ROCKHAMPTON REGIONAL COUNCIL

APPROVED PLANS

These plans are approved subject to the current conditions of approval associated with

Development Permit No.: D/94-2018

Dated: 17 September 2018

Slope Stability Assessment Report

DATE: 21st of June, 2018

YOUR REF: N/A
OUR PROJECT JOB NUMBER: GEO168574-B

For
Affordable Quality Homes
PO Box 5254
Rockhampton DC 4701

SITE ADDRESS - Lot 36 on SP176990 (No.14) Connemara Drive, Kawana

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1.0 INTRODUCTION

This report presents the results of a geotechnical walkover assessment of stability investigation carried out by STA Consulting Engineers at Lot 36 on SP176990 (No.14) Connemara Drive, Kawana.

2.0 SCOPE AND METHOD OF INVESTIGATIONS

The aim of this report is to assess the potential risk of slope instability or Landslide risk for the proposed residential development in its existing and post developed state.

The methodology adopted by STA Consulting Engineers in order to determine the Landslide risk for this site is obtained incorporating the following criteria :-

- Guidelines developed by the Australian Geomechanics Society (AGS), Landslide Risk Management, Volume 42 No. 1, March 2007.

- Landslide Frequency Assessment in accordance with the report "A Method of Zoning Landslide Hazards", prepared by MacGregor and Taylor 2001.

- A review of existing Hazard mapping (where available), aerial photographs and various published information to assist in identifying past activity.

- A review of the client supplied field investigation report as completed by CQ Soil Testing Project Job No. CQ14882 dated the 15th of January, 2018 in order to understand subsurface conditions.

- A walkover survey to record surface evidence of slope instability and to assess the ground slope/s and general site conditions.

2.1 Qualifications of Responsible Firm

This report is prepared by a Registered Professional Engineer of Queensland (RPEQ) specialising in geotechnical engineering.

3.0 PROPOSED DEVELOPMENT

It is understood the proposed development at Lot 36 on SP176990 (No.14) Connemara Drive, Kawana is to involve the construction of a double storey residential dwelling. The upper floor is to be timber on bearers and joists supported by slab on ground to the lower floor. The external finish is to be face brick work with a light weight sheet metal roof.

The proposed earthworks are to involve a cut and fill operation for the purpose of creating a level building platform. The approximate cut and fill depths are up to 2.2 metres and 2.1 metres respectively. It has been indicated that the cut and fill batters are to be supported using suitably designed retaining walls.

4.0 GEOTECHNICAL SITE INVESTIGATION

The following information has been interpreted from the supplied soil test investigation report as completed by CQ Soil Testing Project Job No. CQ14882 dated the 15th of January, 2018**.**

4.1 Fieldwork & Laboratory Testing

From the supplied soil test report, it has been indicated that three (3) bore holes were undertaken at the proposed building location to a maximum depth of 2.0 metres.

4.2 Regional Geology

Reference to the Department of Natural Resources, Mines and Energy electronic series indicates that the site is located near the geological boundary between a number of units :-

1. Lakes Creek Formation of the Early Permian age comprising predominantly of siltstone and lithic sandstone.

2. The Rockhampton Group of the Early Carboniferous age comprising of Dark grey mudstone, siltstone, felsic volcaniclastic sandstone, polymictic conglomerate, ooid-bearing sandstone and conglomerate with mudstone rip-up clasts, oolitic and pisolitic limestone and minor skeletal limestone.

3. The highest terraces of flood plain alluvium comprising of clay, silt, sand and gravels of the Quaternary age.

4.3 Subsurface Conditions

The sequence encountered in the bore logs by CQ Soil Testing Pty Ltd can be described as dense to very dense clayey sandy GRAVEL for the full depth of bore holes # 1 and # 2, whilst In bore hole # 3, uncontrolled fill (clayey sandy gravel) to 0.4 metres depth underlain by residual gravelly clayey sand and clayey sandy gravel to 1.6 metres, over weathered rock.

It must be noted, the supplied soil test report has three bore logs attached with the test locations identified on the corresponding site sketch, however it was identified that the log sheets reference Bore Hole # 2 on both pages 8 and 9 of the report. Taking into consideration supplied bore hole locations it has been determined for the purpose of this report that the bore log represented on page 9 is in fact bore hole # 3.

There is a danger that by simplifying the geological conditions as described above, small-scale variations that may have significant engineering implications can be overlooked. Where specific information is required, the reader should in all instances refer to the full soil test report as completed by *CQ Soil Testing Project Job No. CQ14882 dated the 15th of January, 2018.*

4.4 Groundwater

Groundwater was not identified on the bore logs at the time of the subsurface investigation. However seepage can be expected at the soil/ rock interface during and after prolonged periods of rain.

5.0 SLOPE STABILITY ASSESSMENT

5.1 Stability Walkover Assessment Findings

As requested a visual walkover inspection for assessment of stability was undertaken at Lot 36 on SP176990 (No.14) Connemara Drive, Kawana.

The site under review is identified as being a residential allotment 1385 square metres in overall area. The block is regionally located approximately 6 kilometres North of the Rockhampton CBD, positioned within an established housing development comprising of similar residential properties. Large vacant rural lands remain to the North of the development.

At the time of the site assessment, the following observations were made :-

- Topographically the site is situated mid slope of a prominent hill, the crest being approximately 100 metres to the South East.
- The land shape is predominantly planar/ convex.
- For approximately the first 20 metres into the site the slope is steep falling at approximately 12 to 14 degrees. Approximately mid way into the block the fall increases to approximately 18 to 20 degrees, largely to the Western aspect of the site. Towards the rear the slope begins to decrease to become moderate at 8 to 9 degrees, which continues into the rural lands below the site to the North.
- The site is connected to the mains storm water and sewer networks. A stormwater gully pit was identified to the rear North Western corner of the site.
- No groun water or surface water seepage was observed, nor was any vegetation such as reeds/ sedge grasses typically associated with wet areas identified.
- Vegetation on and adjoining the site consists of grass and trees. Whilst a number of small trees were observed with Basel curvature or misshapen tree trunks, they do not appear to be of any particular pattern or consistently orientated, therefore are not considered indicative of significant soil movements.
- No tension cracks were observed on or across the slope within the vicinity of the site.
- Hummocky or bulging soils were not identified on or at the base of the slope within the vicinity of the site.
- The site is surrounded by a mix of existing residential construction including slab on ground, split level and pole home type construction. From visual inspection only, all appear to be performing as intended.
- Indicators of instability from surrounding man made structures were not identified. This includes but is not limited to signs of rotation or stress in the existing swimming pool, retaining walls, fence posts the performance of existing structures etc....

5.2 Desktop Assessment Findings

- A review of historical imagery has been undertaken. No indicators of past landslip activity or instability on or surrounding the nominated building sites could be identified from these images.

- With reference to interactive maps by the Rockhampton Regional Council, the site is identifiedd within the “ Steep Land “ overlay map with falls ranging between 15 to 25 % +.

5.2 Hazard Identification

A hazard is defined as a condition with the potential for causing an undesirable consequence (the landslide).

The hazard assessment given in this report is consistent with the procedures outlined in the report, "A Method of Zoning Landslide Hazards" by MacGregor and Taylor, 2001. The following major site features have been considered in determining a likelihood estimate or Frequency Analysis in turn, the potential Hazard of the site in order of undertaking the final risk assessment for the proposed building zone and immediate surrounds :

- The Natural Slope Angle
- Local Area Geology
- Concentration of Surface Water
- Evidence of Past Forms of Instability
- The Natural Slope Shape/ Formation
- Material Strength
- Evidence of Groundwater

From the results of studies undertaken by SMEC in similar terrain a correlation between relative frequency and potential Hazard Rating has been determined as presented in the following table :-

RELATIVE FREQUENCY	HAZARD RATING	DESCRIPTION
> 6.0	**VH** (Very High Hazard)	The event is expected to occur.
2.0 - 6.0	**H** (High Hazard)	The event will probably occur under adverse conditions.
0.6 - 2.0	**M** (Moderate Hazard)	The event could occur under adverse conditions.
0.2 - 0.6	**L** (Low Hazard)	The event might occur under very adverse conditions.
< 0.2	**VL** (Very Low Hazard)	The event is conceivable but only under exceptional circumstances.

We have completed a Landslide Frequency Analysis and as an opinion, the hazard for the nominated building location and surrounds of such is provisionally outlined within the following table :-

Applied Relative Frequency	Hazard Rating
0.34	Low

5.3 Risk Assessment

Considering the intended development for this site , the elements considered within the risk assessment are as follows :

- The intended/ proposed buildings and associated outbuildings.
- Persons or Occupants on site.

Taking into consideration the potential landslide hazard for the property incorporating the Guidelines developed by the Australian Geomechanics Society (AGS), Landslide Risk Management, Volume 42 No. 1, March 2007 and the potential impacts to persons and/or property within or directly adjoining the boundaries of the area assessed, based on our findings the risk level for this site is considered "LOW" .

The risk level given is conditional on the risk mitigation measures outlined within this report being fully implemented and maintained for the expected life of the structure.

5.3 Risk Assessment Cont.

The table below outlines our qualitative assessment of landslide risk for the development site :

Hazard	Likelihood	Consequence	Assessed Risk	Comments
1. Shallow translational failure through the residual soils on slopes <15 º	Rare	Minor	Very Low	Unlikely due to the shallow nature of the overlying soils and degree of natural slope thus resulting in minor consequence.
2. Shallow translational failure through the residual soils on slopes >15 º	Unlikely	Minor	Low	Unlikely due to the shallow nature of the overlying soils and installation of retaining structures to proposed cuts thus resulting in minor consequence.
3. Deep seated failure within the weathered rock.	Barely Credible	Major	Very Low	Whilst the consequence of such a failure would be major, the assessed risk is very low due to the rock strength observed and degree of slopes observed.

The potential implications for the associated risk level are outlined within the table below :-

Risk Level	Implications
VH (Very High Risk)	Extensive investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.
H (High Risk)	Detailed investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.
M (Moderate Risk)	May be acceptable provided treatment plan is implemented to maintain or reduce risk levels.
L (Low Risk)	Can be accepted. Treatment to maintain or reduce risk levels should be defined.
VL (Very Low Risk)	Accepted. Managed by routine procedures.

Table 2. Implications of Risk Level Classification Australian Geomechanics Society (AGS 2007).

6.0 RECOMMENDATIONS & RISK MITIGATION MEASURES

The area of the proposed structure has been defined as a "Low" risk, providing the following recommendations are implemented, managed and maintained for the expected life of the structure :-

6.1 House Design

As indicated by the client, the proposed development at Lot 36 on SP176990 (No.14) Connemara Drive, Kawana is to involve the construction of a double storey residential dwelling. The upper floor is to be timber on bearers and joists supported by slab on ground to the lower floor. The external finish is to be face brick work with a light weight sheet metal roof.

The proposed earthworks are to involve a cut and fill operation for the purpose of creating a level building platform. The approximate cut and fill depths are up to 2.2 metres and 2.1 metres respectively. It has been indicated that the cut and fill batters are to be supported using suitably designed retaining walls.

- STA Consulting Engineers are satisfied that a construction type and associated earthworks as described above is suitable for this site, providing the following recommendations outlined are implemented and maintained for the life of the structure.

6.2 Earthworks

- Retain the existing natural contours wherever possible.
- All earthworks to be carried out in accordance with the requirements of Australian Standard AS 3798 Guidelines on Earthworks for Commercial and Residential Developments.

Cuts Minimise depth.

- Support cut batters with engineered retaining walls or profile to an appropriate slope. For this site, exposed cut batters are to be profiled no greater than the following :-

Safe Batter Profile Angles (up to 2.0 metres in height)

Material	Temporary	Permanent
Residual Soils (non cohesive)	1V : 2H	1V : 2H
Residual Clays	1V : 1H	1V : 2H
Very Low Strength Rock	1V : 1H	1V : 1.5H

- Drainage measures MUST be installed immediately up slope and behind all cut batters including those retained to capture both surface and subsurface water movements and divert waters to a suitable, controlled outflow below and clear of the building envelope. All drains must be maintained for the life of the structure.

Fills Minimise height.

- Support filled batters with engineered retaining walls or profile to an appropriate slope. For this site, exposed fill batters are to be profiled no greater than the following :-

Safe Batter Profile Angles (up to 2.0 metres in height)

Material	Temporary	Permanent
Engineered Controlled Fill	1V : 1H	1V : 2H
Uncontrolled Fill	1V : 2H	1V : 4H

* *All fill batters should be overfilled, compacted and cut back to the required profile as outlined in the table above.*

- Strip vegetation, topsoil and key/ bench the natural slope prior to filling. Fill is not to be simply placed onto sloping surfaces greater than ~ 7 degrees.
- Use clean fill materials and compact to engineering standards. Fill should be placed in maximum 200 mm deep layers and be compacted to a minimum of 98 % Standard Maximum Dry Density for cohesive (clay) material or 70 - 90 % Relative Density for non cohesive (sand) materials.
- The finished platform must not slope towards the filled embankment which will allow water to flow/ cascade over the exposed face. Ponding water on the platform must also be avoided.

6.3 Foundations

- Footings should be founded into dense to very dense residual soils or weathered rock profile. This should be determined by the design engineer.
- On site foundation inspections including footing, slab & retaining walls must be undertaken by a suitably qualified and experienced Geotechnical Engineer.

6.4 Drainage

The control of surface and subsurface water is critical to the overall performance of this site. All surface and subsurface water must be captured and directed off site via a suitable outflow. Water MUST not be left to pond on site, nor is water to be left to cascade over any cut or fill batter. Some basic guidelines include but are not limited :-

Surface

- Provide drains at the top of all cut and fill slopes, including those retained.
- Discharge under controlled conditions to the street drainage or to the rear of the site.
- Provide and maintain general falls within drains to prevent blockage by siltation.
- Line spoon drains to minimise the infiltration of surface water and make drains flexible where possible.

Subsurface

- Provide filters around all subsurface drainage.
- Provide appropriate drainage behind ALL retaining structures.
- Use flexible pipelines with access for long-term maintenance.
- Prevent the inflow of surface water.

Waste Water & Storm water

- The site is connected to the mains sewer and storm water systems. All outflows are to be directed to these mains.
- Storage tanks should be watertight and adequately founded. Overflows are to be piped to the existing storm water system.

6.5 Erosion Control & Landscape

- Control erosion as this may lead to instability.
- Re-vegetate exposed areas including unsupported batters with shrubs, grasses and ground covers preferably with plants indigenous to the local area

7.0 CONCLUSION

In conclusion, it is our considered opinion, from a geotechnical viewpoint that the site is suitable for the proposed residence that had been indicated by the client at the time of writing this report .

This recommendation is subject to the implementation of the measures specified within this report. On site foundation inspections including footing, slab & retaining walls must be undertaken by a suitably qualified and experienced Geotechnical Engineer.

Thank you for entrusting us with this work, if we can be of any further assistance in this matter, please let us know.

For and on behalf of
STA Consulting Group Pty Ltd

Robin Cao BEng
MIEAust CPEng NPER RPEQ 12198

Digitally signed by STA Consulting Engineers
DN: c=AU, st=QUEENSLAND, l=Milton, ou=Geotechnical Department, o=STA Consulting Engineers, cn=STA Consulting Engineers, email=engineering.dept@staconsulting.com.au
Date: 2018.06.22 15:23:34 +10'00'

APPENDICES

APPENDIX A

Soil Profile and Laboratory Results

CQ SOIL TESTING
Servicing all of Central Queensland

Soil Logs

BOREHOLE 1		
Depth (m)	**Visual Class'n Symbol**	**Visual Description of Material**
0.0 2.0	GC	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, D-VD w/depth.

Borehole terminated at 2.0 m

DCP TEST RESULTS		
Depth (mm)	**Blows per 100 mm**	**Indicative kPa**
100	8	200
200	9	250
300	12	250
400	Drill	
500	Drill	
600	Drill	
700	>15	>300
800	Drill	
900	Drill	
1000	Drill	
1100	Drill	
1200	>15	>300
1300	Drill	
1400	Drill	
1500	Drill	
1600	Drill	
1700	>15	>300
1800		
1900		
2000		
2100		
2200		
2300		
2400		
2500		
2600		
2700		
2800		
2900		
3000		
4100		
4200		
4300		
4400		
4500		
4600		
4700		
4800		
4900		
5000		

MOISTURE CONDITION	CONSISTENCY	RELATIVE DENSITY
D – Dry	VS – Very Soft	VL – Very Loose
M – Moist	S – Soft	L – Loose
W – Wet	F – Firm	MD – Med Dense
	ST – Stiff	D – Dense
	V/ST – Very Stiff	VD – Very Dense
	H – Hard	

Allowable Bearing Pressure calculated using the guidelines in "Determination of Allowable Bearing Pressure under Small Structures" by MI Stockwell (NZ Engineering June 1997)

DCP test results are to be used as a guide only to relative density and consistency of soils. Changes in moisture contents or the presence of coarse grained material can greatly influence the outcome of this test.

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Figure 1. Bore Logs per CQ Soil Testing, Job No. CQ14882.

CQ SOIL TESTING
Servicing all of Central Queensland

Soil Logs

BOREHOLE 2		
Depth (m)	**Visual Class'n Symbol**	**Visual Description of Material**
0.0 1.7	GC	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, D-VD-H w/depth.

Tungsten carbide bit refusal in hard gravel at 1.7 m

DCP TEST RESULTS		
Depth (mm)	**Blows per 100 mm**	**Indicative kPa**
100	8	200
200	>14	>300
300	Drill	
400	Drill	
500	Drill	
600	Drill	
700	>15	>300
800	Drill	
900	Drill	
1000	Drill	
1100	Drill	
1200	Drill	
1300	>15	>300
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MOISTURE CONDITION	CONSISTENCY	RELATIVE DENSITY
D – Dry	VS – Very Soft	VL – Very Loose
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Allowable Bearing Pressure calculated using the guidelines in "Determination of Allowable Bearing Pressure under Small Structures" by MI Stockwell (NZ Engineering June 1997)

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Report No CQ14882 QBCC License No - 1117681 Page - 8

Figure 2. Bore Logs per CQ Soil Testing, Job No. CQ14882.

CQ SOIL TESTING
Servicing all of Central Queensland

Soil Logs

BOREHOLE 2		
Depth (m)	Visual Class'n Symbol	Visual Description of Material
0.0 0.4	GC	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, brown, D, D. Fill
0.4 1.4	SC	Gravelly Clayey SAND, fine to coarse grained, low plasticity fines, grey-yellowish brown w/depth, D, D. Natural
1.4 1.6	GC/XW	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, VD. Weathered rock

Tungsten carbide bit refusal in hard gravel at 1.6 m

DCP TEST RESULTS		
Depth (mm)	Blows per 100 mm	Indicative kPa
100	4	120
200	8	200
300	9	250
400	9	250
500	7	200
600	8	200
700	9	250
800	11	250
900	10	250
1000	12	250
1100		
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4800		
4900		
5000		

MOISTURE CONDITION	CONSISTENCY	RELATIVE DENSITY
D – Dry	VS – Very Soft	VL – Very Loose
M – Moist	S – Soft	L – Loose
W – Wet	F – Firm	MD – Med Dense
	ST – Stiff	D – Dense
	V/ST – Very Stiff	VD – Very Dense
	H – Hard	

Allowable Bearing Pressure calculated using the guidelines in "Determination of Allowable Bearing Pressure under Small Structures" by MI Stockwell (NZ Engineering June 1997)

DCP test results are to be used as a guide only to relative density and consistency of soils. Changes in moisture contents or the presence of coarse grained material can greatly influence the outcome of this test.

Figure 3. Bore Logs per CQ Soil Testing, Job No. CQ14882.

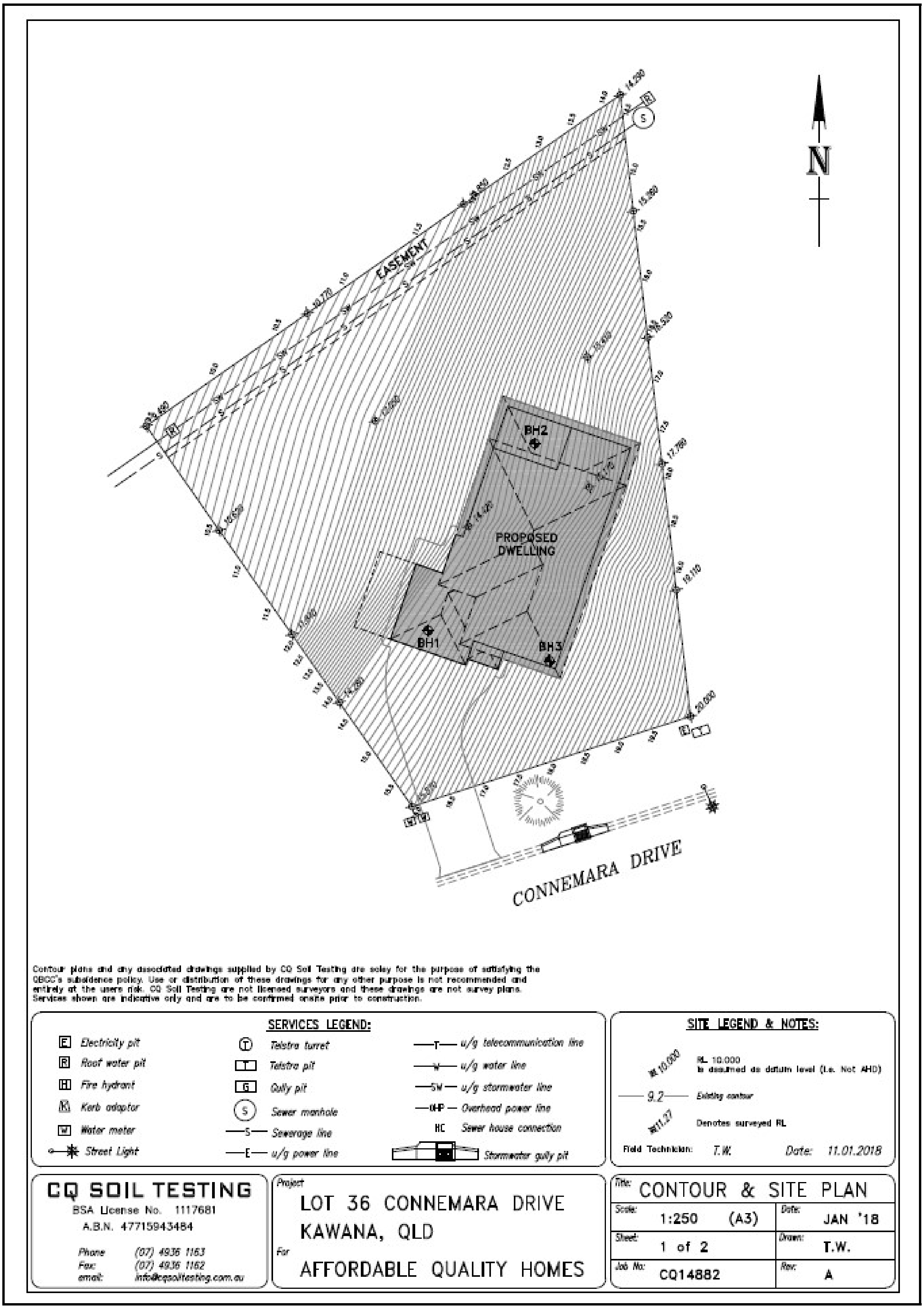


Figure 4. Bore Hole Locations per CQ Soil Testing, Job No. CQ14882.

APPENDIX B

Landslide Frequency Analysis

GEOLOGY: Lakes Creek Formation

Location: Lot 36 on SP176990 (No.14) Connemara Drive, Kawana

1.Basic Frequency 0.0004

2. Slope Angle

Area		Level	Factor
	Less than 5 degrees	L	0.1
x	Between 5 and 15 Degrees	M	0.5
	Between 15 and 30 degrees	M	0.8
	Between 30 and 45 degrees	H	1.2
	More than 45 Degrees	M	0.8

3. Slope Shape

Area		Level	Factor
	Crest or ridge	L	0.7
x	Planar/ Convex	M	0.9
	Rough/ Irregular	M	1.2
	Concave	H	1.5

4. Area Geology

Area		Level	Factor
	Volcanic Extrusive Rock	H	1.1
	Sedimentry Rock	M	1
x	Low Grade Metamorphic Rock	M	1
	High Grade Metamorphic Rock	L	0.9
	Volcanic Intrusive Rock	M	1

5. Material Strength

Area		Level	Factor
	Rock at Surface	VL	0.1
	Residual Soil < 1m deep	L	0.5
x	Residual Soil 1 - 3m deep	M	0.9
	Residual Soil > 3m deep	H	1.5
	Colluvial Soil < 1m deep	H	1.5
	Colluvial Soil 1 - 3m deep	VH	2
	Colluvial Soil > 3m deep	VH	4

Relative Frequency	Hazard Rating
< 0.2	Very Low
0.2 - 0.6	Low
0.6 - 2.0	Moderate
2.0 - 6.0	High
> 6	Very High

6. Concentration of Surface water

Area		Level	Factor
	Ridge	L	0.7
	Crest	M	0.8
	Upper Slope	M	0.9
	Mid Slope	H	1.2
x	Lower Slope	H	1.5

7. Evidence of Groundwater

Area		Level	Factor
x	None Apparent	L	0.7
	Minor Moistness	M	0.9
	Generally Wet	H	1.5
	Subsurface Springs	VH	3

8. Evidence of Instability

Area		Level	Factor
x	No sign of instability	L	0.8
	Soil Creep	H	1.2
	Minor Irregularity	VH	2
	Major Irregularity	VH	5
	Active Instability	VH	10

Summary

2	Slope Angle		0.5
3	Slope Shape		0.9
4	Area Geology		1
5	Material Strength		0.9
6	Concentration of surface water		1.5
7	Evidence of ground water		0.7
8	Evidence of Instability		0.8
9	Relative Frequency (2x3x4x5x6x7x8)		0.34

Relative Frequency **= 0.34**

Hazard Rating **= Low**

**The numerical factors allocation to these site features are based on judgement and experience*

APPENDIX C

Site Photographs

Figure 5. View North, North West towards site.

Figure 6. View West across rear of site.

Figure 7. View East across site.

Figure 8. View North East along rear boundary.

APPENDIX D

Site Maps

Figure 9. Google Earth Image.

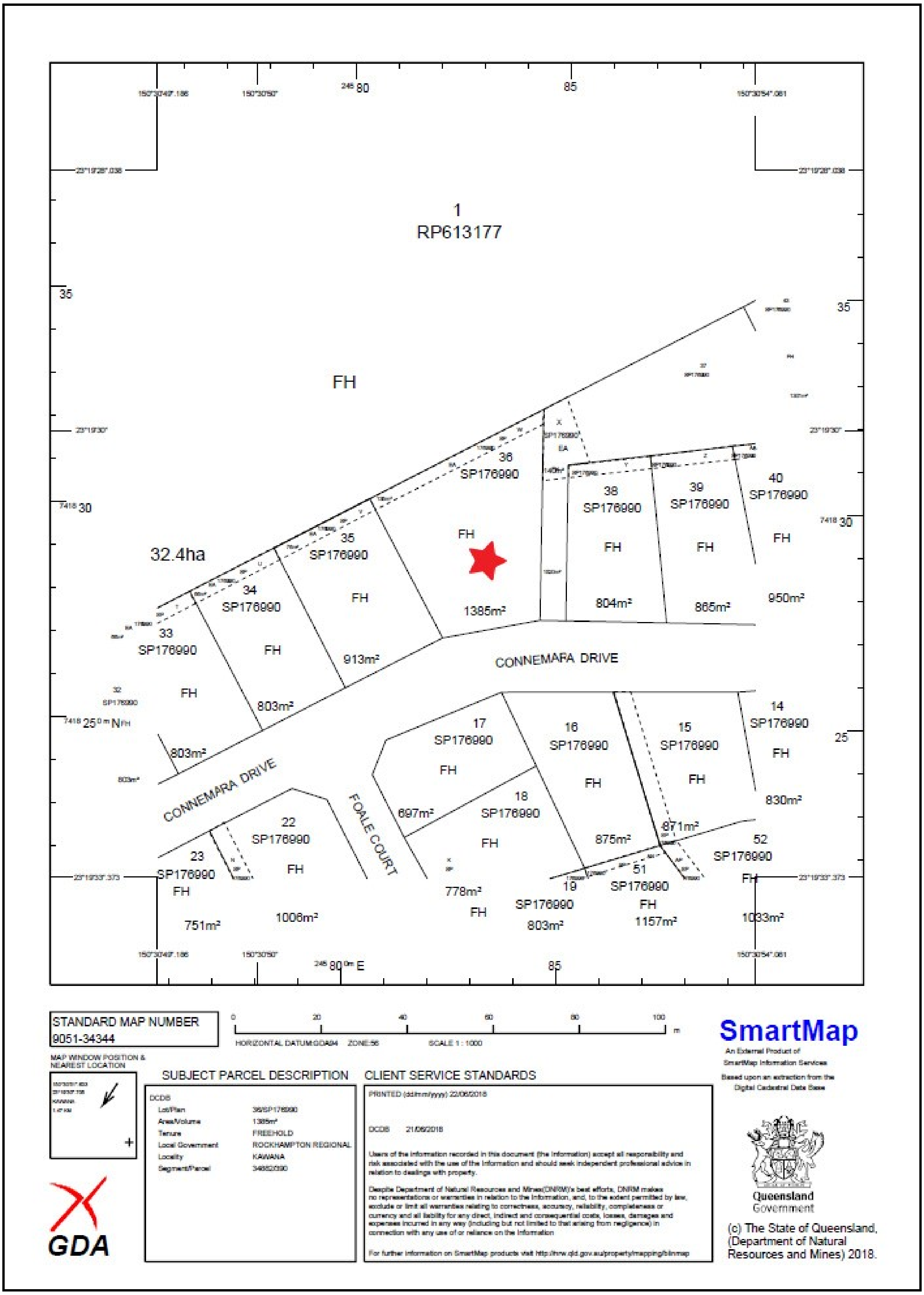


Figure 10. Registered Plan.

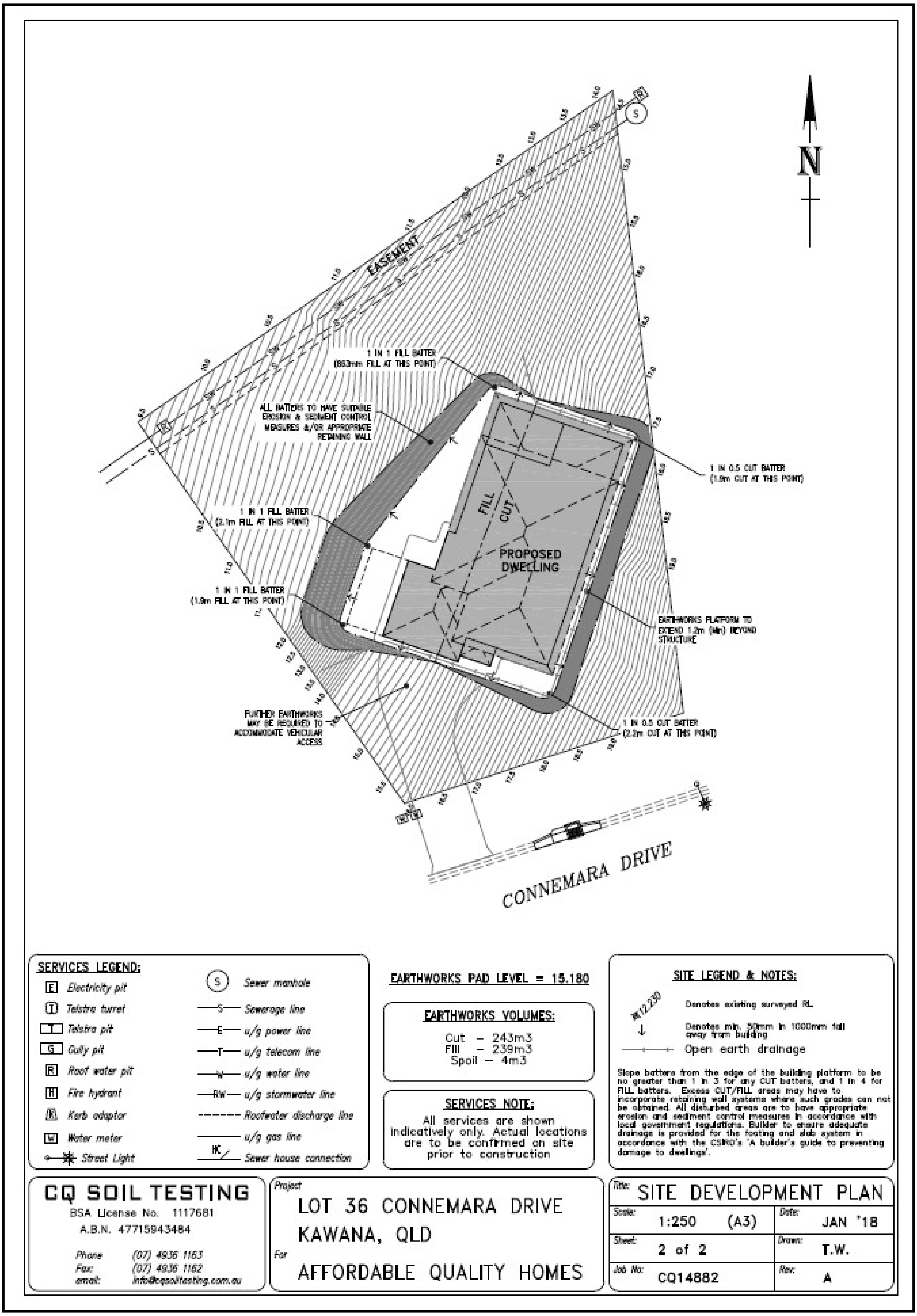


Figure 11. Siting and Contour Plan.

Figure 12. Steep Land Overlay Map - Rockhampton Regional Council Planning Scheme Mapping.

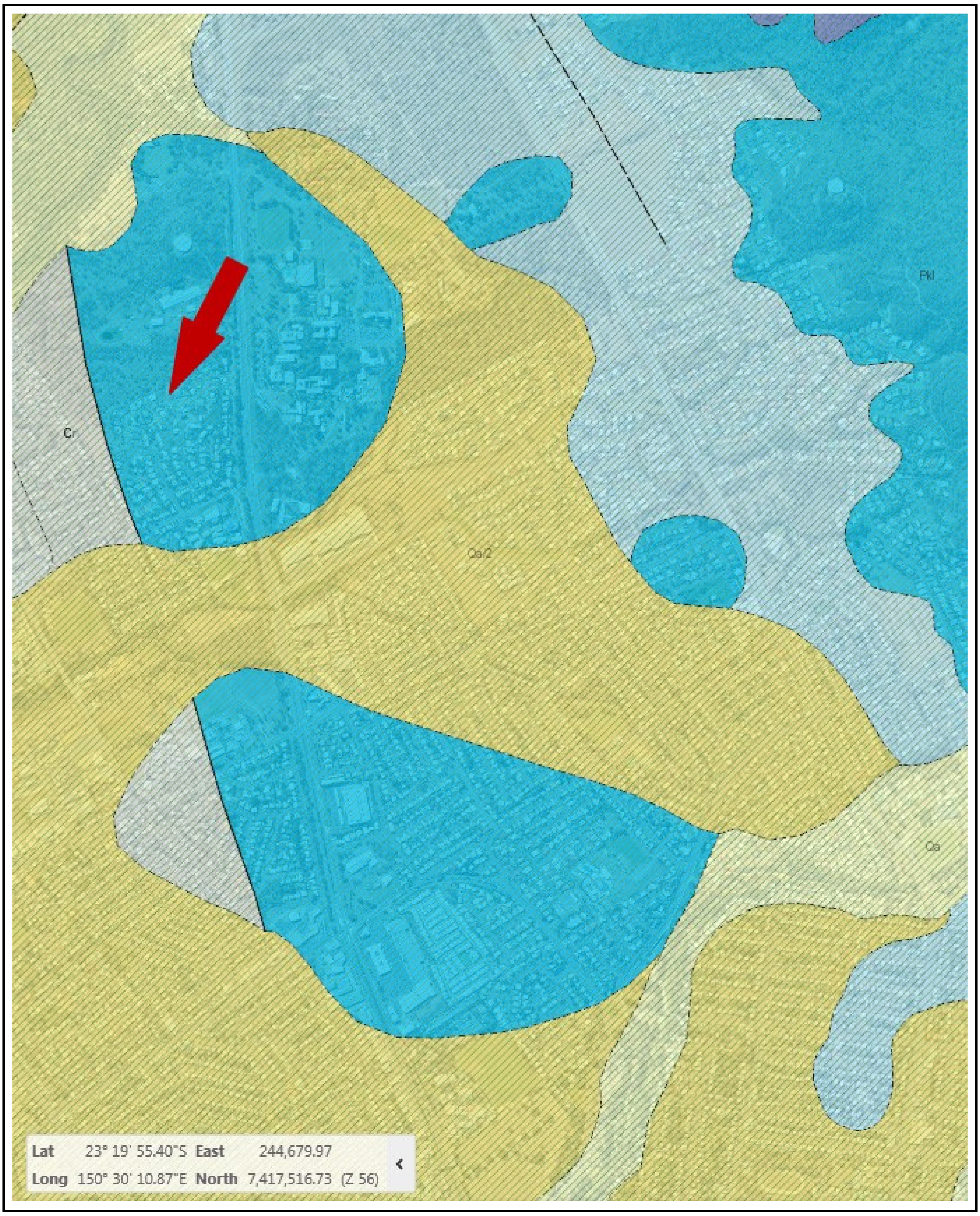


Figure 13. Regional Geology - Department of Natural Resources, Mines and Energy - Qld State Government.

APPENDIX E

Qualitative Terminology for use in Assessing Risk to Property

(Appendix C AGS2007)

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}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 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%		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%	100%	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%	40%	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%	10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%	1%	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.

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

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

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

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

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

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

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

APPENDIX F

Stability of Retaining Structures

Stability of Retaining Structures

Geotechnical stability of all proposed retaining structures must be carried out against sliding, overturning and global slope instability. The retaining structures must also be stable against bearing capacity failure (or excessive base settlements). Moreover, the retaining structure itself must be adequately designed against any potential structural failures such as flexural failure or shear failure.

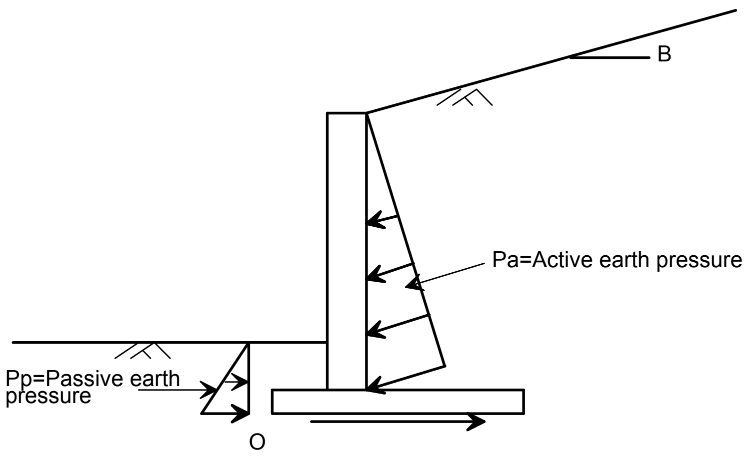


Fig. 7: Typical retaining structure and the lateral earth pressure distributions

Figure 7 shows a typical retaining structure including lateral earth pressure distributions. The retained soil behind the retaining structure will exert active lateral earth pressure if the retaining structure allows some lateral movement; otherwise lateral earth pressure at rest (K_o condition) should be used during design and stability assessments. The soil in front of the wall will cause passive earth pressure, as shown in Fig. 7.

All development applications involving retaining structures must assess the geotechnical stability and factor of safety against the following:

a) Sliding caused by the active earth pressure and resistance by passive earth pressure and frictional force at the base the retaining structure;

b) Overturning about the toe (point O in Fig. 7) as a result of driving moment caused by the active earth pressure and resisting moment caused by the passive earth pressure, the self-weight of the retaining structure and weight of the retained soils behind the structure; and

c) Global slope instability considering a large slip circle passing through the underneath of the retaining structure and the retained soils.

The stability assessment shall ensure that all retaining structures will achieve a factor of safety (FOS) > 1.5 against sliding, overturning and global slope instability.

Referenced "Geotechnical Stability Assessment Guidelines JUNE 2007: Version 1.0 Gold Coast City Council" Section 5.2 Page 19.

APPENDIX G

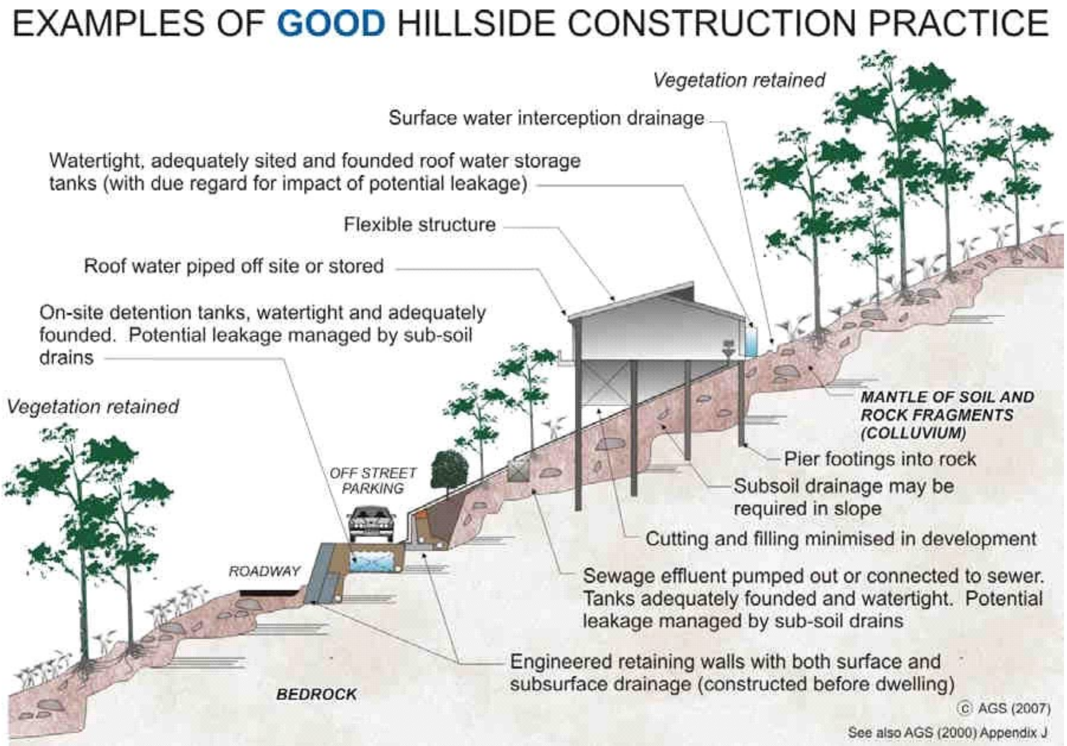
Hillside Construction

Good Hillside Construction Practice

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.

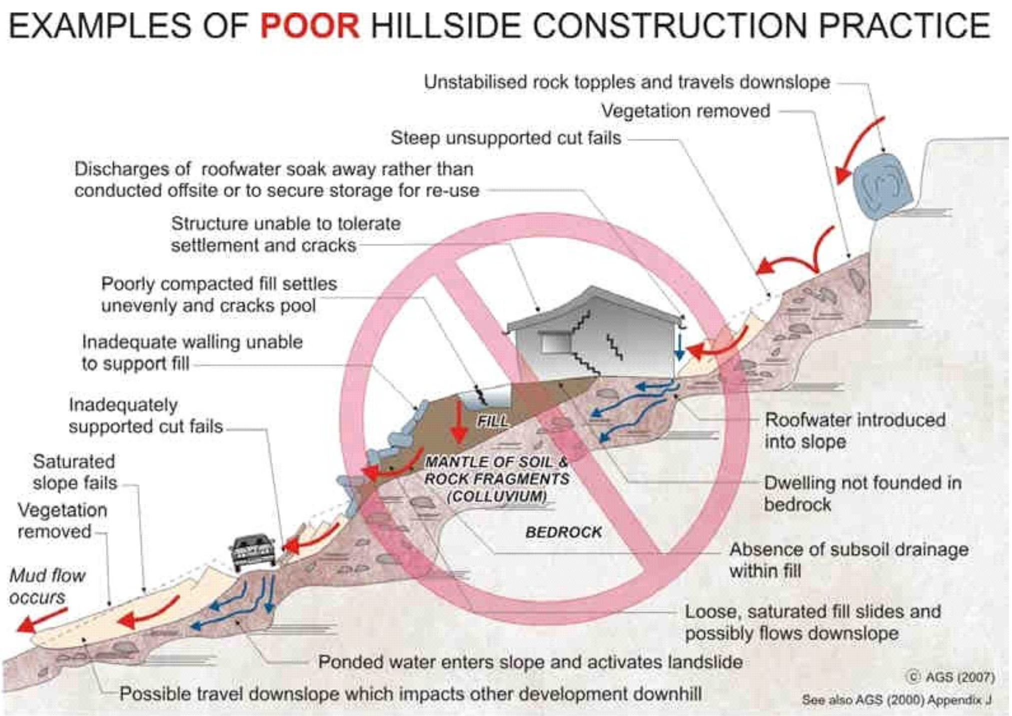
Flexible structures -have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality. **Vegetation clearance -**on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities 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

Poor Hillside Construction Practice

AUSTRALIAN GEOGUIDE LR8 (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:

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.

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