GEO-ENVIRONMENTAL SOLUTIONS

LANDSLIP RISK ASSESSMENT

PROJECT:

Alterations & Additions - Residential Dwelling

Site Address:

8 Meath Avenue
Taroona
TAS
7053

CLIENT:

Kate Fee

DATE:

27/11/2024

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FIGURES

TABLE

1 INTRODUCTION

Geo-Environmental Solutions Pty Ltd (GES) were engage by Kate Fee (the Client) to conduct a geotechnical investigation to assess for landslip risk for some proposed alterations and additions at the existing dwelling, the site lays within the Kingborough Interim Planning Scheme mapped 'Medium-Active' landslide zone. located on the Taroona Landslide Complex.

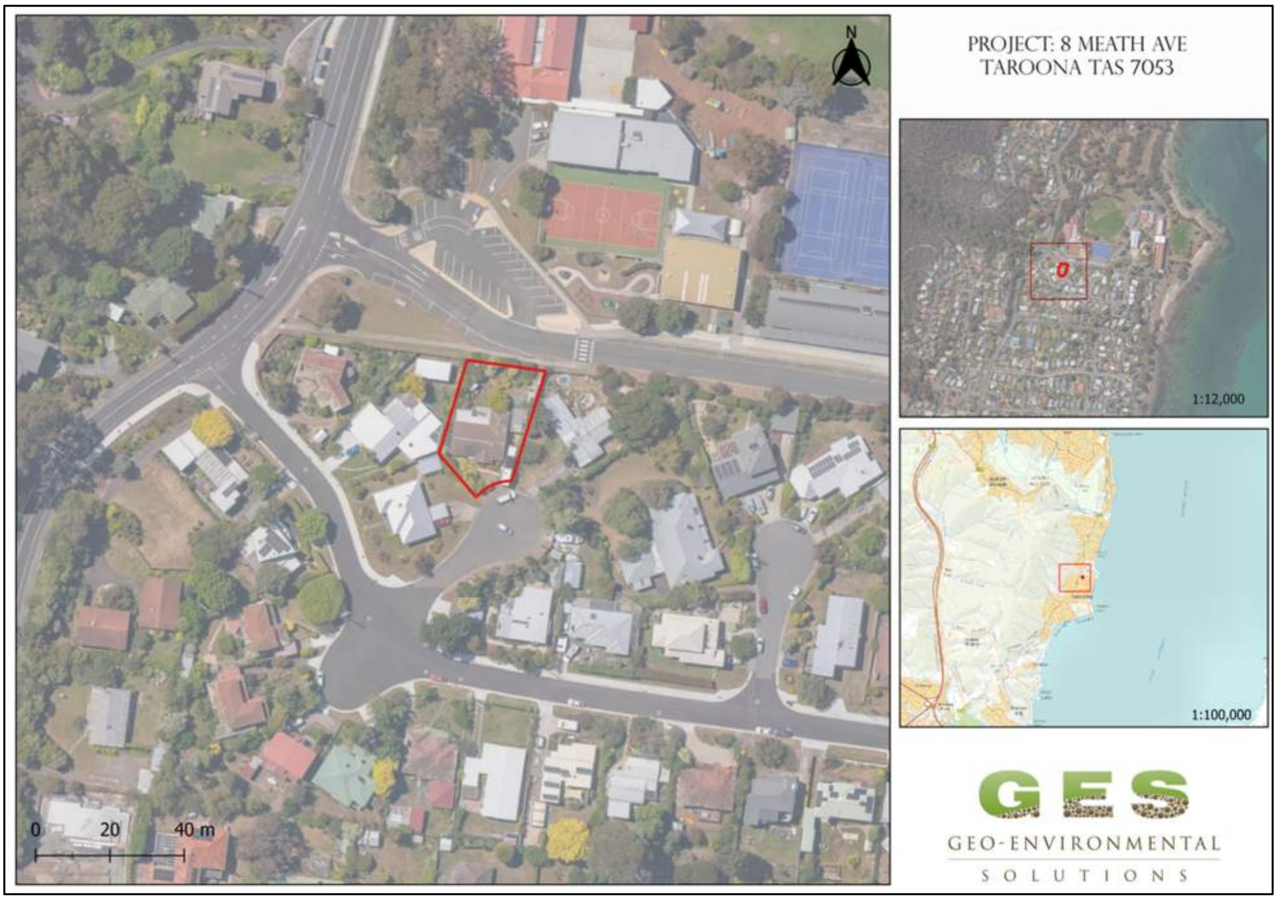

Figure 1 - Location of the site at 8 Meath Avenue, Taroona (shown in red)

The proposed development is located at cadastral title (CT 14905/22) located at 8 Meath Avenue in Taroona (The Site). GES are to undertake this geotechnical assessment relating to the proposed alterations & additions of the existing dwelling at the site in conjunction with the requirements of the Landslide Hazard Code, part of the Kingborough Council Interim Planning Scheme 2015. GES have written this report with reference to the Australian Geomechanics Guidelines (AGS 2007).

GES have undertaken this assessment using 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 Landslip Hazard Code;
- Conduct a Landslip risk assessment of the proposed works with reference to the Australian Geomechanics Society (AGS) *Landslip 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.
- Use bore hole drilling information, geological mapping and site inspections to determine site physical conditions.
- Conduct a site risk assessment for the proposed development ensuring relevant performance criteria are addressed.
- Where applicable, provide recommendations on remediation of any 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 – 14905/22

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

3.2 Australian Building Code Board

This report presents a summary of the overall site risk to Landslip hazards. This assessment has been conducted for the year 2074 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 Tasmanian Legislation website:

https://www.legislation.tas.gov.au/view/html/inforce/2024-06-27/act-2016-025#GS4@Gs1@Nd2662015425510@EN

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

- For the purposes of the Act, land is a landslip hazard area if –
  - the land is shown on a planning scheme overlay map as being land that is within a landslip hazard area; and
  - the land is classified as land within a hazard band of a landslip hazard area.
- For the purposes of the definition of *hazardous area* in section 4(1) of the Act –
  - classification under a landslip determination as being land that is within a hazard band of a landslip hazard area is a prescribed attribute; and
  - a landslip hazard area is a hazardous area.

3.4 Tasmanian Interim Planning Scheme Landslip Overlay – Kingborough Council

The site predominately lies within Medium-Active landslip overlay (Figure 2).

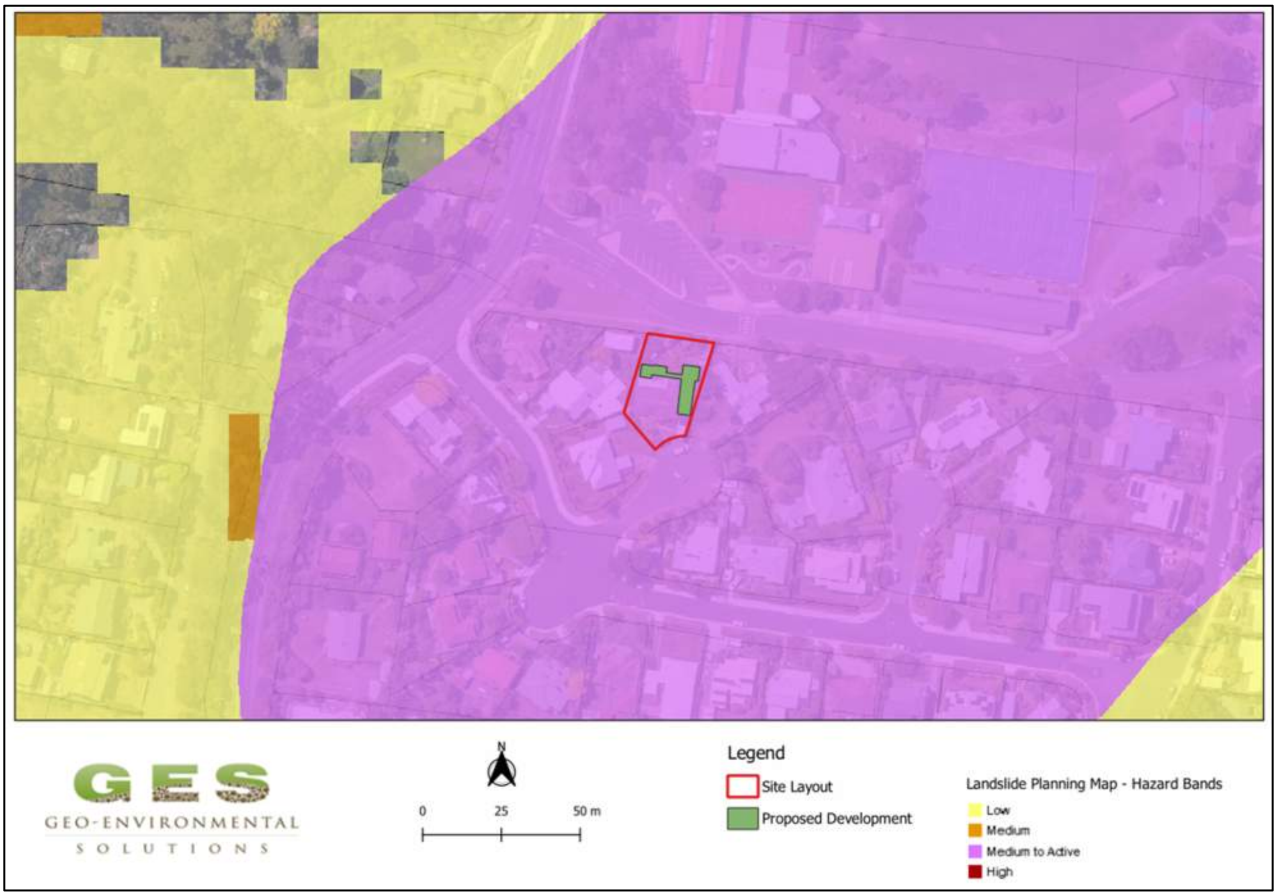

Figure 2 – Landslip Overlay at the Site (The List) with approximate location of proposed development

3.5 Site and Proposed Works

The project site is located in the southeast region of Tasmania, near Hobart city centre. Currently, the site has an existing dwelling with a land area of approximately 680 m^2. The proposed development involves construction of alterations & additions to the area located in the northern and eastern portion of the site.

Access to the site is through the existing driveway along the southeast of Meath Ave.

Plans for the existing dwelling have been provided to GES by the client which are presented in Figure 3 (refer DA drawings, 'P100, Proposed Site Plan-Fee House Alterations & Additions, dated 2/05/2024').

3.5.1 Development & Works Acceptable Solutions

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

3.5.2 Landslip Hazard Code (LHC)

Given that the proposed dwelling is within the 'Medium-Active' Landslip Hazard Area and there are no acceptable solutions for the proposed works, the Performance Criteria will need to be addressed.

3.5.3 Development Performance Criteria

The following performance criteria need to be addressed:

- *E3.7.1 P1*

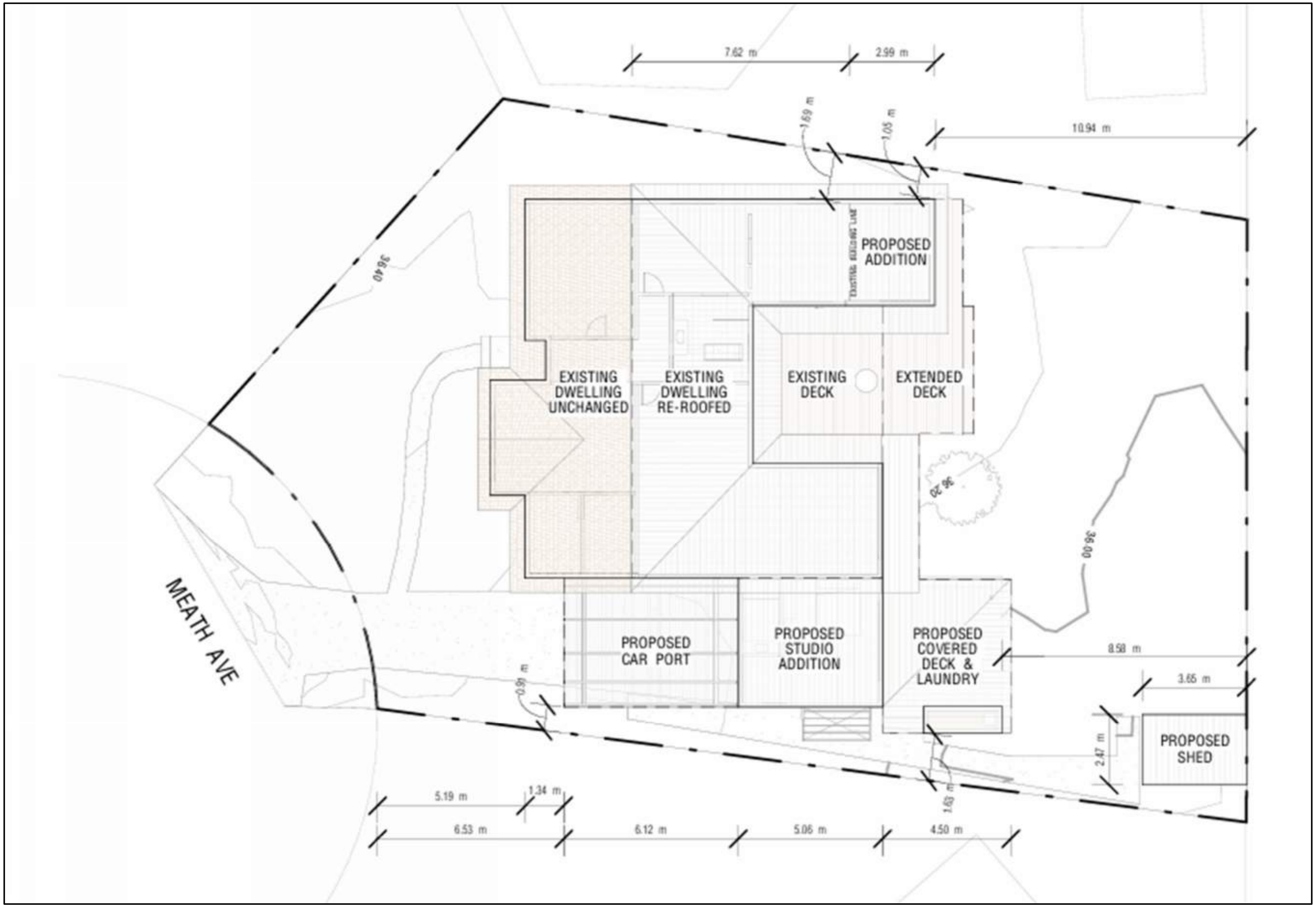

Figure 3 - Site Plan showing proposed extent of works (extract from 'DA Architectural Drawings (1). 2023.10.20.pdf')

4 Site Mapping

4.1 Geological Mapping

Based on the MRT 1:25,000 Mineral Resources Tasmania (MRT) mapping of Southeast Tasmania, the site geology comprises of the following geological unit (refer Figure 4):

- Map Unit – Qaf: Alluvial fans.

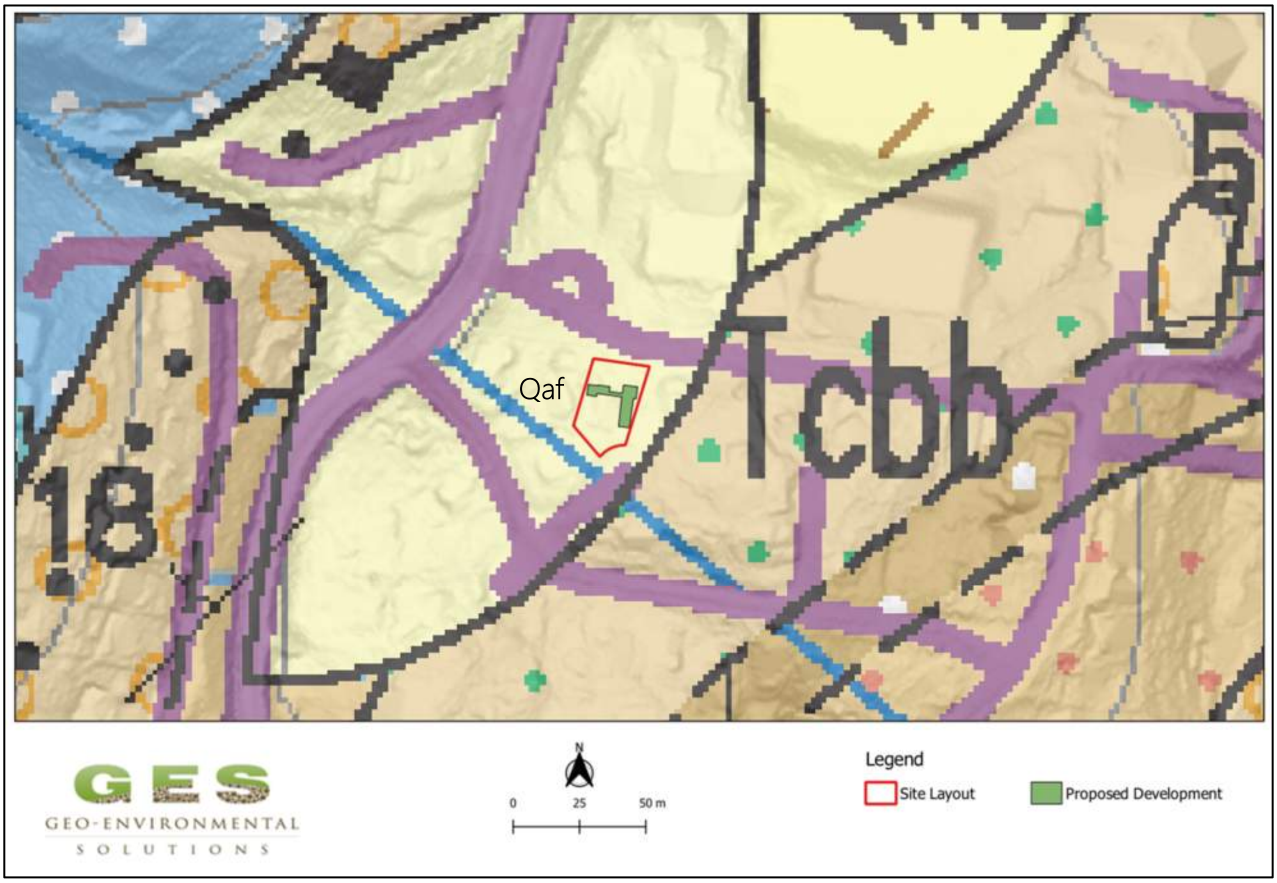

Figure 4 – Mapped geology (source: LIST Mapping 1:250,000); site shown in red outline

4.2 Site Geomorphology

The project area is positioned on east and southeast facing slope. The proposed development occupies the area situated along the northern and eastern portion of the site. Elevation on the site is approximately at 36 meters above the Australian Height Datum (AHD) across the site. The dwelling sits on gentle slopes, exhibiting gradients between 5 to 10 degrees. To depict the onsite slope angles, a slope gradient map was generated using QGIS software and Kingborough 2022 LiDAR data (refer to Figure 5).

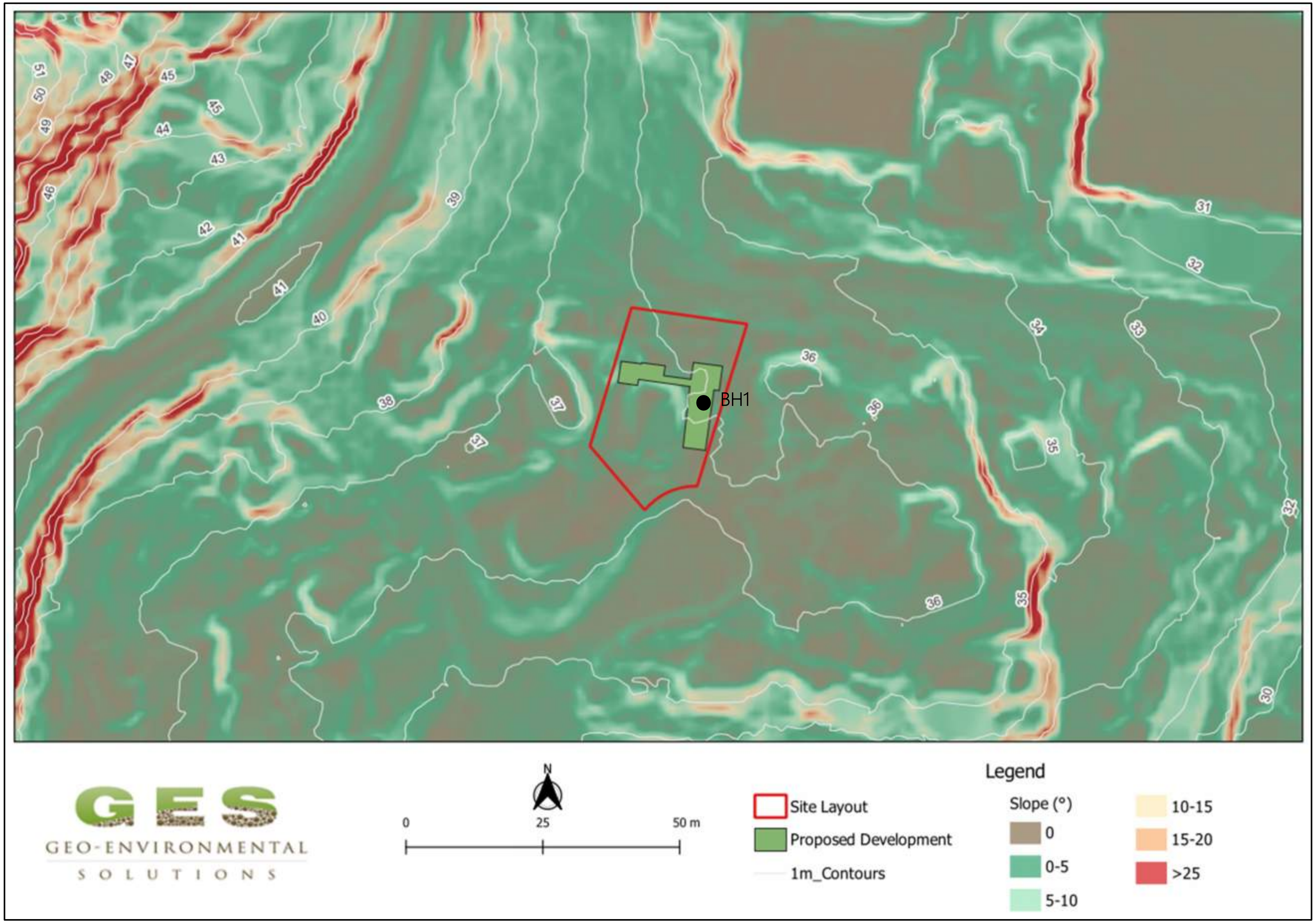

Figure 5 - Slope model developed from Kingborough 1m-2022 LiDAR data (borehole approx. location in black)

4.3 MRT Landslide Hazard Mapping

4.3.1 Landslide Inventory and Geomorphology

The MRT mapping shows the site to be located on an active earth translational slide (deep seated) with coastal deep-seated slides to the north and south of the site. The head scarp of the Taroona landslide is located approximately 200 m west of the site following the alignment of the Channel Highway. The site itself is located on the southern flank of the landslide. (Figure 6). Table 3 presents a summary of landslides, within similar geological and geomorphological settings to the site.

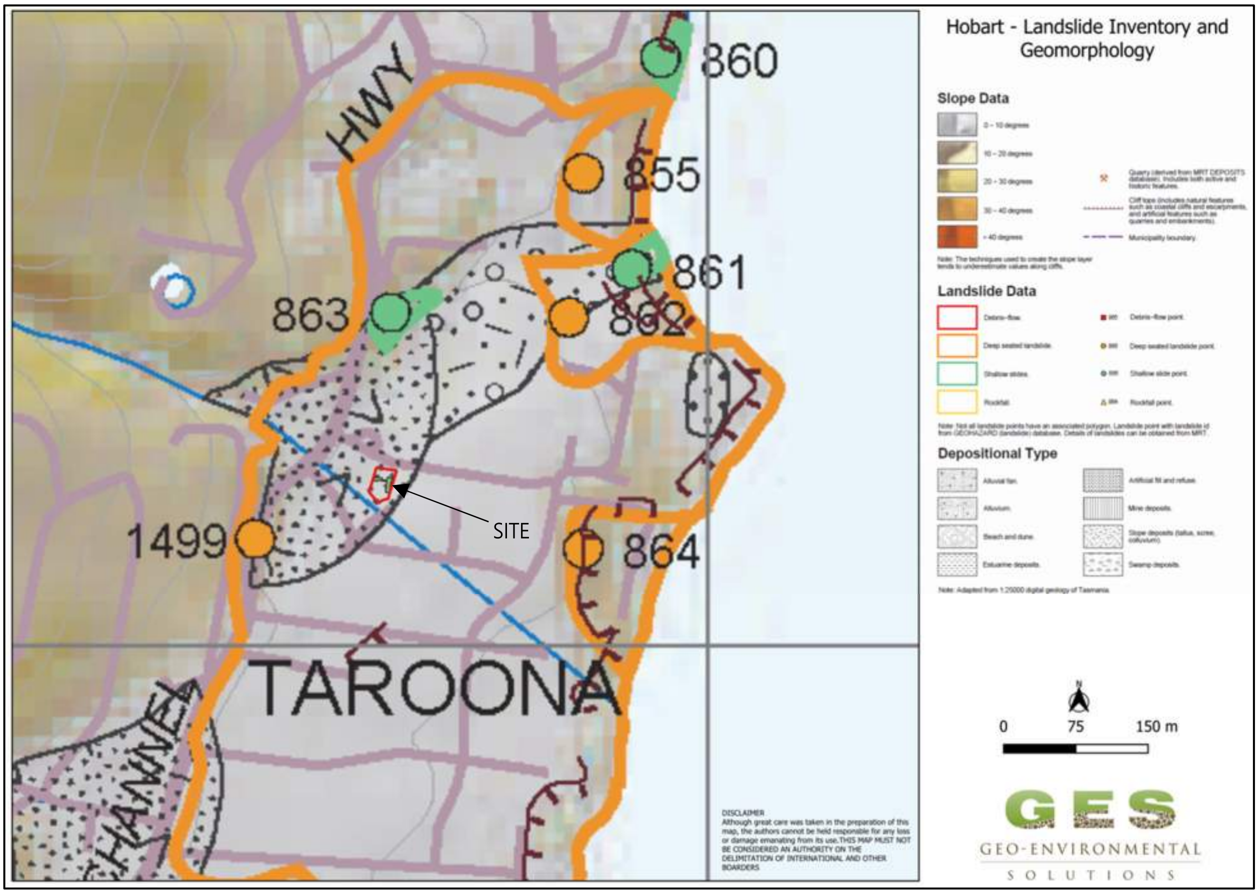

Figure 6 – Hobart landslide inventory map (Mazengarb 2004) with overlay of proposed development (in green) within the site (layout shown in red)

Table 1 - Mineral Resources Tasmania Landslide Inventory Points

ID	Location	Feature Type	Classification	Activity State	Inspection Type	Inspector
855	104 Channel Hwy. Taroona; high school sports ground	Discrete Landslide	Debris Translational Slide	Recent or Active, before 1977	Field Visit; Published geological map	Donaldson, R.C.; Latinovic, M.; Moon, A. and McDowell, B. (P)
861	104 Channel Hwy. Taroona; high school car park	Discrete Landslide	Debris Slide	Recent or Active, circa 1967	Field Visit (P)	Rallings, R. A. (P); Latinovic, M.; Moon, A. and McDowell, B.
862	104 Channel Hwy. Taroona; high school car park	Discrete Landslide	Debris Rotational Slide	Recent or Active	Field Visit (P)	Rallings, R. A. (P); Latinovic, M.; Moon, A. and McDowell, B.
863	104 Channel Highway. Taroona	Discrete Landslide	Debris Translational Slide	Recent or Active, before 1999	Field Visit (P)	Latinovic, M. (P). UR2001_01 (Calver. C.R.. Forsyth. S.M.. Latinovic. M.. Waite. A. 2001)
864	Melinga Place. Taroona	Possible Landslide	Debris Slide	Activity Unknown	Field Visit; Air photo interpretation (P)	Latinovic, M.; Moon, A. and McDowell, B.; Stevenson, M.D.
3199	Vicinity of Taroona Primary School and Taroona High School	Discrete Landslide	Earth Translational Slide	Recent or Active, before 1946	Field Visit (P)	Stevenson, M.D.

4.3.2 Shallow Slide and Flow Susceptibility

No shallow slide and flow run-out hazard has been identified below the site (Figure 7). A runout area has been identified south of the site, following the alignment of a drainage line.

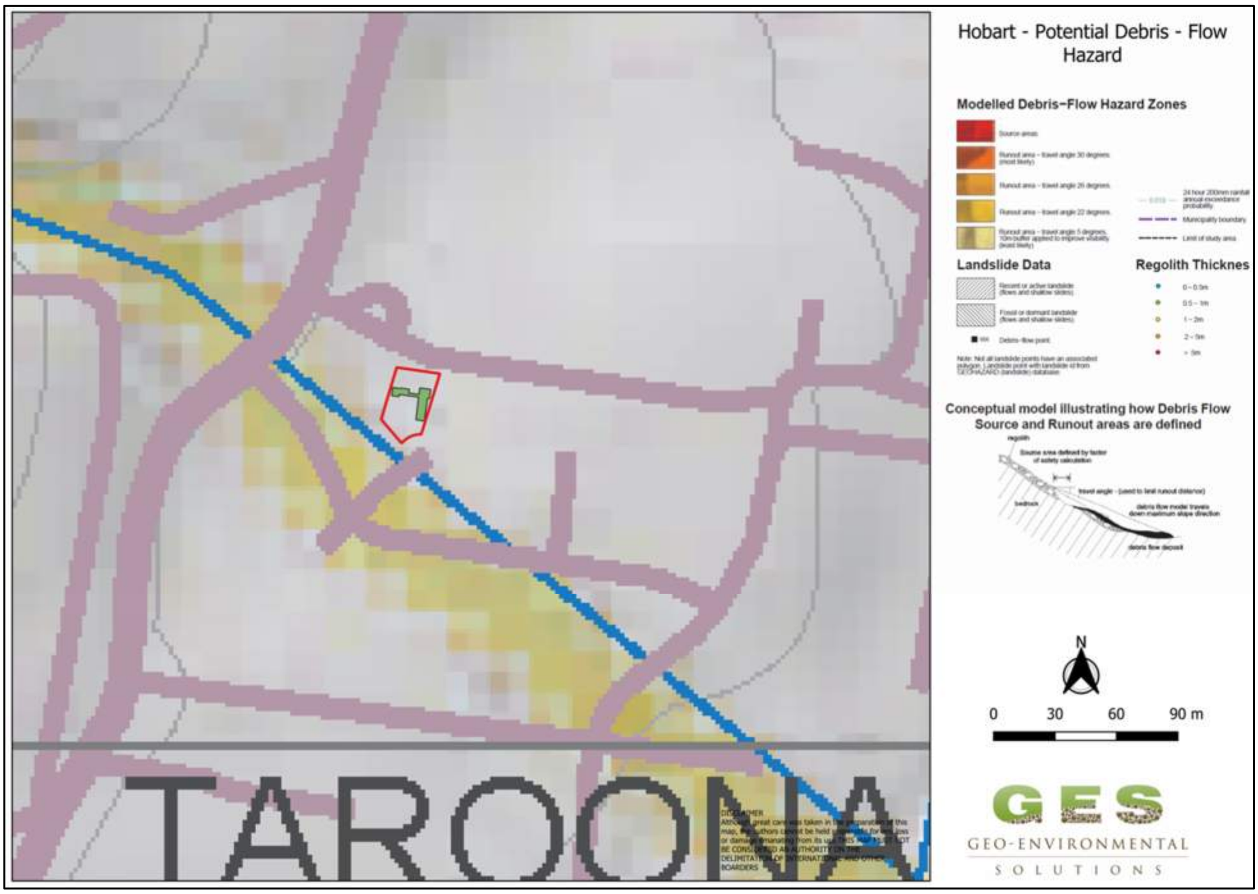

Figure 7 – Hobart shallow slide and flow susceptibility map (Mazengarb 2004) with overlay of proposed development (in green) within the site (layout shown in red)

4.3.3 Deep Seated Landslide Susceptibility

Deep seated slope instability has been identified based on the underlying geology and the slope angles in and around the vicinity of the site (refer Figure 7). The development area on site has been classified by MRT as 'Setback Area (A)', which is based on a threshold angle of 10° for Tertiary Sediments (based on tertiary sediments encountered at Taroona).

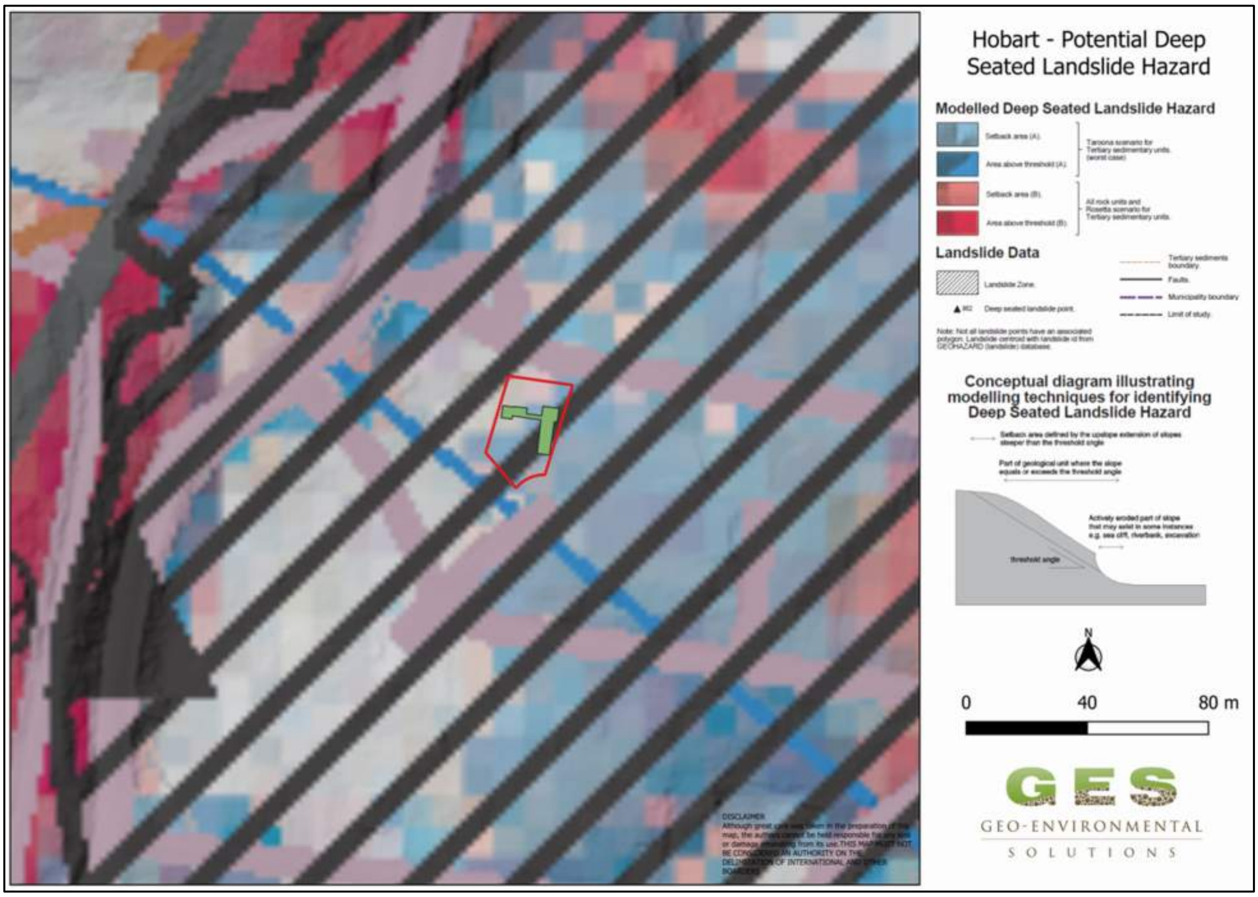

Figure 8 – Hobart deep seated landslide susceptibility map (Mazengarb 2004) with overlay of proposed development (in green) within the site (layout shown in red)

4.4 Field Investigation, Site Observation & Previous Investigations

4.4.1 Previous Reports

The Taroona Landslide Complex has been well documented through reports and ongoing carried out across the site. The landslide has resulted in extensive property damage throughout the area, dating back as early as 1967. A number of inclinometers were installed across the landslide to record ground movement in the order of 70 to 100 mm since installation. The greatest landslide movement has been recorded towards the edges of the landslide, where the slip plane is relatively shallow.

Reports indicate that between 2010 and 2018, no inclinometer movement has been detected towards the southern limit of the landslide but up to 62.5 mm was recorded to the north. An inclinometer located within close proximity to the site was showing ground movement within the upper 2 m of the inclinometer profile.

4.4.2 Field Investigation - 2024

A site visit was undertaken on 16th of August wherein a single bore hole was completed to identify the distribution and variation of the soil materials at the site. Table 2 provides a summary of the ground conditions encountered in BH01 (refer Figure 5 for approx. locations).

Table 2 Site Soil Bore Logs

BH01 Depth (m)	*USCS*	*Description*
0.0-0.10	*SM*	Silty SAND: dark brown, moist, dense.
0.10-0.80	*CH*	Silty CLAY: high plasticity, dark brown, w≈PL, stiff.
0.80-5.00+	*CH*	Silty CLAY: high plasticity, pale brown-grey, w≈PL, very stiff. No Refusal.

4.4.3 Site Classification

The site has been classified as Class P (>75mm *Ys* range) due to the site being located on an active landslide. The natural clay soils on soil present high plasticity and reactivity characteristics and are likely to exhibit ground surface movement with an indicative (Y's) range of greater than 75 mm.

It is strongly recommended for the building to be founded on adjustable piers to allow for compensation of ground movement. This allows the building to move independent of the foundation system. Piers should extend to 4.5 m depth below the zone of surface movement (~2 m);

5 Landslip Hazard Analysis

5.1 Landslip Characteristics

Based on the slope characteristics including site geology, slope geometry and slope angles, MRT Landslip mapping/inventory and site observations, the following scenarios have been identified as potential slope failure mechanisms for the site (Figure 7):

- Scenario 1 – Deep seated rotational slide through dep seated clay impacting pool walls leading to potential for water leakage and subsequent excess subsurface moisture impacting adjacent buildings

Figure 9 - Conceptual Cross Section of Slope Failure Mechanism relevant to the site (Not to scale)

This scenario has been presented have been presented in the figure above, showing the typical slope failure plane of a deep-seated failure occurring directly under the proposed development. The failure plane depth is unknown. However, undulations in the slip plane are likely to result in differential ground surface movement at the site.

5.2 Frequency Analysis

Table 3 presents the frequency analysis for the identified slope failure mechanisms. Terminology used is in accordance with the Australian Geomechanics Society (AGS) guidelines for Landslip risk management (2007a,b,c,d).

Table 3 Frequency analysis for Landslip hazards Scenario 1

Scenario	Failure Mechanism	Unit Affected	Observed in the field	Potential Size	Potential Speed	Water Content	Current Likelihood	Treated Likelihood
Scenario 1	Deep-seated failure	Alluvial fan	Yes – currently active landslide	Very large	Very slow	Moist	Almost Certain	Almost Certain

5.3 Risk Analysis

5.3.1 Risk to Property

There is currently a very high risk to property assuming no risk management is carried out. Treated risk may be reduced to moderate (Table 4).

Table 4 Consequence analysis for Landslip hazards – Property

Scenario	Issue	Current Risks			Landslip Risk Management	Treated Risks
		Likelihood of occurrence	Consequence to property	Level of risk to property		Level of risk to property
Scenario 1	Deep-seated failure	Almost Certain	Major/Catastrophic	Very High	• Building to be founded on adjustable piers to allow for compensation of ground movement. Piers should extend to 4.5 m depth. • Proposed building should be light-weight, rigid, removable and under no circumstances constructed of brick. • All service connections to the house should have flexible connections.	Moderate

5.3.1 Risk to Life

Risk to life is considered acceptable following the recommended hazard treatment in Table 4 given the likelihood and consequence of a shallow slide failures within the soils and or fill, or within cutting (Table 5).

Table 5 Consequence analysis for Landslip hazards 1 – 2 – Life – Post Treatment

Hazard	Scenario 1
Factor	Deep-seated slope failure
Likelihood	Almost Certain
Indicative Annual Probability	0.1
Use of Affected Structure/Site	Entire development
Probability of Spatial Impact	Major damage anticipated = 1
Proportion of Time	Estimated 12 hours a day. = 0.5
Probability of Not Evacuating	Soils around the site exhibit signs of stress (cracking) allowing time to evacuate. = 0.1
Vulnerability	Building unlikely to collapse = 0.1
Risk for Person Most at Risk	5×10^{-4}
Risk Evaluation	Tolerable

5.3.2 Societal Risk

The Societal Risk Graph plot presented in Figure 10. showing the estimated individual risks for scenarios 1 and 2 as presented in Figure 6 (outlined in the AGS 'Landslide Risk Management Concepts and Guidelines', 2000). The risks are estimated based on people in the structure spending up to 12 hours per day in internal areas the property.

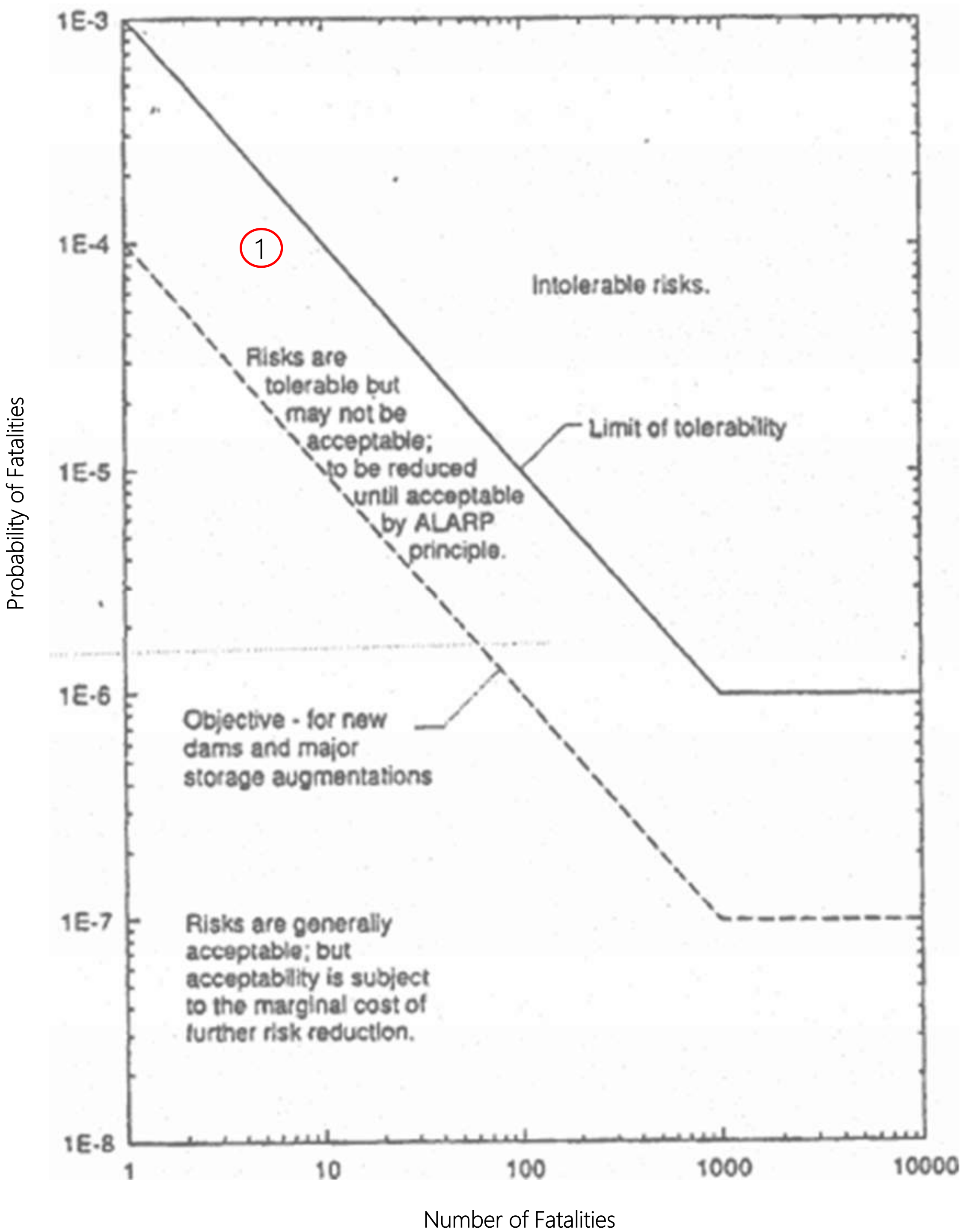

Figure 10 Societal Risk Graph of Probability of Fatalities vs Number of Fatalities (ANCOLD 1998)

6 Conclusions and Recommendations

Based on the outcome of the review of geotechnical information, slope stability and hazard analysis and risk assessment, the following conclusions are made:

- The site is located in a medium - active landslide hazard zone;
- Slope instability mechanism for the site is from a deep-seated soil slide at depth under the site. It is likely the slip surface is undulating, resulting in differential ground surface movement as the landslide moves slowly downslope (at an average rate of 5 mm per year);
- It is strongly recommended for the building to be founded on adjustable piers to allow for compensation of ground movement. This allows the building to move independent of the foundation system. Piers should extend to 4.5 m depth below the zone of surface movement (~2 m);
- The proposed building should be light-weight, rigid, removable and under no circumstances constructed of brick; and
- All service connections to the house should have flexible connections.

With the implementation of all above recommendations the proposed works satisfies the performance criteria and is considered as it represents a tolerable risk for the life of the use and development with Code (E3) as per Hobart Council Interim Planning Scheme.

GES should be contacted immediately should conditions greatly differ to that which are stated in this report.

7 LIMITATIONS STATEMENT

This Assessment Report has been prepared in accordance with the scope of services between Geo-Environmental Solutions Pty. Ltd. (GES) and 'the Client'. To the best of GES's knowledge, the information presented herein represents the Client's requirements at the time of printing of the Report. However, the passage of time, manifestation of latent conditions or impacts of future events may result in findings differing from that discussed in this Report. In preparing this Report, GES has relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations referenced herein. Except as otherwise stated in this Report, GES has not verified the accuracy or completeness of such data, surveys, analyses, designs, plans and other information.

8 REFERENCES

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

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APPENDIX 1 – Acceptable Solutions

Landslip 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 – Qualitative 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.

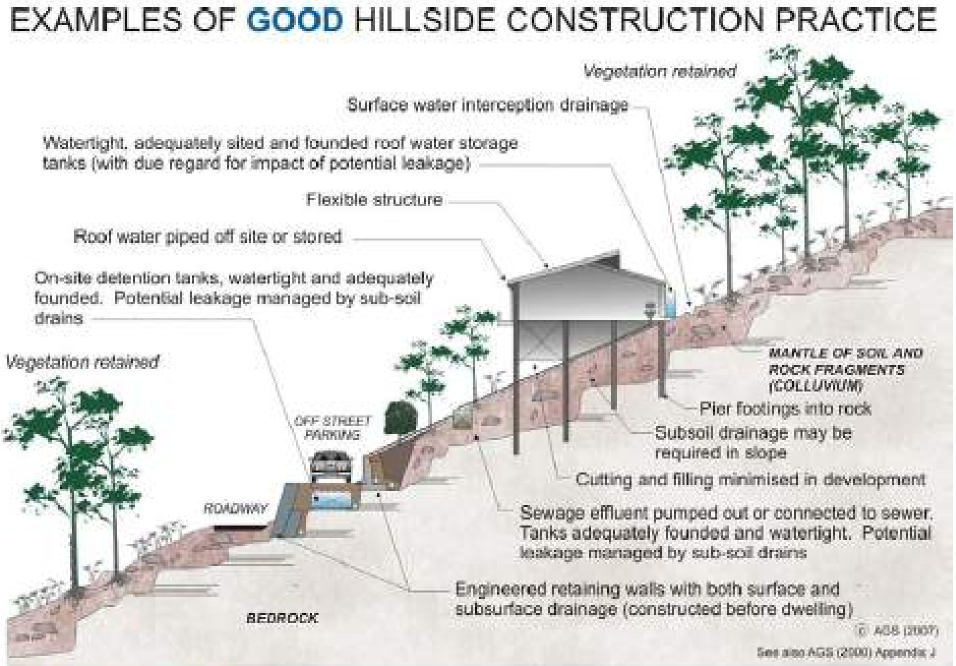
Performance Criteria E3.7.1 P1 Buildings and works must satisfy all of the following:	Relevance	Management Options	Managed (treated) Risk Assessment			Further Assessment Required
			Consequence	Likelihood	Risk	
(a) no part of the buildings and works is in a High Landslide Hazard Area;	N/A	N/A	N/A	N/A	N/A	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.	Capable of feasible and effective treatment through hazard management measures	Building to be founded on adjustable piers to allow for compensation of ground movement. Piers should extend to 4.5 m depth. Proposed building should be light-weight, rigid, removable and under no circumstances constructed of brick. All service connections to the house should have flexible connections.	Insignificant	Almost Certain	Moderate	No

APPENDIX 3 - Australian Geomechanics Society (AGS) Landslip Risk

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.



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.

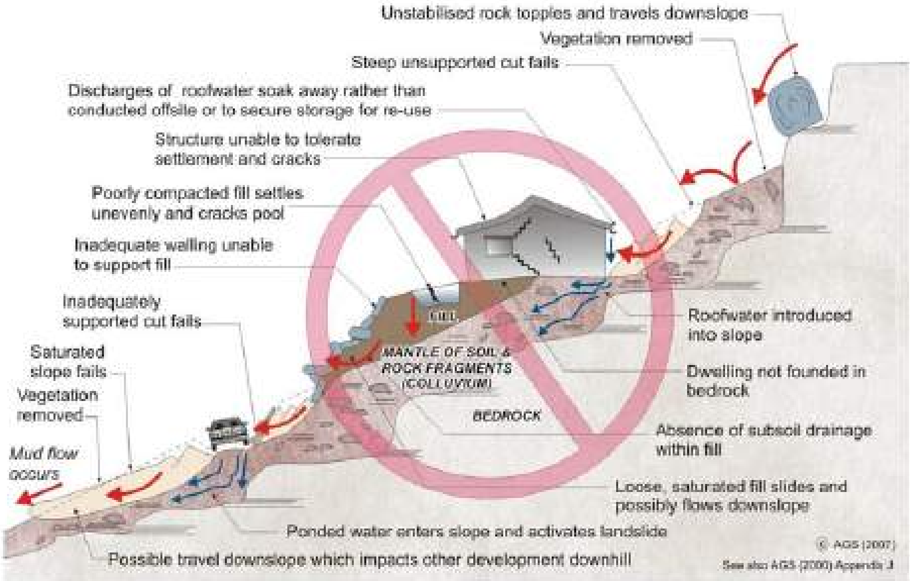
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

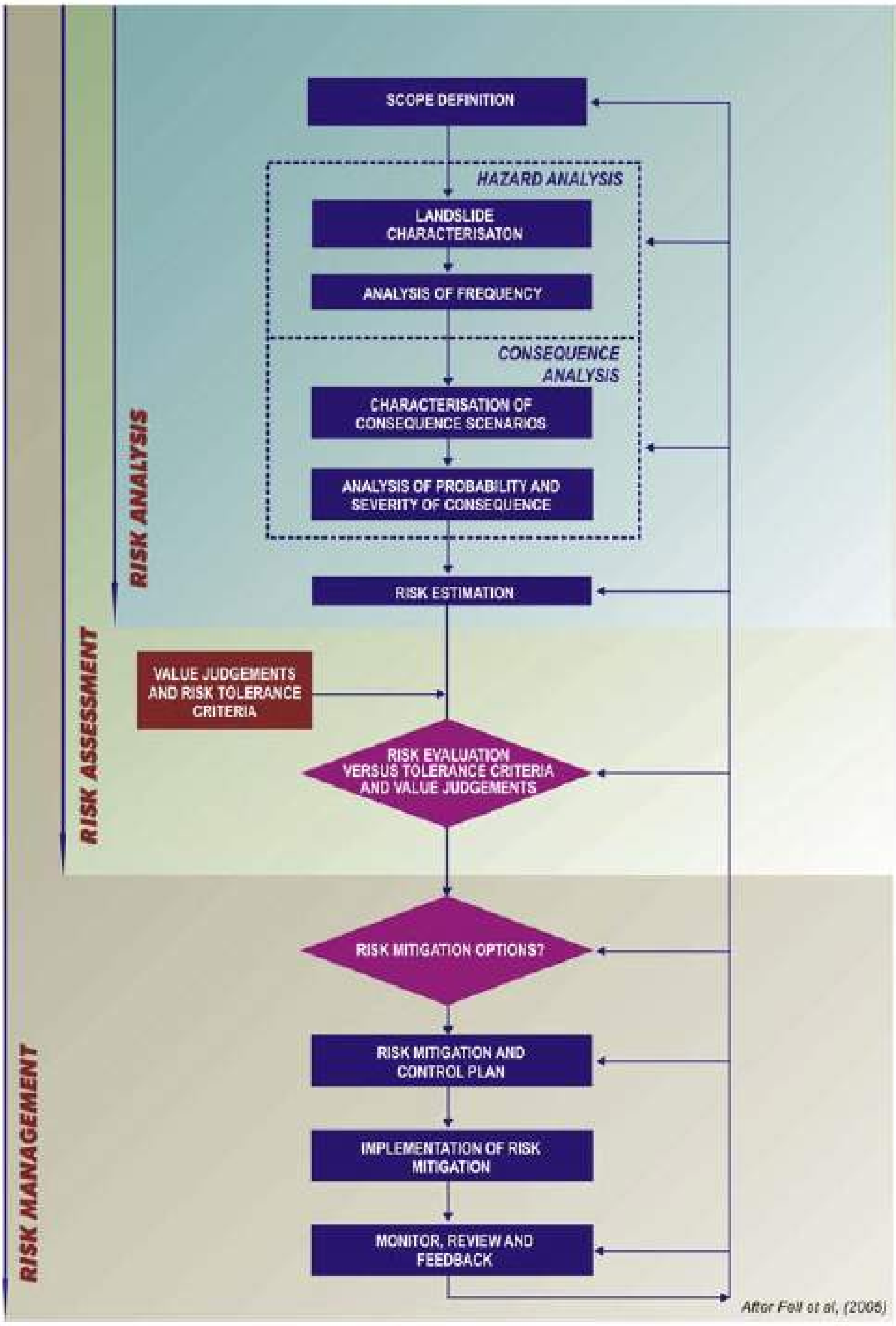
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to 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.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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



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.

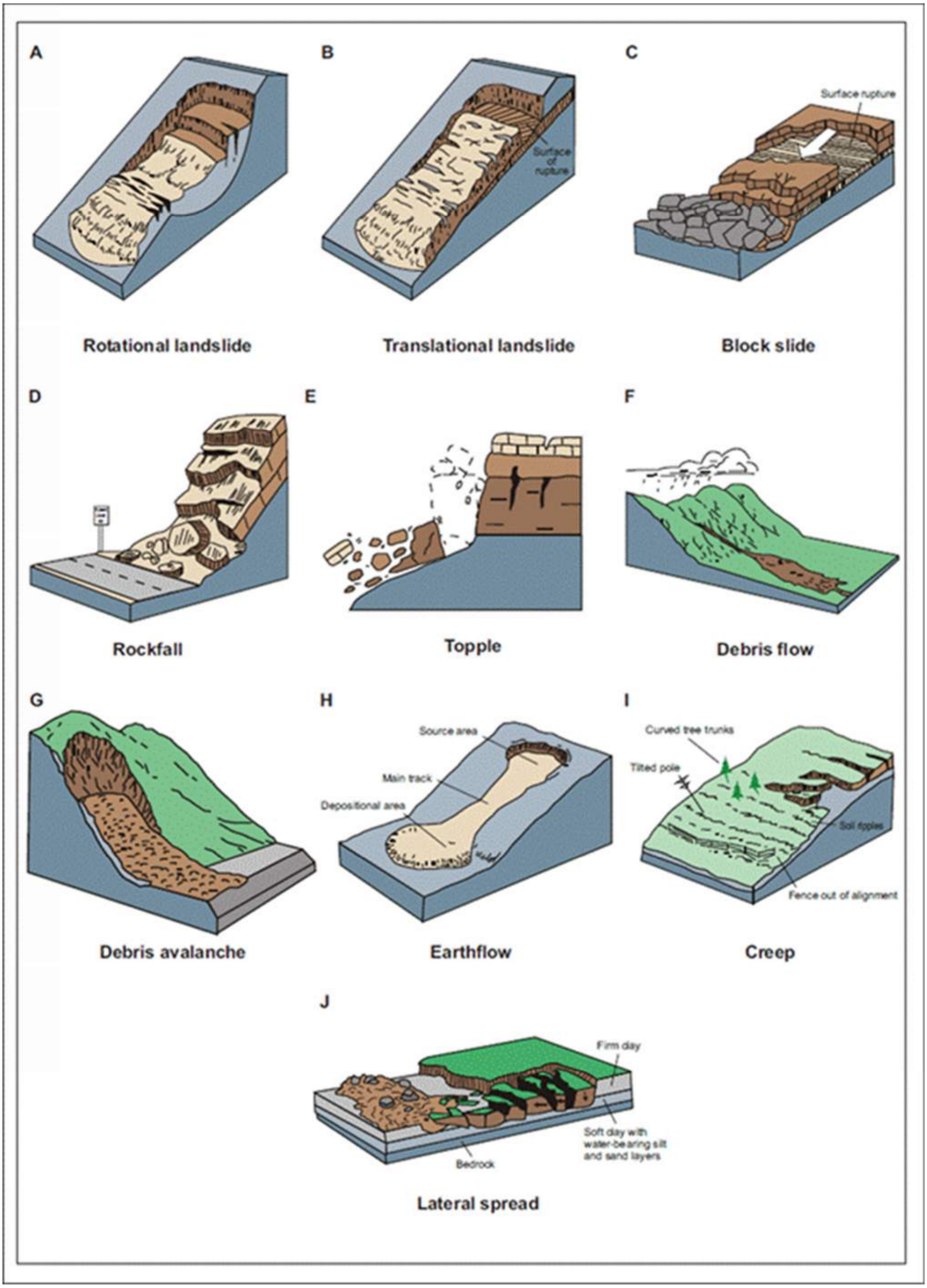
The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence ***fall***, ***topple***, ***slide***, ***spread*** and ***flow***.

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).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly Coarse	Predominantly Fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (Deep creep)	Debris flow (Soil creep)	Earth flow
COMPLEX		Combination of two or more principle types of movement		

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.


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 Site Photos