16 April 2018 Project No. 18098-001-Rev0

CQ Soil Testing
Attention: Mr Scott Walton

Email: scott@cqsoiltesting.com.au

SLOPE STABILITY ASSESSMENT FOR PROPOSED RESIDENCE
15 KILKENNY COURT (LOT 9 ON SP176990), KAWANA

Dear Scott,

1.0 INTRODUCTION

Tectonic has undertaken a slope stability assessment for a proposed residence at 15 Kilkenny Court, Kawana. This report presents the results of our slope stability assessment, together with geotechnical advice for the project. In summary, subject to implementation of the recommendations made herein, it is assessed that there is a Low Risk of slope instability affecting the proposed development in accordance with the Australian Geomechanics Society "*Guidelines for Landslide Risk Management*", dated March 2007 (AGS 2007).

1.1 Details of Site and Development

The property is described as Lot 9 on SP176990 and covers an area of 1125 m^2. The site slopes moderately to the east. Existing residences are located on surrounding properties. Text Figure 1 on the following page illustrates the site location and approximate building position. A more detailed description of the site is given in Section 2.

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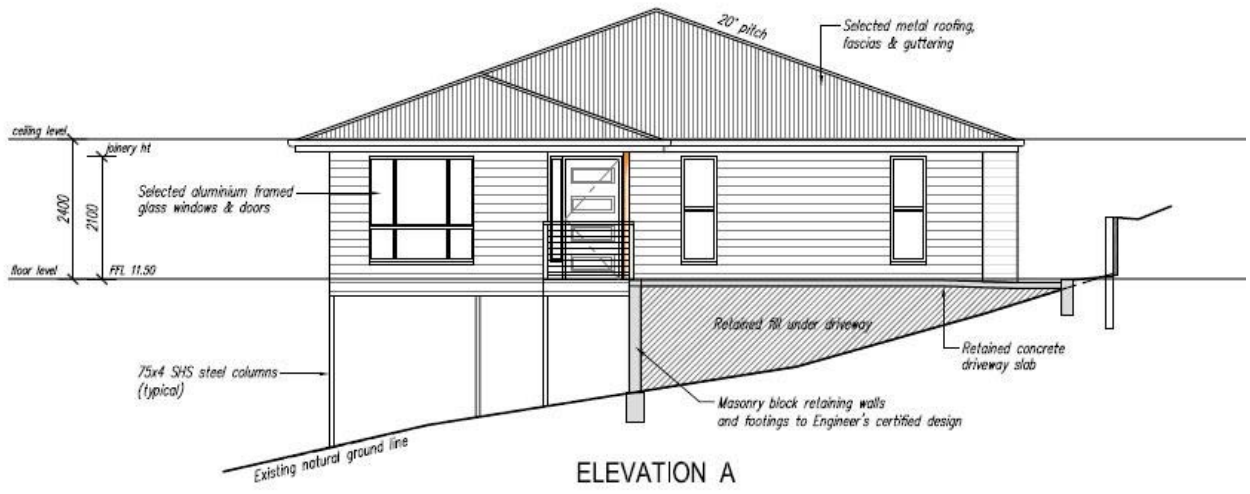
Text Figure 1: Aerial image of site and surrounds (Image source: Natural Resources, Mines and Energy, Queensland Government, Queensland Globe, licensed under Creative Commons, 2017); overlain house plan by Tectonic

Residential design drawings provided to us (Gill Kerr Plan & Drafting Service drawing no. 17-744 Sheets 1 to 11 Rev 0 dated 1-4-18) indicate that the proposed residence will comprise an elevated pole home with an at-grade garage constructed on a retained fill platform. The drawings indicate that the residence will be of lightweight construction comprising external wall cladding, timber framing, and steel roof sheeting. Filling up to about 2.6 m in height is indicated on the drawings on the northern side of the house to construct a level building pad for the garage and driveway. The fill is proposed to be retained by a masonry block retaining wall. An elevation of the proposed house is shown in Text Figure 2.



Text Figure 2: Extract of northern elevation (Gill Kerr PDS drg. ref. 17-744 Sheet 6), looking from Kilkenny Court

1.2 Method and Scope of Investigation

As part of our slope stability assessment, a desk-top study was carried out comprising a review of the residential design drawings including a ground level contour plan, published geological maps, council landslide hazard overlay, aerial photos, a soil test report by CQ Soil Testing (CQ job no. CQ15065, report dated 29 March 2018), and site photos provided by CQ.

The results of the desk-top study are included in Section 2 below.

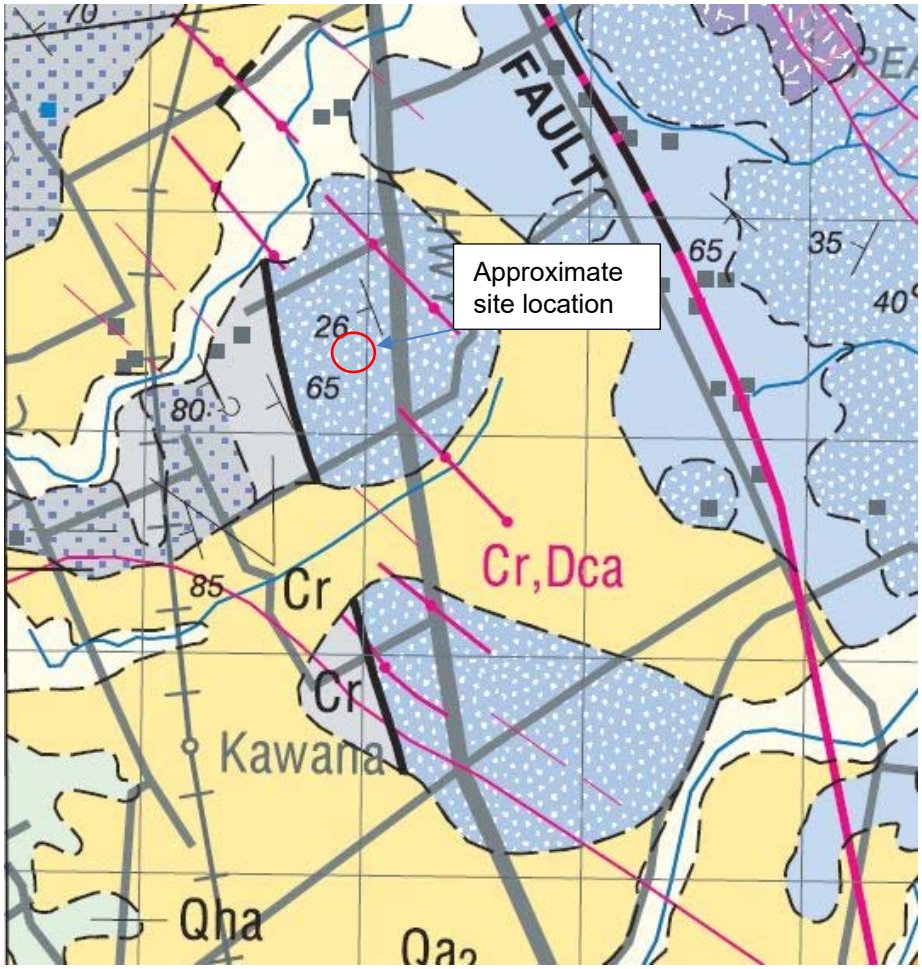
1.3 Qualifications of Responsible Engineer

This report has been prepared by Mr Scott Davis, an RPEQ with more than 10 years of experience in geotechnical engineering, including a number of slope stability projects.

2.0 DESCRIPTION OF EXISTING CONDITIONS

2.1 Geology

Available geological information[1] (refer to Text Figure 3) indicates that the site is underlain by the Permian age Lakes Creek formation comprising *siltstone and lithic sandstone*.



Text Figure 3: Extract of 1:100,000 Rockhampton geology map

[1] State of Queensland, Department of Natural Resources, Mines and Water, Rockhampton 1:100,000 Geology Map, Sheet 9051 Revised March 2006

The CQ investigation comprised three boreholes within the proposed building footprint drilled to depths of between 1.3 m and 2.1 m below ground level (BGL) at which depths auger refusal was reached on weathered rock. The subsurface conditions reported in the CQ report are as follows:

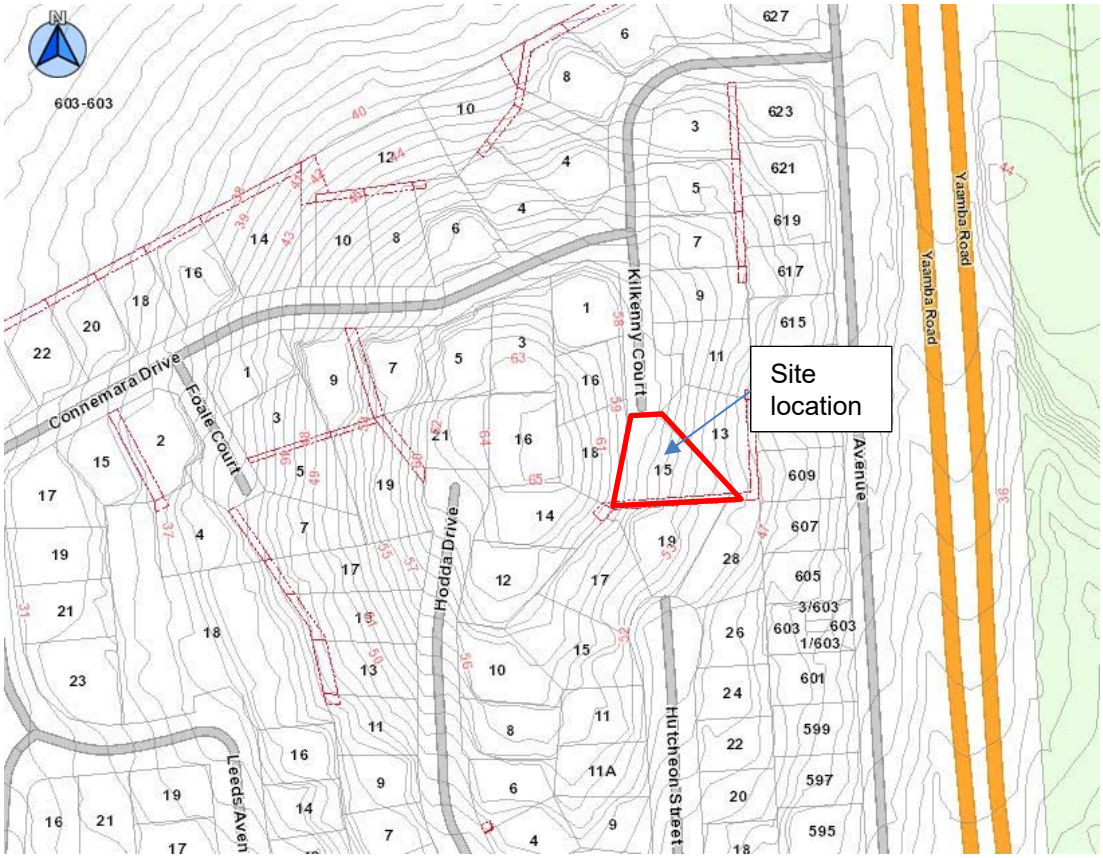
- Dense natural gravelly clayey sand to depths between 0.2 m to 0.6 m BGL; then
- Very stiff to hard clay/sandy clay of medium and high plasticity to depths ranging between 1.2 m and 2.0 m BGL; underlain by
- Very dense clayey sandy gravel; over
- Weathered rock to the depth of investigation (i.e. 1.3 m to 2.1 m BGL), where auger refusal was encountered.

No groundwater was encountered in the CQ boreholes, with soils being described as dry or moist. It should be noted that groundwater seepage may develop from permeable horizons within the soil profile. This may vary due to prevailing weather conditions, particularly following periods of heavy or prolonged rainfall.

CQ have classified the site as '*Class M*' as per AS2870-2011 based on an estimated characteristic surface movement (ys) of 31 mm to 40 mm. It should be noted that the placement of fill can affect the characteristic ground surface movement and the site classification should be reviewed following the completion of earthworks.

2.2 Topography

The site is located on the eastern side of hill which has a summit approximately 40 m to the west. Ground surface contours above and through the subject site are generally consistent, with elevations ranging between about RL 58 m and RL 50 m and falling to the east based on Rockhampton Regional Council (RRC) web mapping information (refer to Text Figure 4).



Text Figure 4: Extract of RRC web mapping ground surface contours

Contour information shown on the residential design drawing (drawing ref. 17-774 Sheet 3) and from the RRC web mapping site both indicate that the site slopes relatively consistently at between about 10˚ and 12˚.

The topography on the site would be generally described as linear planar. Site conditions are shown in Text Figures 5 and 6 below.

Text Figure 5: Site conditions in proposed building envelope, looking south (photo provided by CQ)

Text Figure 6: Site conditions at western site boundary showing existing timber retaining wall (photo provided by CQ)

2.3 Groundwater

No signs of surface groundwater seepage ('springs') were reported by CQ, nor encountered in the boreholes.

2.4 Surface Drainage

There is an upslope catchment extending approximately 40 m to 50m west of the site and surface runoff is anticipated to be directed towards the development area as general sheet flow. Based on contour information the broader topography should not result in concentrated water flows into the subject site. Given the gradients across the site (about 10˚ to 12°), and generally low permeability soils and weathered rock as recorded in the borehole investigation by CQ, surface water should drain well from the site.

2.5 Vegetation

The site of the proposed residence is cleared with vegetation mostly comprising grass. Three small to medium sized trees were present in the upper and central parts of the site, along with a cluster of larger trees towards the eastern boundary.

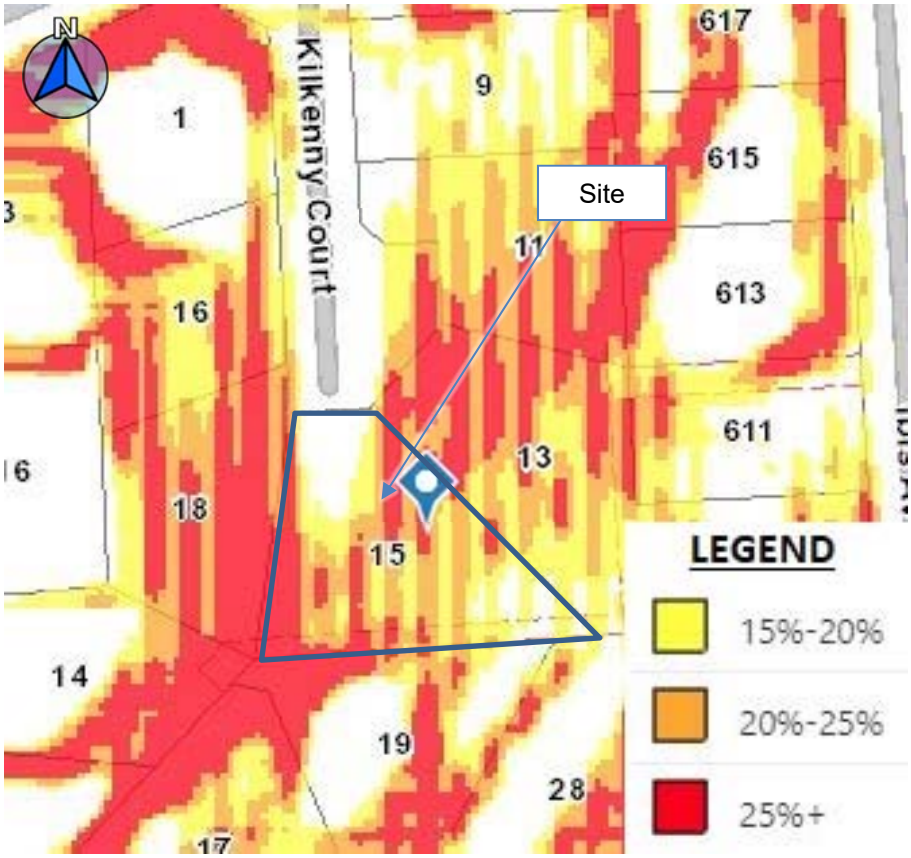
2.6 Buildings and Other Structures

There were no existing buildings or other structures on the site at the time of the CQ investigation other than a timber sleeper retaining wall on the common boundary with the property to the west. The timber retaining wall is shown in Text Figure 6 (on the page above) and based on the photo by CQ appears to be in reasonable condition and not showing any obvious signs deformation that may be attributable to slope instability.

3.0 ASSESSMENT OF LAND STABILITY

3.1 Existing Conditions

An extract of the RRC Planning Scheme Steep Land Overlay plan is presented in Text Figure 7 below and shows the site is mapped as steep land with slopes of greater than 15%. Some areas of the site (mostly south-west corner) are mapped as having a slope of 25% or greater (red areas), however as can be seen in Text Figures 5 and 6 on the pages above, this corner of site is not appreciably steeper than the central area of the site.



Text Figure 7: Extract from RRC Planning Scheme steep land overlay mapping

It should be noted that the RRC mapping is an indication of land slope (land sloping at >15% or more) rather than potential landslide susceptibility. For slopes over 15%, RRC requires a site specific geotechnical report to address stability. Based on available information, the site does not exhibit any indicators of slope instability. No landslide back scarps, tension cracks, or areas of naturally 'hummocky' ground are apparent in photographs supplied by CQ, and slopes are relatively gentle to moderate (up to about 12˚).

We have carried out a review of aerial photos taken between August 2012 and October 2017 and no evidence of previous slope instability was identified.

3.2 Stability Assessment

The risk assessment for this project has been carried out following AGS 2007 Practice Note Guidelines for Landslide Risk Management. Relative levels of risk and their implications are given in Table 1 below, and the *Qualitative Terminology for Use in Assessing Risk to Property* is attached.

Table 1: Stability Risk Levels

Risk Level		Example Implications(1)
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 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 regulators' approval) but requires investigation, planning and implementation of treatment options to reduce 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 required.
VL	Very Low Risk	Acceptable. Manage by normal slope maintenance procedures.

Note: (1) 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.

Considering the existing site conditions (Refer Section 2), and subject to the implementation of recommendations given below, it is our opinion that there is a **Low (L) Risk** of global slope instability affecting the proposed residential development. Regulators (Rockhampton Regional Council) normally require that a Very Low or Low Risk of landslide affecting property must be demonstrated to enable development approval. Summarised in Table 2 below is our qualitative assessment of landslide risk for the site. A summary of qualitative terminology for use in assessing risk to property is attached (taken from AGS 2007).

Table 2: Details of Qualitative Risk Assessment for Property (AGS 2007)

Hazard	Likelihood	Consequence	Assessed Risk	Comments
1: Shallow landslide in future fill or very stiff natural clays above the footing depth.	**Unlikely**	**Medium**	**Low**	The likelihood of a relatively shallow failure through the fill and/or natural soils is assessed as **Unlikely** provided the recommendations in this report are implemented, and also considering the gentle to moderate ground slopes, proposed retaining structures, and strength of the natural materials (very stiff or better). A potential **Medium** impact from such instability is assessed, with the resultant risk to be **Low** as per AGS 2007.
2: Deep failure in weathered rock below proposed foundation depth.	**Barely Credible**	**Major**	**Very Low**	The likelihood of a deep failure through the weathered rock is assessed as **Barely Credible** because of the relatively light residential loads, rock strength, and relatively shallow depth to rock (~1.3 m to 2.1 m BGL), along with the gentle to moderate slope angles. Although the consequence of such a failure could be **Major**, given that large parts of the site could be affected, the resultant risk is **Very Low** as per AGS 2007.

The potential impacts on slope stability of the development components have been assessed, and the measures recommended below in Section 4 have been designed to mitigate those impacts.

4.0 RECOMMENDATIONS

General recommendations to help maintain the stability of the site are given in the document "*Some Guidelines for Hillside Construction*", which is attached.

4.1 Earthworks

Filling up to about 2.6 m in height is proposed under the footprint of the garage and driveway in the north western corner of the site. The fill embankment is proposed to be supported using a reinforced masonry block retaining wall. No cut earthworks are indicated on the residential design drawings. The proposed earthworks are considered acceptable from a slope stability viewpoint provided they are undertaken in accordance with the recommendations given in this report. It is recommended that the fill height does not exceed the proposed height and is restricted in area to the garage and driveway footprint, unless assessed and approved by a geotechnical engineer. In other areas of the site fill heights should be limited to no more than 1 m.

Following any clearing of vegetation, remaining tree stumps and large roots must be 'grubbed out' and any organic rich topsoil stripped from the construction area. Topsoil materials or mulch must not be used in structural fill, however may be placed across landscaping areas.

Prior to filling, **sloping ground in proposed fill areas must be benched** to 'key in' fill material to the slope. The benched subgrade should then be proof rolled by a minimum 8 tonne roller to identify any soft/loose material. Any soft/loose material should be over-excavated to expose a stiff (or stiffer) foundation, and should be backfilled with compacted fill.

Embankment fill should be placed in layers 150 mm to 300 mm thick (loose thickness) and be compacted by repeated rolling to achieve a dry density ratio of at least 95% of the maximum Dry Density Ratio (DDR)(Standard Compaction). Confirmatory compaction testing must be carried out at regular intervals. A minimum of two tests per vertical lift is recommended where structural fill heights are to exceed 300 mm. It is recommended that fill earthworks be carried out and certified to Level 1 Standards in accordance with AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments*.

It is recommended that any imported fill material be cohesive in nature and have material properties complying with the following:

- Soaked CBR > 10%
- Plasticity Index < 15%
- Shrink-swell index ≤ 1%
- Maximum particle size < 75 mm

It should be noted that the placement of fill can affect the characteristic ground surface movement and the site classification should be reviewed following the completion of earthworks.

Fill batters (if required) are to be over-filled by 0.5 m (horizontally) and then trimmed back to the well compacted material. Permanent cut batters in stiff clay (or stiffer) or weathered rock, and batters in compacted fill should be formed no steeper than 1V:2H. Where insufficient space prevents such battering, cuts will need to be supported by a retaining wall. Permanent soil or fill batters will require erosion protection (e.g. revegetation or surface protection).

4.2 Retaining Structures

Retaining structures must be founded as described in Section 4.3 below. Retaining structures greater than 1 m high (such as those proposed for the garage and driveway) will require engineer design and certification of construction. We suggest the following parameters may be adopted for retaining wall design.

Table 3: Retaining Wall Design Parameters

Retained material	Unit weight (kN/m^3)	Friction angle (Degrees)	Lateral earth pressure coefficients		
			K_a (Cantilever wall)	K_o (Non-yielding wall)	K_p
Very Stiff Clay (Natural)	19	30	0.33	0.50	3.00
Weathered rock	21	38	0.23	0.38	4.26
Future Fill	*	*	*	*	*

*Depends on type of fill used, and level/quality of compaction

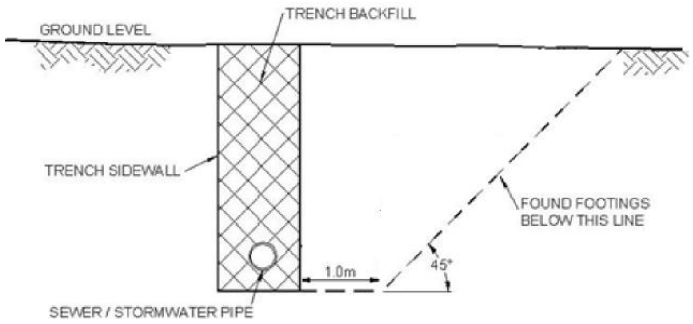
These parameters do not include allowance for surcharge above the wall, or additional loads imposed by sloping ground.

4.3 Footing Design

It is recommended that footings for the residence and proposed retaining walls penetrate through any fill and natural soil to be founded a minimum of 0.2 m into weathered rock. Therefore, founding depths of between 1.5 m and 2.3 m below existing ground level are anticipated based on the CQ borehole reports. Where fill is placed, footing depths from future ground levels will be greater. Bored piers are assessed to be a suitable footing type and for footings founded in weathered rock as recommended above, may be designed using an allowable end bearing capacity of 400 kPa.

Footing design should also account for the potential soil reactivity (assessed as a Class M site by CQ). It should be noted that the placement of fill can affect the characteristic ground surface movement and the site classification should be reviewed following the completion of earthworks.

All footings should found such that they are not adversely affected by any adjacent excavations, batter slopes, trenches, or retaining walls that are not designed to support building loads. Footings should found at least below a plane extending 1 m horizontally from the base of trenches/batter slopes/excavations/retaining walls, then rising up at 1V:1H, as illustrated in Text Figure 8.



Text Figure 8: Footing depth required to prevent undermining

Footing bases must be cleaned following mechanical excavation to expose undisturbed materials over the full base area. A suitably qualified and experienced engineer should inspect the footing excavations to confirm appropriate foundation materials and cleanliness prior to pouring concrete.

If any ground conditions encountered during construction are found to differ from those noted above, Tectonic and CQ must be notified immediately and an inspection carried out to determine if changes to footing design are required.

4.4 Drainage

Surface diversion drainage must be constructed upslope (western side) of the proposed residence, and above the crest of any cut or fill embankments and retaining walls (e.g. grassed or landscaped swales or diversion mounds). Grated channel drains are recommended across the driveway to intercept any runoff flowing towards the house. Adequate site drainage must be installed to ensure that stormwater is directed away from building walls and footings, and is not allowed to flow over any fill batters in an uncontrolled fashion (e.g. as overflow run-off from roof gutters).

Subsurface drainage must be installed behind any retaining walls in order to prevent the development of hydrostatic pressure (e.g. slotted 'aggi' pipe wrapped in filter 'sock' placed in gravel backfill).

All excess surface water collected around the residence (including overflow from rainwater tanks) should be directed to the council stormwater system.

Subsurface disposal of stormwater must not be undertaken (including infiltration pits).

5.0 SUMMARY & CONCLUSIONS

Based on the findings of our assessment we consider, from a geotechnical viewpoint, that the site is suitable for the proposed development and that there should be a Low Risk of slope instability. This advice is subject to implementation of the recommendations given in this report, in particular:

- Filling in the garage and driveway footprint does not exceed the proposed height of 2.6 m unless assessed and approved by a geotechnical engineer. In other areas of the site fill heights should be limited to no more than 1 m.
- Sloping ground in proposed fill areas must be benched to 'key in' fill material to the slope.
- Supporting the residence and retaining walls on bored piers taken at least 0.2 m into weathered rock (estimated founding depth 1.5 m to 2.3 m below existing ground level).
- Retaining structures greater than 1 m high (such as those proposed for the garage and driveway) will require engineer design and certification of construction
- Surface diversion drainage must be constructed upslope (western side) of the proposed residence and collected surface water or tank overflow water is to be directed to the council stormwater system. Subsurface disposal of stormwater must not be undertaken (including infiltration pits).

6.0 LIMITATIONS

Your attention is drawn to the document Limitations, which is attached to this letter report.

Please contact the undersigned should you wish to discuss any of the above matters.

Yours faithfully

TECTONIC GEOTECHNICAL PTY LTD

Scott Davis BEng CPEng RPEQ 16439
Senior Geotechnical Engineer

Ashley Davey BEng (Geological) RPEQ 8159
Director/Principal Geotechnical Engineer

Attachments: CQ Report CQ15065, dated 29/3/18
Qualitative Terminology for Use in Assessing Risk to Property
Some Guidelines for Hillside Construction
Limitations

Geotechnical Testing and Borehole Logs

CLIENT: **N Edwards**

SITE ADDRESS: **Lot 9 (SP176990)**
15 kilkenny Court, Kawana

JOB NUMBER: **CQ15065**

ISSUE DATE: **29/03/2018**

BH1

Project name	Lot 9 Kilkenny Court, Kawana
Client	N Edwards
Date drilled	29/03/2018
Driller	Scott Walton
Method	Solid Auger
Logged by	Scott Walton
Notes	Slope Stability

Depth (m)	Visual Class'n Symbol	Visual Description of Material	Sample
0.0 0.3	SC	Gravelly Clayey SAND, fine to coarse grained, low plasticity fines, brown, D, D.	
0.3 0.7	CH	CLAY, high plasticity, with fine to coarse grained sand, reddish brown, M, VST.	
0 .7 2.0	CI	Sandy CLAY, medium plasticity, fine to coarse grained, brown, D-M w/depth, VST-H w/depth.	
2.0 2.1	GC/XW	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, VD. **Weathered rock**	

Tungsten carbide bit refusal at 2.1 m

Classification tests:
0.4 –0.7 m

% Passing 75 um	ND
Natural MC%	20
Liquid Limit	ND
Plastic Index	ND
Iss	3.2
Emerson Class	ND

Test Methods:
AS 1289 2.1.1, 3.1.1, 3.1.2, 3.3.1, 3.3.2, 3.4.1, 3.6.1, 3.8.1, 3.9.1, 3.9.2: Moisture content (oven drying); liquid limit (Casagrande); plastic limit; plasticity index; cone plasticity index; linear shrinkage; sieve analysis; Emerson class number

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	

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.

DCP TEST RESULTS

Depth (mm)	DCP Blows/100mm Dynamic Cone	DCP Blows/100mm Perth SAND
100	8	200
200	9	250
300	10	250
400	Drill	
500	Drill	
600	Drill	
700	7	200
800	8	200
900	9	250
1000	12	250
1100	Drill	
1200	Drill	
1300	Drill	
1400	10	250
1500	>13	>300
1600		
1700		
1800		
1900		
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2100		
2200		
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3300		
3400		
3500		
3600		
3700		
3800		
3900		
4000		
4100		
4200		
4300		
4400		
4500		
4600		
4700		
4800		
4900		
5000		

BH2

Project name	Lot 9 Kilkenny Court, Kawana
Client	N Edwards
Date drilled	29/03/2018
Driller	Scott Walton
Method	Solid Auger
Logged by	Scott Walton
Notes	Slope Stability

Depth (m)	Visual Class'n Symbol	Visual Description of Material	Sample
0.0 0.2	SC	Gravelly Clayey SAND, fine to coarse grained, low plasticity fines, brown, D, D.	
0.2 0.4	CH	CLAY, high plasticity, with fine to coarse grained sand, reddish brown, M, VST.	
0.4 1.2	CI	Sandy CLAY, medium plasticity, fine to coarse grained, brown, D-M w/depth, VST-H w/depth.	
1.2 1.3	GC/XW	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, VD. **Weathered rock**	

Tungsten carbide bit refusal at 1.3 m

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	

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DCP TEST RESULTS

Depth (mm)	DCP Blows/100mm Dynamic Cone	DCP Blows/100mm Perth SAND
100	Drill	
200	Drill	
300	8	200
400	9	250
500	9	250
600	9	250
700	Drill	
800	Drill	
900	13	300
1000	13	300
1100	13	300
1200	>15	>300
1300		
1400		
1500		
1600		
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3400		
3500		
3600		
3700		
3800		
3900		
4000		
4100		
4200		
4300		
4400		
4500		
4600		
4700		
4800		
4900		
5000		

BH3

Project name	Lot 9 Kilkenny Court, Kawana
Client	N Edwards
Date drilled	29/03/2018
Driller	Scott Walton
Method	Solid Auger
Logged by	Scott Walton
Notes	Slope Stability

Depth (m)	Visual Class'n Symbol	Visual Description of Material	Sample
0.0 0.6	SC	Gravelly Clayey SAND, fine to coarse grained, low plasticity fines, brown, M, D.	
0.6 1.6	CI	Gravelly Sandy CLAY, medium plasticity, fine to coarse grained, reddish brown, M, VST.	
1.6 1.7	GC/XW	Clayey Sandy GRAVEL, fine to coarse grained, low plasticity fines, yellowish brown, D, VD. **Weathered rock**	

Tungsten carbide bit refusal at 1.7 m

Classification tests:
0.6 –1.0 m

% Passing 75 um	57
Natural MC%	11
Liquid Limit	46
Plastic Index	19
lss	ND
Emerson Class	ND

Test Methods:
AS 1289 2.1.1, 3.1.1, 3.1.2, 3.3.1, 3.3.2, 3.4.1, 3.6.1, 3.8.1, 3.9.1, 3.9.2: Moisture content (oven drying); liquid limit (Casagrande); plastic limit; plasticity index; cone plasticity index; linear shrinkage; sieve analysis; Emerson class number

MOISTURE CONDITION	CONSISTENCY	RELATIVE DENSITY
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M – Moist	S – Soft	L – Loose
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	H – Hard	

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DCP TEST RESULTS

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500	7	200
600	9	250
700	Drill	
800	Drill	
900	Drill	
1000	Drill	
1100	10	250
1200	>14	>300
1300	Drill	
1400	Drill	
1500	13	300
1600	>15	>300
1700		
1800		
1900		
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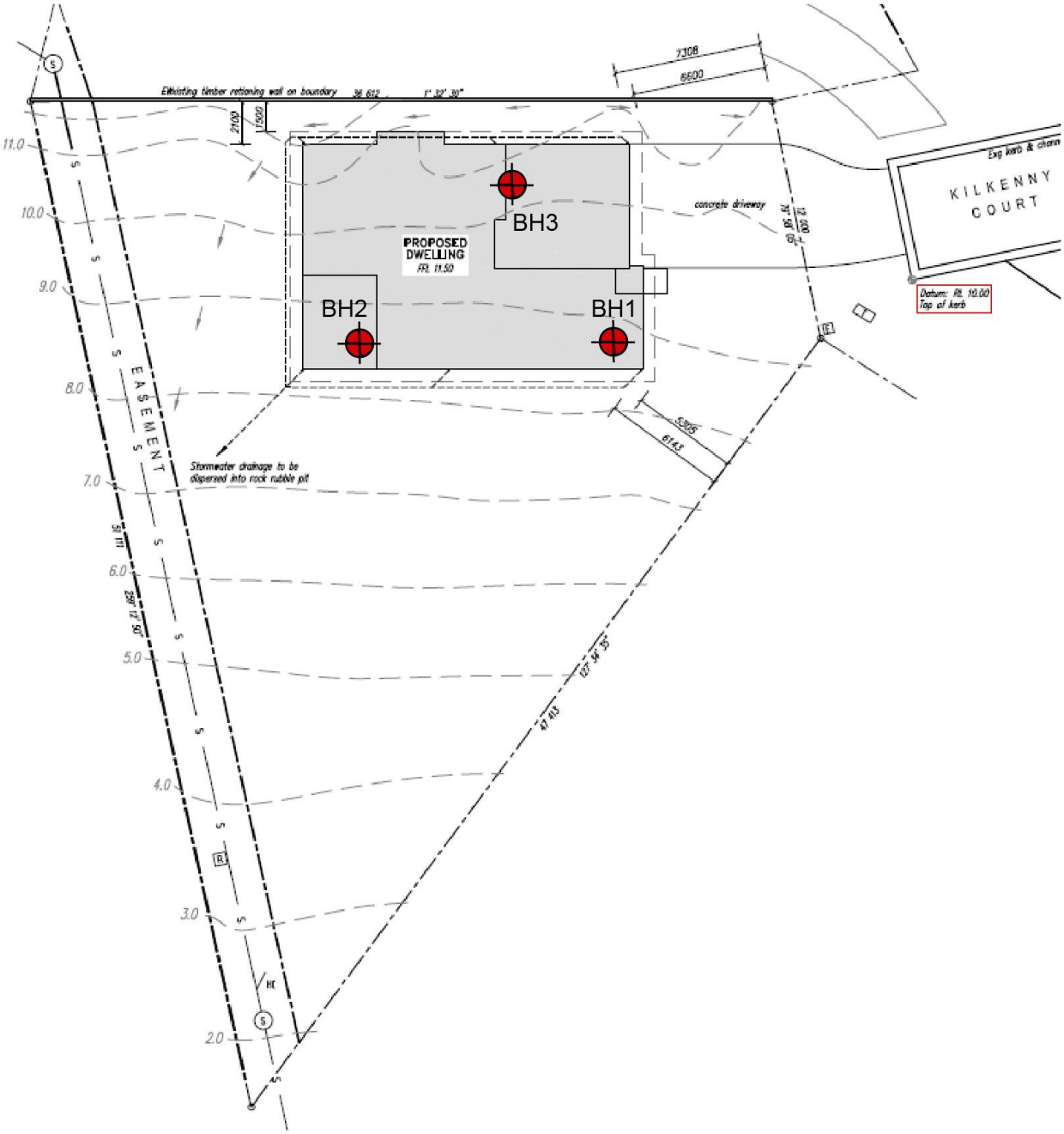
7308
6600
Exg kerb & chann
KILKENNY
COURT
Datum: RL 10.00
Top of kerb
BH3
PROPOSED
DWELLING
FFL 11.50
BH2
BH1
concrete driveway
EASEMENT
Stormwater drainage to be
dispersed into rock rubble pit
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

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

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

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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

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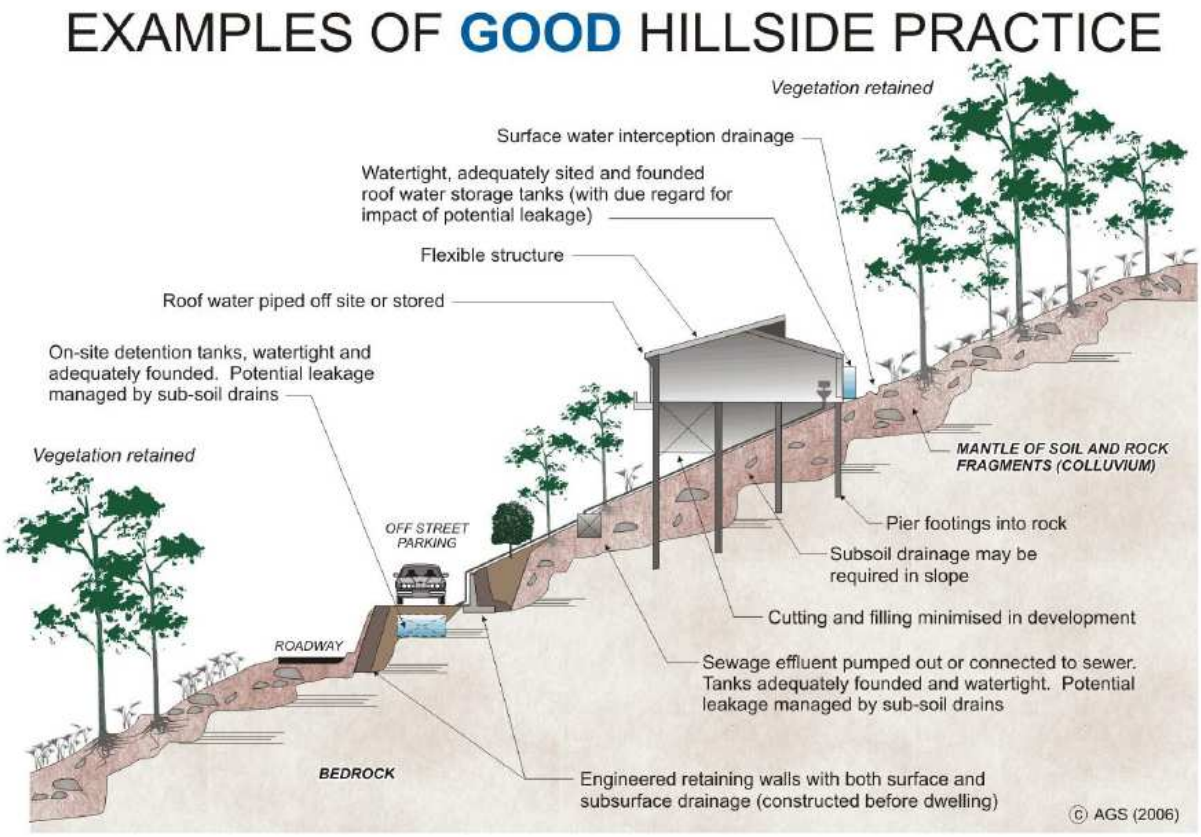
EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
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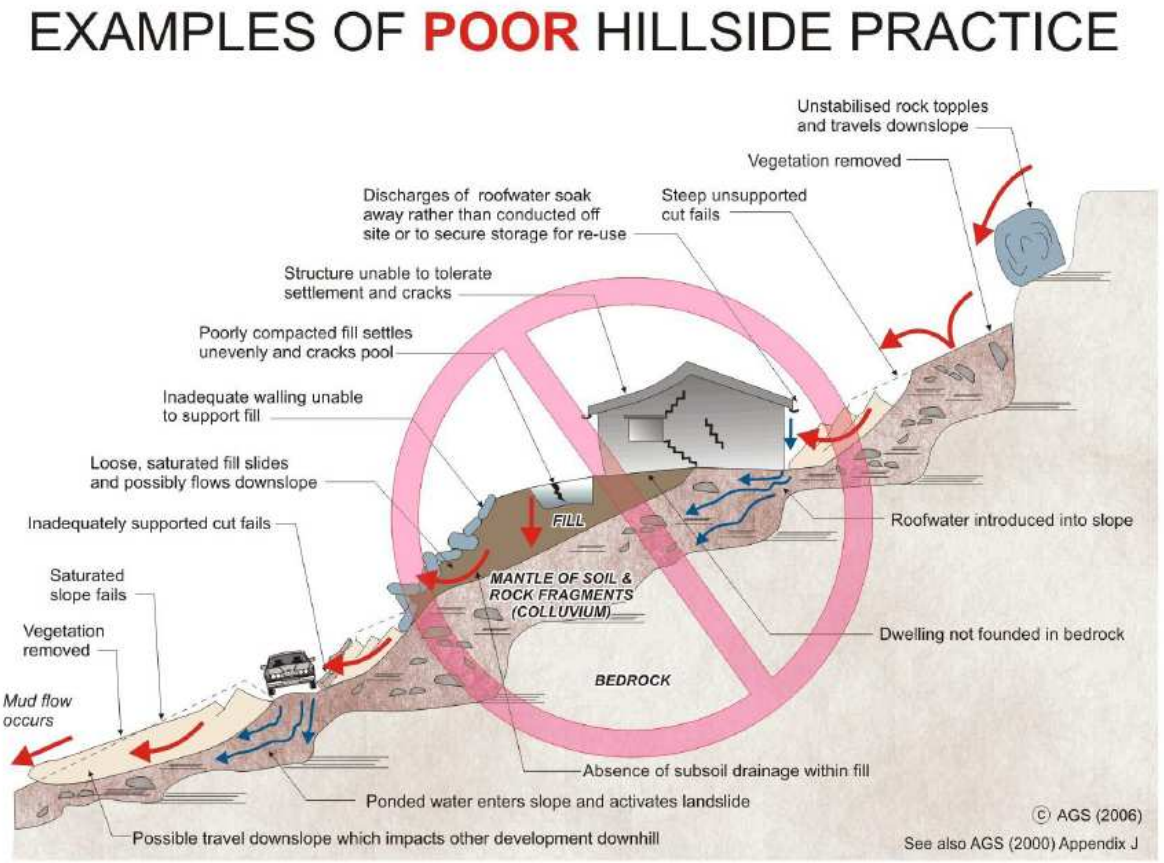
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
Inadequately supported cut fails
FILL
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
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See also AGS (2000) Appendix J

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