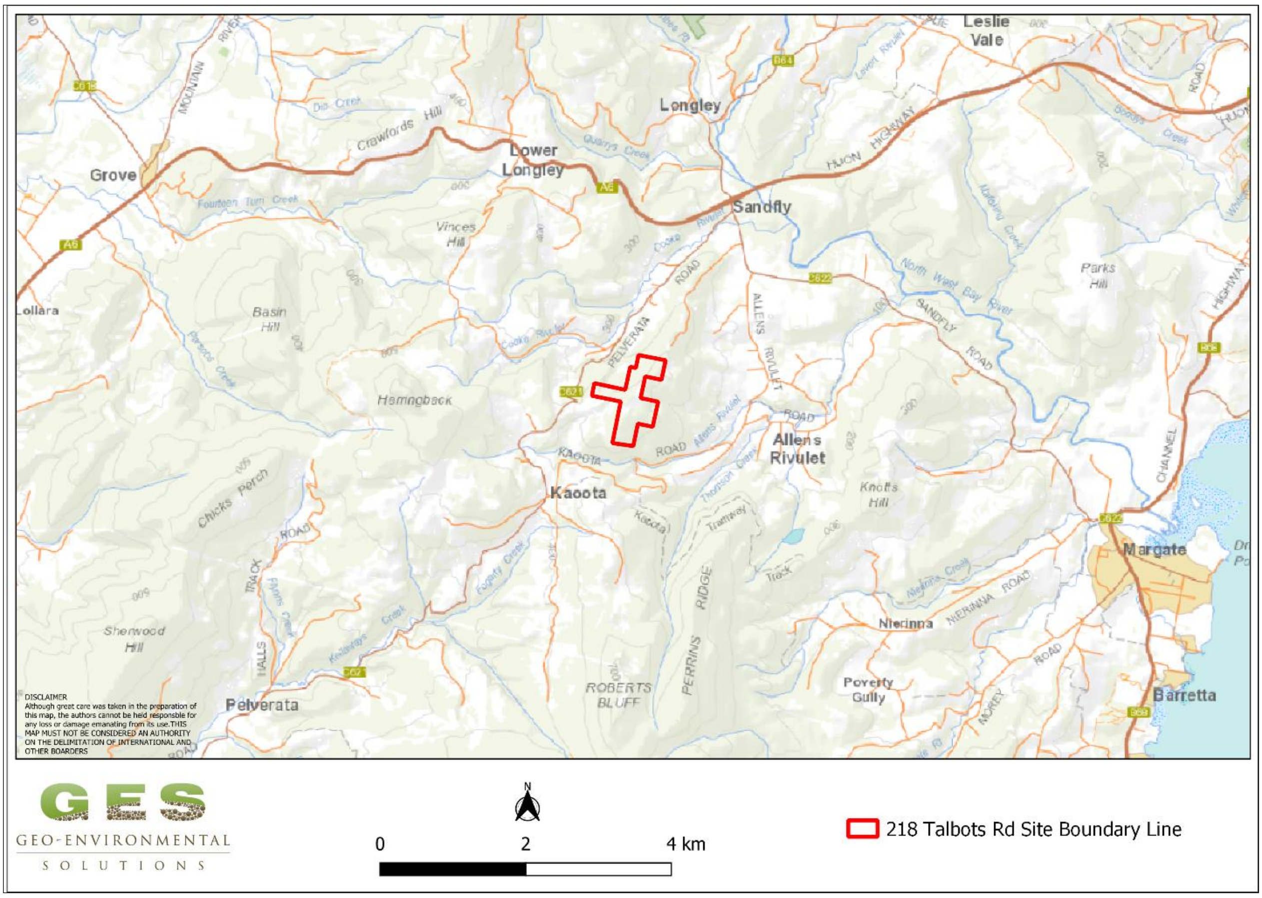


Figure 1 Regional Location of Project Area (The LIST)

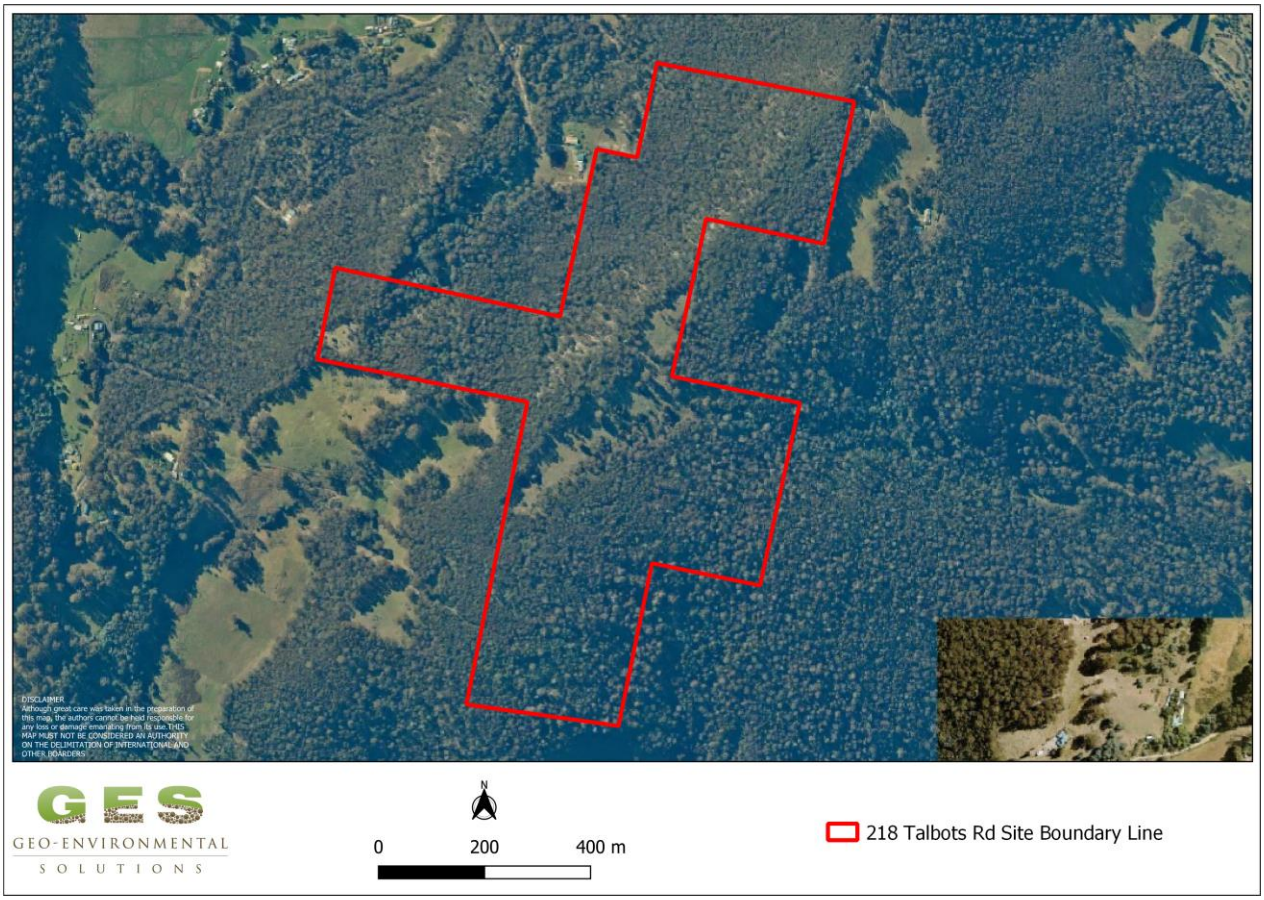


Figure 2 Local Project Area Setting (The LIST)

3.2 Australian Building Code Board

This report presents a summary of the overall site risk to landslide hazards. This assessment has been conducted for the driveway which is intended to service the building development and should be assessed for the year 2072 which is representative of a 'normal' 50-year building design life category.

Per the Australian Building Code Board (ABCB 2015), when addressing building minimum design life:

> *'The design life of buildings should be taken as 'Normal" for all building importance categories unless otherwise stated.'*
>
> As per Table 3-1, the building design life is 50 years for a normal building.

Table 3-1 Design life of building and plumbing installations and their components

Building Design Life Category	***Building Design Life (years)***	***Design life for components or sub systems readily accessible and economical to replace or repair (years)***	***Design life for components or sub systems with moderate ease of access but difficult or costly to replace or repair (years)***	***Design life for components or sub systems not accessible or not economical to replace or repair (years)***
Short	1 < dl < 15	5 or dl (if dl<5)	dl	dl
Normal	50	5	15	50
Long	100 or more	10	25	100

Note: Design Life (dl) in years

3.3 The Tasmanian Building Regulations 2016

Building in hazardous areas

As outlined in the Department of Justice web site:

http://www.justice.tas.gov.au/building/building-and-plumbing/building_in_hazardous

Hazardous areas include areas which are bushfire prone, comprise reactive soils or substances, or are subject to coastal erosion, coastal flooding, riverine flooding, and landslip.

Division 5 - - Landslip. Section 59. Landslip hazard areas

(1) For the purposes of the Act, land is a landslip hazard area if –
  a. the land is shown on a planning scheme overlay map as being land that is within a landslip hazard area; and
  b. the land is classified as land within a hazard band of a landslip hazard area.

(2) For the purposes of the definition of *hazardous area* in section 4(1) of the Act –
  a. classification under a landslip determination as being land that is within a hazard band of a landslip hazard area is a prescribed attribute; and
  b. a landslip hazard area is a hazardous area.

3.4 *Interim Planning Scheme Overlays*

3.4.1 Landslide Overlay

The proposed road to the site is partially within the low landslide hazard area overlay, as defined by the Interim Planning Scheme Landslide Hazard Mapping (MRT 2015). The access driveway is to enter the site from the northeast and travel to the southwest towards the proposed development at the top of the hill. The proposed residential dwelling is not within a landslide overlay, so it was exempt from this code. This report only to review the proposed road development (Figure 3).

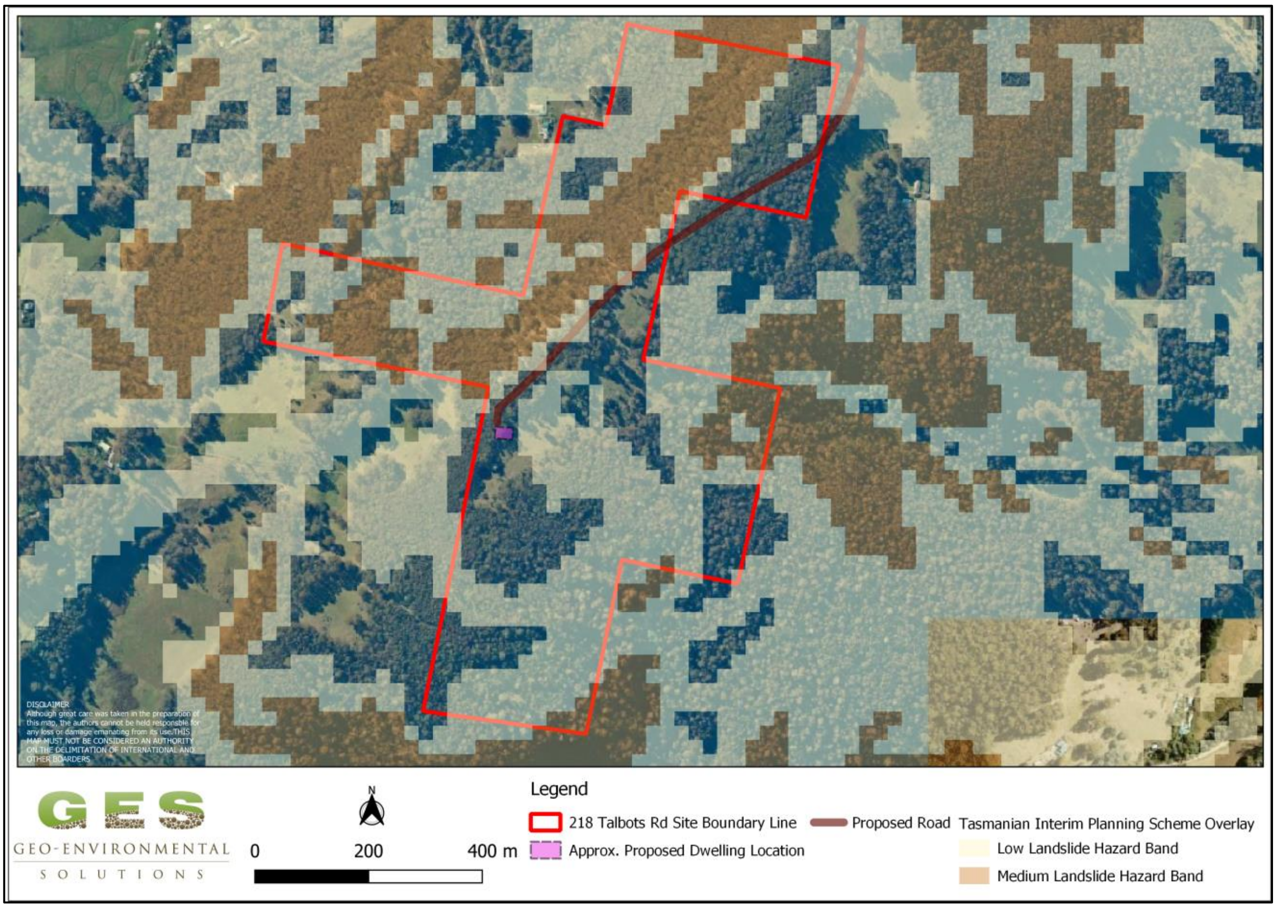


Figure 3 Landslide Overlay Near the Site (The LIST)

3.5 *Assessed Works*

The proposed development to be assessed consists of an approx. 1km long access driveway that will provide access to a proposed dwelling and garage from Talbots Road. The small portion of the road is an existing track which will be required to be widened to use for access and the remaining road will be newly built.

3.5.1 Development & Works Acceptable Solutions

Where applicable, the need for further performance criteria compliance is outlined in Appendix 1.

3.5.2 Landslide Hazard Code (LHC)

Given that the proposed driveway resides in the low Landslip Hazard Areas and the excavation works are in excess of 100m^3 and 1000m^2 and there are no acceptable solutions for buildings and works, other than minor extensions or major works, in a low Landslip Hazard Area, the E3.7.1 P1 and E3.7.3. P1 performance criteria will need to be addressed for the proposed driveway.

3.5.3 Development Performance Criteria

The following performance criteria need to be addressed:

- E3.7.1 P1
- E3.7.3 P1

4 Site Mapping

4.1 *Mapped Geology*

Based on the MRT 1:50,000 Mineral Resources Tasmania (MRT) Geology of Kingborough , the site geology comprises of the following geological units:

- **Jurassic Igneous Rocks (Map Unit – Jd):** Dolerite, (tholeiitic) with locally developed granophyre (Figure 4)

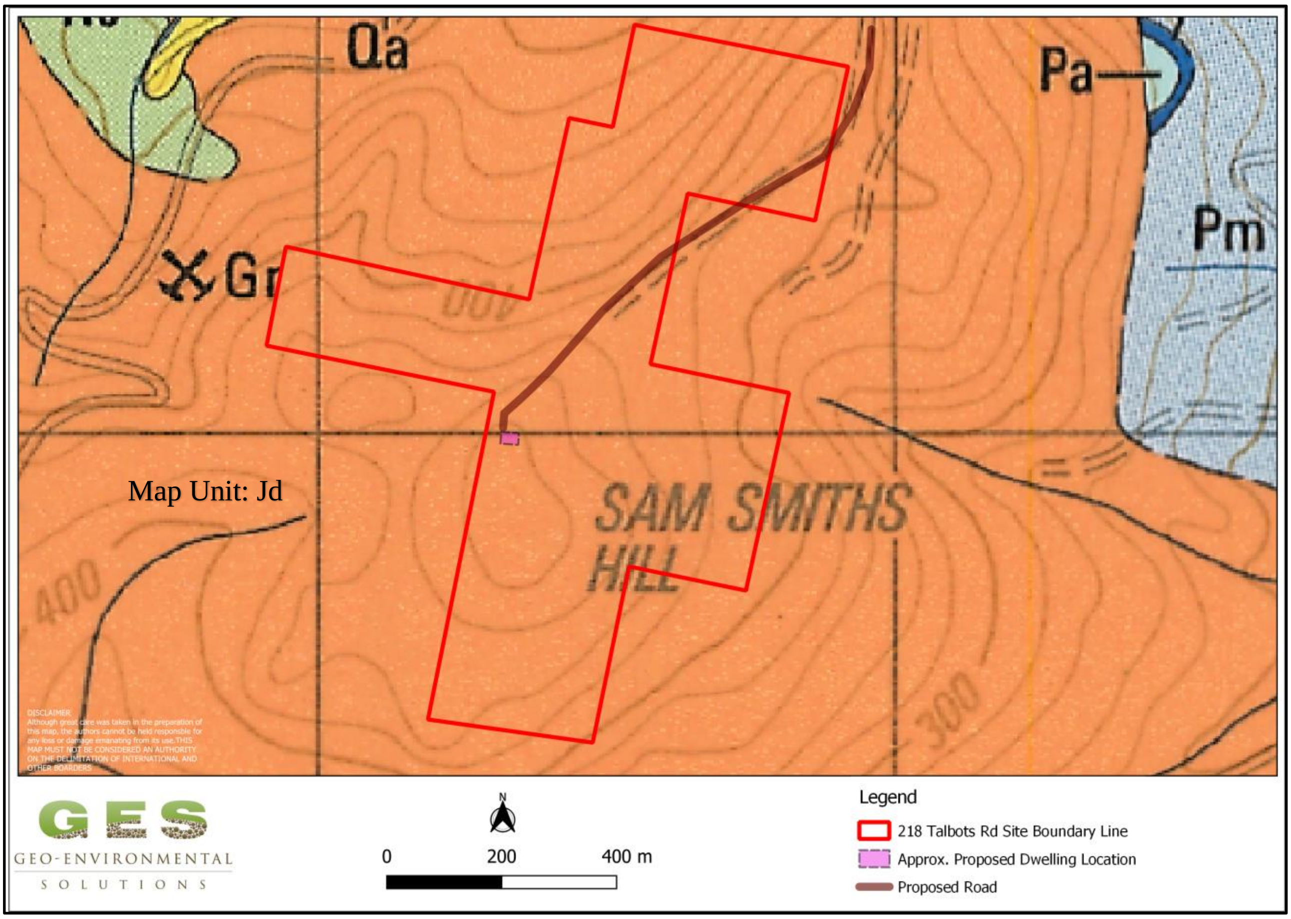


Figure 4 Site Geology (Extract from 1:50,000 Mineral Resources Tasmania (MRT) Geology of Kingborough

4.2 *Site Geomorphology*

The proposed building development is located on the top of northeast to southeast oriented ridgeline associated with Sam Smiths Hills. The site ranges in elevation from approx. 485 m AHD at the top of Sam Smiths Hill where the proposed dwelling is going to be located to 425 m AHD at the northeast of site. The site does not have any existing dwelling. A slope angle map created from Mount Wellington River Derwent 2010 LiDAR DEM data has been created displaying the slope angles onsite Figure 5. Slope angles typically range between 10° and 20° where the proposed driveway is with some steep slopes on the north side of the proposed road. The steep north facing slopes are relatively densely vegetated with mature trees, which makes majority of the site. Where slopes are not as steep, grass and/or weed species are the dominant vegetation type. The site has a dam, which is located to the southeast from the proposed dwelling.

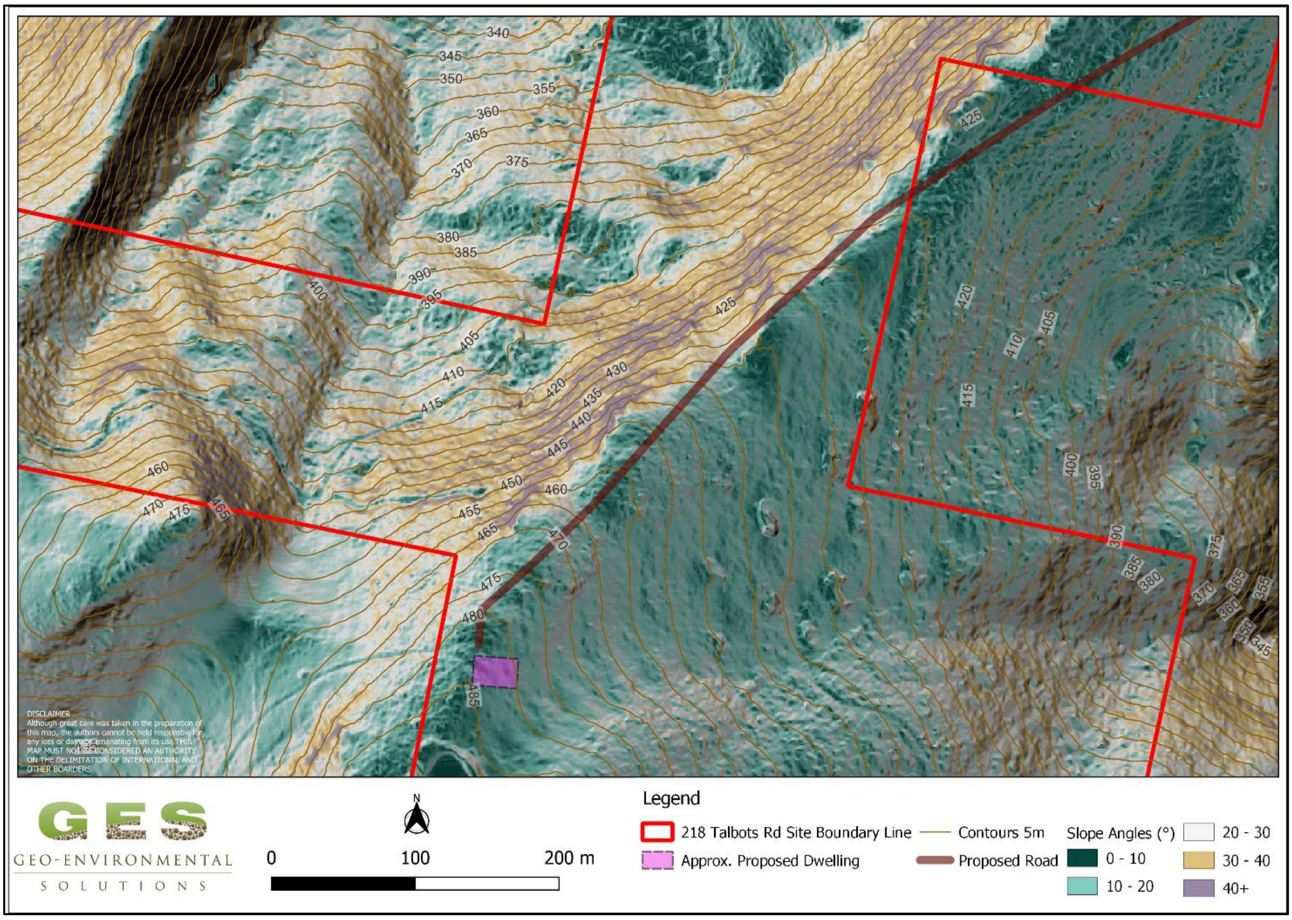


Figure 5 Slope Angle Model from Mount Wellington River Derwent 2010 LiDAR DEM Data.

4.3 Site Investigation

Site investigations were undertaken by GES on 16/01/2023 to assess the site classification in accordance with AS2870-2011. Pertinent information from these investigations has been used in the construction of this report. The soils found on the site are developing from Dolerite colluvium and exhibit a shallow clay layer overlying clayey gravels. Ground water was not encountered during the site investigations.

5 Landslide Hazard Analysis

5.1.1 Landslide Characteristics

Based on the slope characteristics including site geology, slope geometry and slope angles, MRT landslide mapping/inventory and site observations, the following scenarios have been identified as potential slope failure mechanisms for the site:

- Scenario 1 – Shallow slide failure within natural soils beneath, or immediately downslope of the proposed driveway.
- Scenario 2 – Shallow rotational failure of cut batters above proposed access road.

Scenarios 1-2 are represented in Table 1 below.

5.1.2 Frequency Analysis

Table 1 presents the frequency analysis for the identified slope failure mechanisms. Terminology used is in accordance with the Australian Geomechanics Society (AGS) guidelines for landslide risk management (2007a,b,c,d).

Table 1 Frequency analysis for landslide hazards 1 - 2

Scenario	Failure Mechanism	Unit Affected	Observed in the field	Potential Size	Potential Velocities	Water Content	Current Likelihood	Treated Likelihood
Scenario 1	Shallow slide failure within natural soils beneath, or immediately downslope of the proposed driveway.	Natural soils.	No	Small with potential regression upslope towards driveway	Slow to rapid	Wet/ saturated	Possible	Unlikely
Scenario 2	Shallow slide failure within cut above driveway	Over-steepened clay soils	No	Very small to small	Moderate to rapid	Moist to Wet	Possible	Unlikely

5.2 Risk Analysis

5.2.1 Risk to Property

Risk has been considered for the proposed development pre- and post-construction. Recommended risk treatment will reduce the risk for scenarios 1 - 2 to Low in Table 2.

Table 2 Consequence analysis for landslide hazards

Scenario	Issue	Current Risk			Recommended risk treatment	Residual Risk following implementation of risk treatment		
		Likelihood of occurrence	Consequence to property	Level of risk to property		Likelihood of occurrence	Consequence to property	Level of risk to property
Scenario 1	Shallow Slide or Flow Failure	Possible	Minor	Moderate	Vegetation cleared for the proposed development and road should be the minimum required for bushfire hazard management; Cut slopes on site are to be graded to 1V:1H within dolerite bedrock and 1V:2H within the soil; Fill slopes on site are to be graded to 1V:3H and are to be keyed into underlying clay site soils; A cut-off v-drain should be considered above the cuttings in areas of high-water flow. Earthworks should be conducted with the drier summer months. Good hillside construction practices should be adopted as per Australian Geoguide LR8;	Unlikely	Minor	Low
Scenario 2	Shallow Slide Failure	Possible	Minor	Moderate	Vegetation cleared for the proposed development and road should be the minimum required for bushfire hazard management;	Unlikely	Minor	Low

					Cut slopes on site are to be graded to 1V:1H within dolerite bedrock and 1V:2H within the soil; Fill slopes on site are to be graded to 1V:3H and are to be keyed into underlying clay site soils; A cut-off v-drain should be considered above the cuttings in areas of high water flow. Earthworks should be conducted with the drier summer months. Good hillside construction practices should be adopted as per Australian Geoguide LR8;			

5.2.2 Risk to Life

Risk to life is considered acceptable given the treated likelihood and consequence scenarios 1 and 2 (Table 3).

Table 3 Consequence analysis for landslide hazards – Life – Post-treatment (Scenarios 1-2)

Factor	Scenario 1	Scenario 2
Hazard	Shallow slide or flow failure within natural soils beneath, or immediately downslope of the proposed driveway.	Shallow slide failure within cut embankments above driveway.
Likelihood	Unlikely	Unlikely
Indicative Annual Probability – $P_{(H)}$	0.001	0.001
Probability of Spatial Impact - $P_{(S:H)}$	Potential to undermine the stability of the driveway and potential regression. 0.1	Potential for debris to cover road with potential for interaction with vehicles. Small scale failure size. 0.2
Temporal Spatial Probability– $P_{(T:S)}$	Residual soils should exhibit signs of stress (tension cracking prior to failure). Anticipated velocities should allow for time for evacuation and/or remediation. – Personnel assumed on driveway for 2 hours daily (conservative) 0.2	Residual soils should exhibit signs of stress (tension cracking prior to failure). Anticipated velocities should allow for time for evacuation and/or remediation. – Personnel assumed on driveway for 2 hours daily (conservative) 0.2
Vulnerability – $V_{(D:T)}$	Structure unlikely to collapse. 0.2	Possibility for a portion of cut batters/ retaining walls to collapse and potentially impacting small portions of the driveway and interact with vehicles. 0.3
Risk for Person Most at Risk – $R_{(LoL)}$	4.0×10^{-6}	1.2×10^{-5}

Note 1: It has been assumed that each person has an equal probability of death for each of the hazards.
Societal Risk has not been assessed for the development.

6 Conclusions and Recommendations

Based on the outcome of the hazard analysis and risk assessment, the following conclusions are made:

- The landslide risk assessment has been undertaken for the proposed driveway only;
- The site is underlain by the Jurassic-aged (Geological Map Unit: Jd) – Dolerite, (tholeiitic) with locally developed granophyre;
- The risk of slope destabilisation is considered low;
- Vegetation cleared for the proposed development and road should be the minimum required for bushfire hazard management;
- Cut slopes on site are to be graded to 1V:1H within dolerite bedrock and 1V:2H within the soil;
- Fill slopes on site are to be graded to 1V:3H and are to be keyed into underlying clay site soils;
- A cut-off v-drain should be considered above the cuttings in areas of high water flow.
- Earthworks should be conducted with the drier summer months.
- All earthworks on site should be conducted in accordance with AS3798-2007.
- Good hillside construction practices should be adopted as per Australian Geoguide LR8;
- Provided the recommended hazard treatments are carried out in full, it is concluded that the proposal is compliant with the landslide hazard code of the Kingborough Council Interim Planning Scheme (Code E3).

Geo-Environmental Solutions should be immediately contacted during development should subsurface conditions appear significantly different from those described in this report.

7 References

AGS (2007a). Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007

AGS (2007b). Commentary on Guideline for Landslide Susceptibility, Hazard and Risk Zoning. Australian Geomechanics, Vol 42 No 1 March 2007

AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

AGS (2007d). Commentary on Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

AGS (2007e). The Australian Geoguides for Slope Management and Maintenance. Australian Geomechanics Vol 42 No 1 March 2007

AS1170 (2007). Australian Standard. Structural design actions. Part 4: Earthquake actions in Australia. prepared by Committee BD-006, General Design Requirements and Loading on Structures. It was approved on behalf of the Council of Standards Australia on 22 May 2007. This Standard was published on 9 October 2007.

AS1289 (2000). Australian Standard. Various methods as Prepared by Committee CE/9, Testing of Soils for Engineering Purposes. Approved on behalf of the Council of Standards Australia on 3 December 1999 and published on 28 February 2000.

AS1726 (2017). Australian Standard. Geotechnical Site Investigations. Approved on behalf of the Council of Standards Australia on 7 April 2017 and published on 2nd May 2017.

AS2870 (2011). Australian Standard. Residential slabs and footings. prepared by Committee BD-025, Residential Slabs and Footings. Approved on behalf of the Council of Standards Australia on 20 December 2010. This Standard was published on 17 January 2011.

AS4133 (2000). Australian Standard. Prepared by Committee CE/9, Testing of Soils for Engineering Purposes. Approved on behalf of the Council of Standards Australia on 3 December 1999 and published on 28 February 2000.

Calver, C.R. (compiler) 2007. Digital Geological Atlas 1:25,000 Scale Series. Sheet 5223 Blackmans Bay. Mineral Resources Tasmania.

Mineral Resources Tasmania (MRT) 2013. Hazard Planning Maps – Landslide, Version 2. Produced by the Department of Premier and Cabinet

Tasmanian Government, Director's Determination – Landslip Hazard Areas. Version 1.0 6 February 2020.

Appendix 1 Acceptable Solutions

Landslide Code Areas

Standard	Code		Acceptable Solution	Performance Criteria
Use	E3.6.1 Hazardous Use	A1	Hazardous use relates to an alteration or intensification of an approved use.	P1
		A2	No acceptable solution.	P2
	E3.6.2 Vulnerable Use	A1	Vulnerable use is for visitor accommodation.	A1
		A2	No acceptable solution.	A2
Development	E3.7.1 Buildings and Works, other than Minor Extensions	A1	No Acceptable solution	P1
	E3.7.2 Minor Extensions	A1	Buildings and works for minor extensions must comply with the following: (a) be in a Medium Landslide Hazard Area.	P1
	E3.7.3 Major Works	A1	No acceptable solution.	P1
Subdivision	E3.8.1 Subdivision	A1	No Acceptable solution	P1
		A2	Subdivision is not prohibited by the relevant zone standards.	P2

Appendix 2 Quantitative Risk Assessment Tables

Likelihood & Consequence Index

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

Qualitative Risk Matrix

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.

Performance Criteria E3.7.1 P1 Buildings and works must satisfy all of the following:	Relevance	Management Options	Managed (treated) Risk Assessment			Further Assessment Required
			Consequence	Likelihood	Risk	
(a) no part of the buildings and works is in a High Landslide Hazard Area;	N/a					
(b) the landslide risk associated with the buildings and works is either: (i) acceptable risk (means a risk society is prepared to accept as it is. That is; without management or treatment); or (ii) capable of feasible and effective treatment through hazard management measures, so as to be tolerable risk. The residual tolerable risk may be assessed using either qualitative or qualitative methods in the landslide risk assessment either: (a) if using the AGS qualitative risk assessment method apply the "As Low As Reasonably Possible (ALARP)" principle with the residual tolerable risk level no higher than a "moderate" risk level under the AGS 2007(c) risk method; or (b) if using the AGS quantitative risk assessment method then the tolerable loss of life for the person most at risk as suggested by the AGS 2007(c) to be: (i) if existing slope / existing development: 10-4 / annum; (ii) if new constructed slope / new development / existing landslide: 10-5 / annum.	The proposed driveway access is positioned in a low landslide hazard zone	Refer to recommendations	Minor	Unlikely	Low	No

Performance Criteria E3.7.3 P1 Major works must satisfy all of the following (same as 3.7.1P3):	Relevance	Management Options	Managed (treated) Risk Assessment			Further Assessment Required
			Consequence	Likelihood	Risk	
(a) no part of the works is in a High Landslide Hazard Area; (b)the landslide risk associated with the works is either: (i) acceptable risk; or (ii)capable of feasible and effective treatment through hazard management measures, so as to be tolerable risk.	The proposed driveway access is positioned in a low landslide hazard zone	Refer to recommendations	Minor	Unlikely	Low	N/A

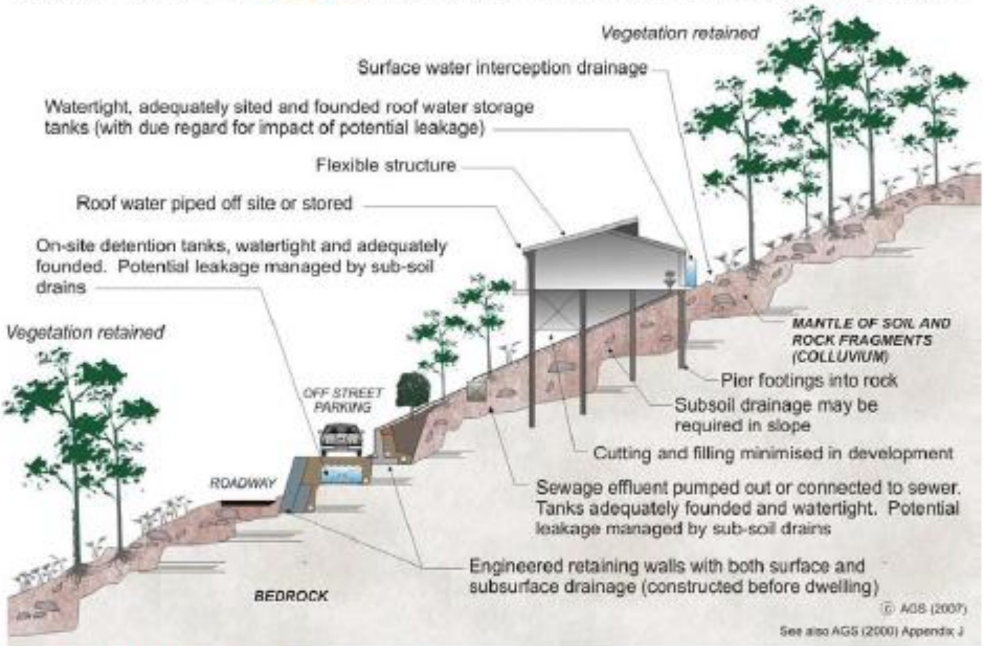
Appendix 3 Australian Geomechanics Society (AGS) *Landslide Risk Management (2007) guidelines*

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

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

Cuttings - are supported by retaining walls (GeoGuide LR6).

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

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

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

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

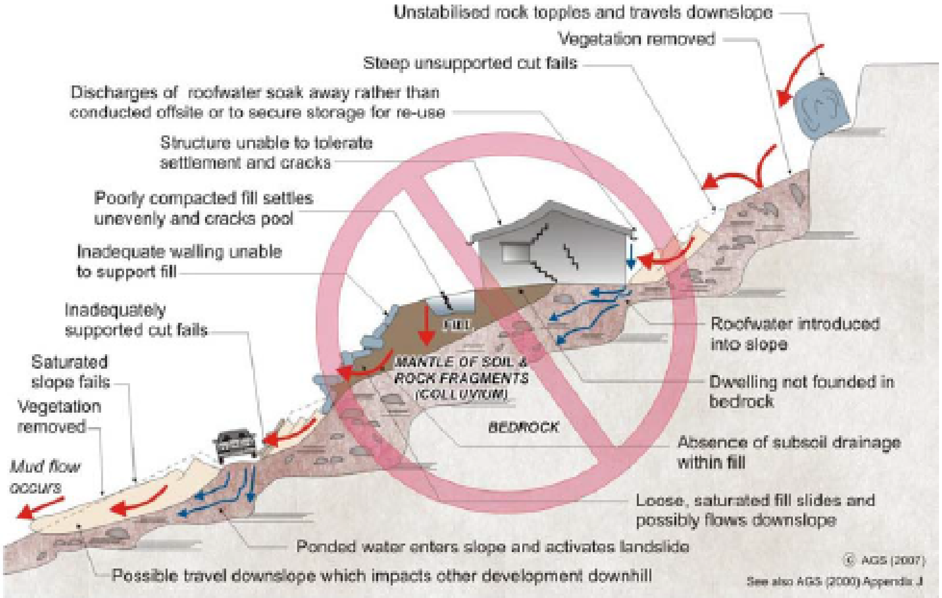
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

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

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

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

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

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

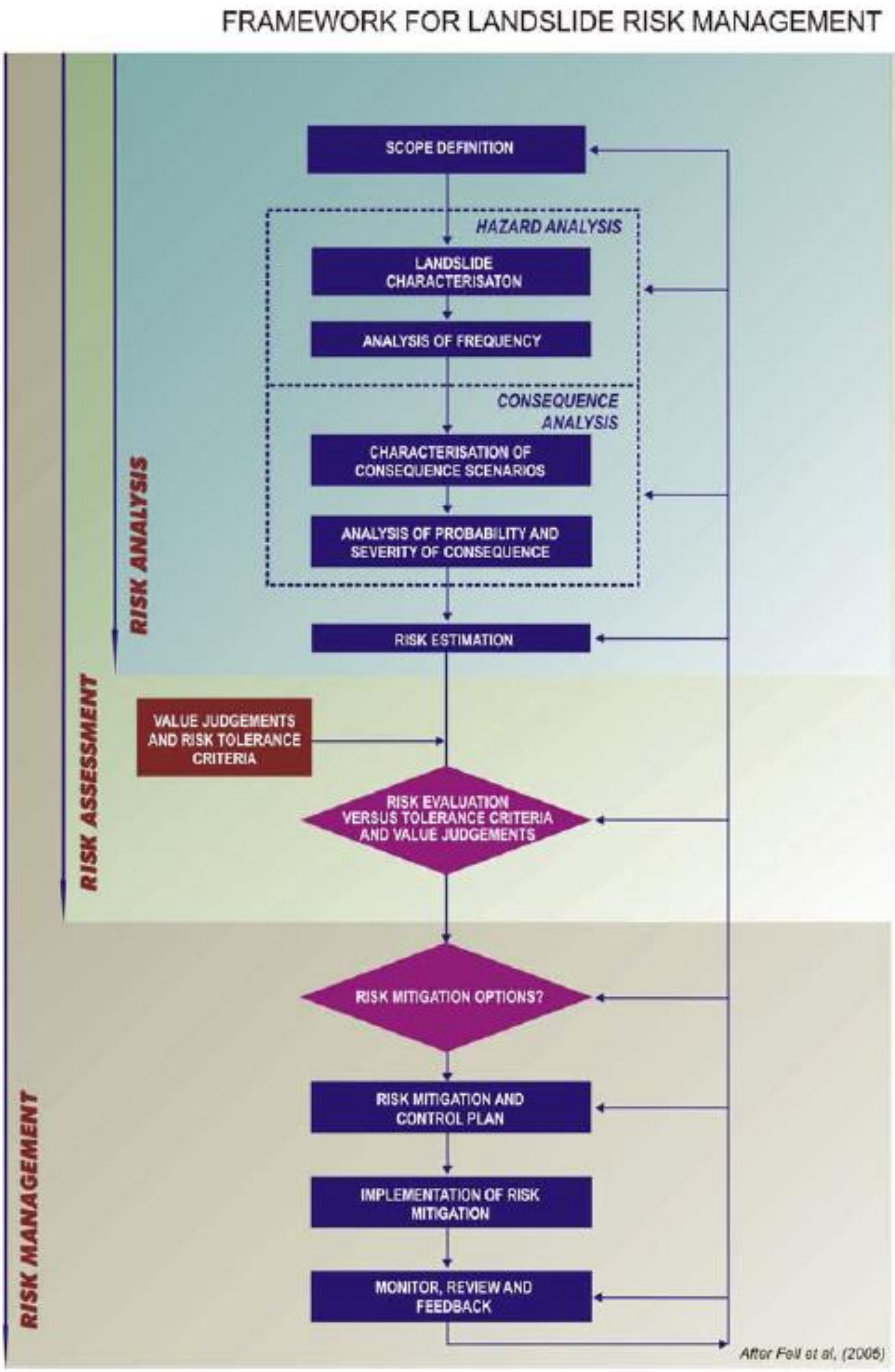
More information relevant to your particular situation may be found in other Australian GeoGuides:

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

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

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.	


FRAMEWORK FOR LANDSLIDE RISK MANAGEMENT
SCOPE DEFINITION
HAZARD ANALYSIS
LANDSLIDE CHARACTERISATON
ANALYSIS OF FREQUENCY
CONSEQUENCE ANALYSIS
CHARACTERISATION OF CONSEQUENCE SCENARIOS
ANALYSIS OF PROBABILITY AND SEVERITY OF CONSEQUENCE
RISK ESTIMATION
VALUE JUDGEMENTS AND RISK TOLERANCE CRITERIA
RISK EVALUATION VERSUS TOLERANCE CRITERIA AND VALUE JUDGEMENTS
RISK MITIGATION OPTIONS?
RISK MITIGATION AND CONTROL PLAN
IMPLEMENTATION OF RISK MITIGATION
MONITOR, REVIEW AND FEEDBACK
RISK ANALYSIS
RISK ASSESSMENT
RISK MANAGEMENT
After Fell et al, (2005)

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 rowspan="2">Rock flow
(Deep creep)</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><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>

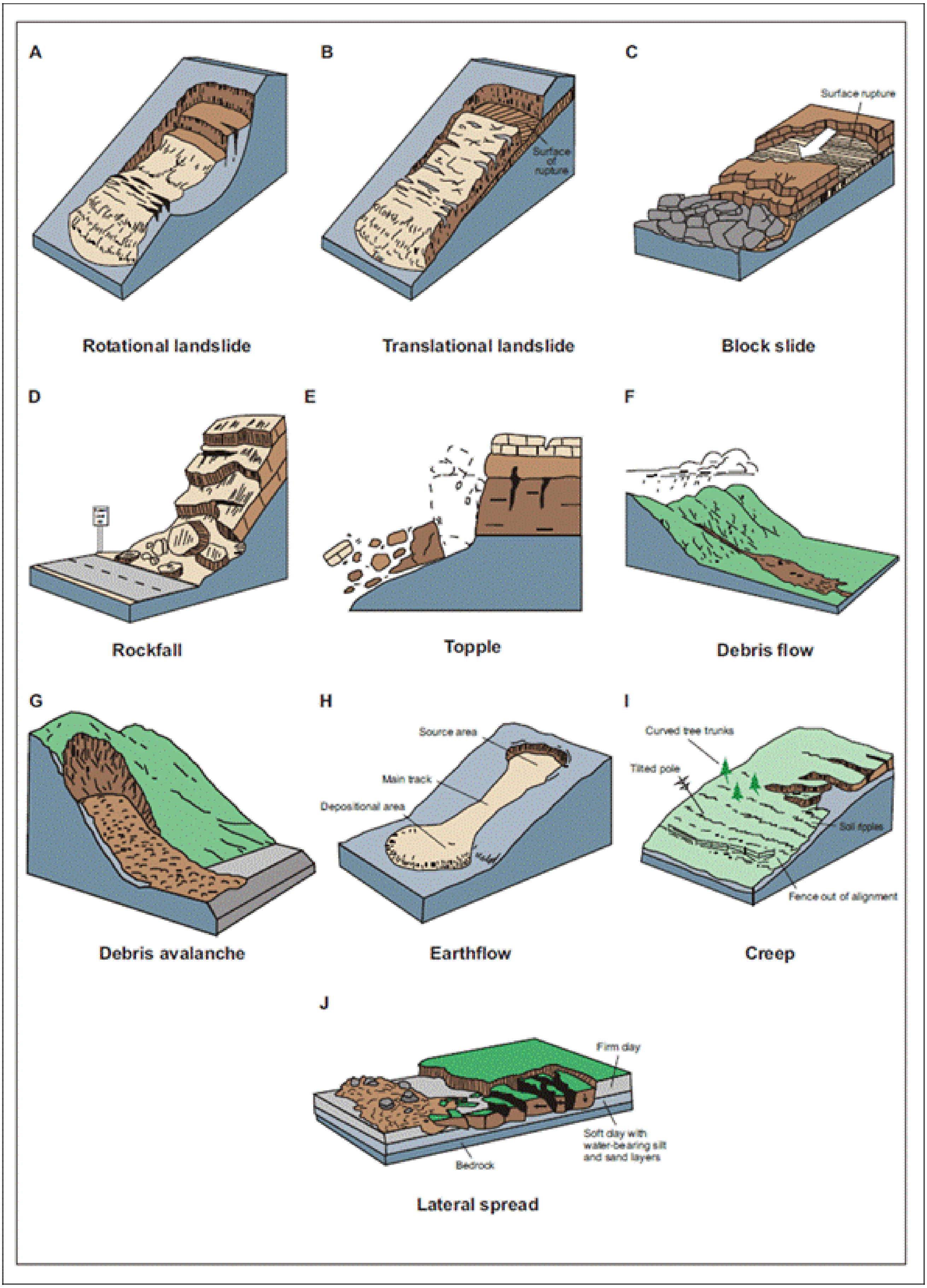
Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at http://landslides.usgs.gov.

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 evacuation 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

Source: From Appendix B of AGS (2007c). Practice Notes Guidelines for Landslide Risk Management. Australian Geomechanics Vol 42 No 1 March 2007

Description	Size (m^2)
	0.01
Very small	
	10
Small	
	1,000
Medium	
	100,000
Large	
	1,000,000
Very large	

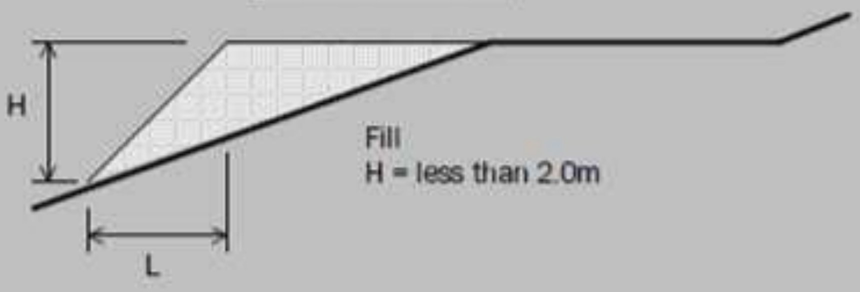
Size is areal extent of failure zone
After: van Schalkwyk, A and Thomas, M.A. (1991). Slope failures associated with the floods of September 1987 and February 1988 in Natal and Kwa-Zulu, Republic of South Africa. Geotechnics in the African Environment, Blight et al. (Eds), pp. 57-63


A
Rotational landslide
B
Surface of rupture
Translational landslide
C
Surface rupture
Block slide
D
Rockfall
E
Topple
F
Debris flow
G
Debris avalanche
H
Source area
Main track
Depositional area
Earthflow
I
Curved tree trunks
Tilted pole
Soil ripples
Fence out of alignment
Creep
J
Firm clay
Soft clay with water-bearing silt and sand layers
Bedrock
Lateral spread

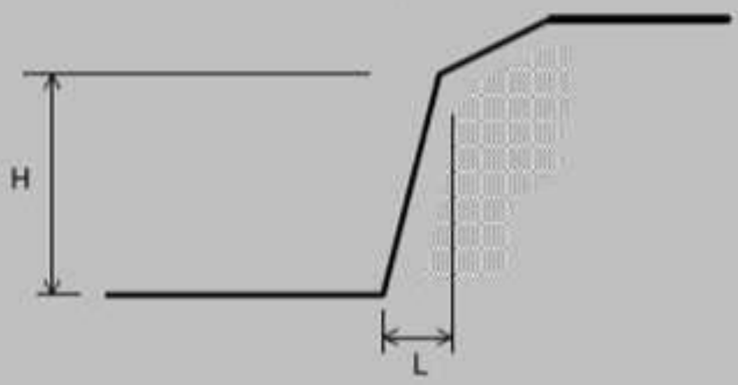
Appendix 4 Batter Angles for Embankments (Guide Only)

Note : Retaining walls or other form of soil retaining methods must be adopted where the slope ratio is greater than that indicated in the table below :-

FILL EMBANKMENTS



CUT EMBANKMENTS



MATERIAL TYPE (refer soils report)		EMBANKMENT SLOPES (Height : Length)	
		Compacted Fill	Cutting
Stable Rock (A*)		2 : 3	6 : 1
Sand (A*)		1 : 2	2 : 3
Silt (P*)		1 : 4	1 : 4
Clay	Firm Clay	1 : 2	1 : 1
	Soft Clay	Not Suitable	2 : 3
Soft Soils (P*)		Not Suitable	Not Suitable