Slope Risk Assessment

Proposed Subdivision - 18 Winterlake Road, Warners Bay

CGS2708

Prepared for
David Hardy

July 2015

Cardno
Geotech Solutions
Shaping the Future

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Document Information

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1 Introduction

This report presents the results of a geotechnical investigation undertaken by Cardno Geotech Solutions (Cardno) on the proposed subdivision of 18 Winterlake Road in Warners Bay (Lot 350 DP 776503).

Two preliminary lot layout concepts were provided by the client indicating that 12 to 14 residential lots are to be created. The two concepts are similar in that an access road would be constructed in the lower portion of the site with building envelopes situated adjacent to the access road. Arbitrary lot numbers were assigned to the 14 lot layout which was used as a base map to record observations for this study.

The conceptual lot layouts supplied do not detail civil design, however, it is anticipated that some cut and fill earthworks will be required to achieve suitable road grade and lot elevations. The proposed development options are illustrated on the drawings attached in Appendix A.

The objective of this investigation has been to:

> Provide a Landslide Risk Assessment in general accordance with AGS2007c guidelines;

> assess the subsurface conditions in the area of the proposed future residences; and

> provide general guidelines for future earthworks.

The work was conducted at the request of Michael Wratten under the terms of our proposal dated 29 May 2015.

2 Site Description

Location - The site is situated on the east flank of a north-south trending ridgeline and is located northwest of the terminus of Winterlake Road in Warners Bay, NSW. The site is accessed from a gate on the west side of a private driveway that ascends from Winterlake Road. The driveway provides access to one residence in the northeast corner of the property and three residences located east of the property.

Vegetation - Portions of the site have been cleared, while portions remained densely covered with mature trees. The site location and extent of clearing is illustrated in Figure 1 overleaf.

Topography - Based on available ground contours (Drawing 1, Appendix A) elevations within the site boundaries range between approximately RL 90m AHD in the south west corner to approximately RL 36m AHD in the southeast corner. The overall slope angel within the site is approximately 12°, however slope angles were measured locally at up to 24°. Steeper ground gradients of up to approximately 60° were locally noted within the two gullies that traverse the site. The ground rises sharply west of the site at approximately 45° to the axis of the ridgeline which is located approximately 60m west of the western site boundary.

Drainage - Drainage within the site is generally by sheet flow into two gullies, the northern gully draining southward toward Winterlake Drive and the southern gully draining generally eastward across Lots 1 and 2 toward the adjacent property to the south. The flanks of the gullies were measured at up to approximately 60°. Evidence of old soil slips and soil creep was observed in both of the gullies including old scarps and tree trunk bowing.

Past Activities - Evidence of past cut-fill earthworks is present in several areas around the site, the cleared area in particular where several indistinct terraces have been formed. A heavily overgrown vehicle track crosses the west portion of the site from northeast to southwest generally parallel to the steep ridge west of the property.

Instability - Other than within the steep sided gullies, no indication of past slope instability was observed within or adjacent to the site. No rubbish or evidence of contamination was observed during the site visit.

Adjacent Property - The ridge west of the site is heavily wooded with occasional outcrops of sandstone. Property to the north and south is vacant, and property east of the site supports semi-rural residential development along Winterlake Road and Chelston Street.

Figure 1: Site location, courtesy of Six Maps (maps.six.nsw.gov.au). Approximate location of the two drainage gullies is indicated with blue arrows.

3 Investigation Methodology

Field investigation was undertaken on 25th of June 2015 comprising reconnaissance mapping, excavation of two hand auger boreholes (HA01 and HA02) and two Dynamic Cone Penetrometer (DCP) tests adjacent to the boreholes. The maximum depth of excavation with the 50mm hand auger was 1.4m below the surface. The hand auger locations and salient site features were set out and recorded with reference to site features, and the approximate locations are shown on Drawing 2 attached in Appendix A.

4 Findings

4.1 Published Data

The Newcastle Coalfield Regional Geology Map [1] indicates that the site is underlain by rocks of the Moon Island Beach Subgroup of the Newcastle Coal Measures which typically comprises conglomerate, sandstone, siltstone, tuff and coal.

The Lake Macquarie Property Enquiry website [2] indicates that the site is located within Geotechnical Zones T1, T2 and T3 and is within a mine subsidence district. Geotechnical Zones are defined in the Lake Macquarie Geotechnical Engineering Policy [3] as follows:

> "Slopes greater than 15°, or equal to with known coal seams and/or tuffaceous claystones present shall be zoned T1.

> Slopes greater than 15°, or equal to without known coal seams and/or tuffaceous claystones present shall be zoned T2.

> Slopes greater than 5° or equal to but less than 15°, with known coal seams and/or tuffaceous claystones present shall be zoned T3."

4.2 Observations

In addition to the general observations summarised in Section 2, the following observations have been considered a as part of the assessment:

4.2.1 Uncontrolled Fill

Evidence of past earthworks is evident in several locations. It appears that efforts were made at some time in the past to create relatively level pads in at several locations within the site. Filling has encroached into the south gully creating batters locally as steep as 60°. Additionally, the north gully has been partly infilled with an embankment fill over drainage pipes to create vehicle access to the west part of the site. The approximate locations of fill deposits are indicated on Drawing 2 in Appendix A.

In the absence of an engineer's certification, the fill is considered to be 'uncontrolled' and is not deemed suitable for support of structures.

4.2.2 Instability

No evidence of large scale slip or instability was observed on site. Ground undulations in the cleared areas are deemed to be the result of past earthworks.

Surficial slips and evidence of ongoing soil creep were noted in both of the steep sided gullies. The slip in the south gully appears to involve natural soils and uncontrolled fill that has been tipped into the gully. The slip in the north gully involves colluvial soils. The instability appears to be confined to the gullies, and no scarps, tension cracks, or disturbed ground that could not be attributed to past earthworks were noted outside the gully areas.

Both of these slips are located predominantly out of the proposed building envelope area. The slip in the northern gully is located approximately 50m northwest of Lot 13, and is not deemed to pose a hazard to future development. The slip in the south gully shall be entirely removed as unsuitable soil as a part of the gully filling operation that is anticipated. After filling, the slip in the south gully would have no impact on future development.

4.2.3 Gullies

Both gullies were carrying a small flow of surface water at the time of the site investigation. Within Lot 13, north of the infilling, the gully contains sandy / gravelly alluvium infill. Boggy conditions were noted upstream of the filled area.

In addition to uncontrolled fill, the gullies can be expected to contain wet, loose/soft unsuitable natural material that will need to be removed prior to filling. It is anticipated that filling along with appropriate drainage infrastructure will be required to achieve road and lot design elevations.

4.3 Subsurface Conditions

Two hand auger borings were conducted in the locations indicated on Drawing 2 in Appendix A. The conditions encountered in BH01 to the depth investigated comprise topsoil overlying CLAY with Silt and traces of siltstone fragments. Fill comprising CLAY with rounded to angular rock fragments up to approximately 20mm in diameter was encountered in BH02. No indications of contaminated or foreign material was observed in the fill materials.

Engineering logs of the borings are included in Appendix B.

4.4 Mine Subsidence

The site is located in a mine subsidence district. The mine Subsidence Board (MSB) reports that although the site has been undermined at depth, it is approved for construction of 2 story brick veneer residential structures with standard footings.

5 Slope / Landslide Risk Assessment

5.1 General

The terms 'hazard' and 'risk' are often misused and are not interchangeable. A hazard is a condition with the potential for causing an undesirable consequence. A particular hazard may be severe, but it may or may not pose a high risk.

Risk is the measure of the probability and the severity of an adverse effect (undesirable consequence) to health, property or environment *from a hazard.* Risk level is estimated by combining likelihood of occurrence with severity of consequences.

In other words, a hazard that could result in major consequences but is very unlikely to occur results in a relatively low risk, and a minor hazard that is almost certain to occur results in a high risk: A minor hazard can be a greater risk than a major hazard.

Risk assessment involves the identification and assessment of hazards, assessment of the likelihood of those hazards impacting the elements at risk, and assessing the potential consequence to the elements at risk. When the element of risk is a person, the likelihood that a person will be present at the time of occurrence is also considered.

Landslide risk assessment addresses not only landslides, but also the hazards of rockfall, rock topple, debris flow, debris avalanche, earthflow, creep and lateral spread. For the purpose of discussion the term 'landslide' includes any or all of the above terms in this report.

In general, risk for a particular hazard is assessed in consideration of the likelihood of occurrence combined with the severity and the consequence of the event occurring.

5.2 Methodology

The risk assessment procedure adopted herein is in general accordance with AGS 2007c [4]. The AGS Guidelines outline an approach that includes a qualitative risk assessment for risk to property and a 'semi-quantitative' assessment for risk to persons.

A detailed semi-quantitative assessment for risk to persons from a landslide event is not in this instance deemed necessary for the proposed residential development in that control measures implemented during earthworks will be implemented during design and construction of the subdivision and the future residences to reduce risk to property to 'low' or 'very low'. A low risk to property with respect to landslide will in most cases result in an environment with a low risk to persons.

For the purposes of this study, it has been assumed that a person would be present in the proposed dwelling at the time of a landslide event, and it has been assumed that the elements at risk are the future residential structures and persons within them.

Likelihood of Occurrence is estimated based on the probability of detachment combined with the probability that the detached object / material, once mobilised, will reach or affect the element at risk. The likelihood of occurrence has been inferred based on observed site conditions and past experience in the area.

The qualitative level of risk to property resulting from a landslide event is based on a measure of the likelihood of occurrence (Table 5-1) combined with the consequence to property (Table 5-2).

Likelihood and consequence are combined in the matrix shown in Table 5-3, resulting in risk level that can range from very low (VL) to very high (VH). The standard definition of the risk levels from AGS 2007c are presented in Table 5-4.

The results of the risk to property assessment for each identified hazard after implementation of engineering controls are presented in Table 5-5.

5.3 Hazard and Associated Risk

Hazards are defined in AGS 2007c [5] as, "A condition with the potential for causing an undesirable consequence."

Potential hazards within and surrounding the proposed subdivision have been considered in the risk assessment. Conditions that may result in minor / nuisance erosion are not addressed in this report.

5.3.1 Slip

Translational or rotational slips could occur in the natural surficial soil and in uncontrolled fill batters present at various locations around the site. Slips involve a mass of soil that remains relatively coherent as it moves relatively slowly downslope (in contrast to debris flows which are quite rapid). Slips can impact a structure from above or can undermine a poorly constructed structure. The potential for slips increases after periods of prolonged heavy rainfall.

It is considered 'unlikely' that the building envelopes that have been designed and constructed in accordance with normal hillside practice could be impacted from slips of natural soils.

Typical control measures would include one or more of the following:

> Remedial earthworks to remove small slips present in the gullies prior to filling;

> Managing / redirecting surface drainage from above the building envelopes through use of appropriately designed and constructed cut-off drains or similar;

> Controlling surficial drainage within the lots, including installation of roof gutters;

> Founding structures in controlled fill or beneath the surficial soils into rock; and

> Incorporating retaining structures as elements of the footing system for future structures.

Control measures should be based on site-specific geotechnical advice addressing the proposed development when conceptual civil plans are available.

The consequences of a shallow slip is assessed as potentially 'medium', and with a likelihood of occurrence of 'unlikely', therefore the resultant risk of a shallow soil slip to appropriately designed and constructed future structures on the lots and to persons within is assessed as Low.

5.3.2 Creep

Creep is the imperceptibly slow down-slope movement of soils as a result of cyclic expansion and contraction due to periodic moisture change under the influence of gravity. Steep natural slopes or poorly constructed fill batters can be affected by creep. Creep affected soils can cause progressive damage to poorly designed and constructed structures.

Indications of soil creep include misaligned fences, walkways or walls, tilted vertical structures (telephone poles) and bowed tree trunks. Tree trunks that are consistently bowed downslope are a strong indicator of active soil creep.

Other than within the confines of the gullies, trunk bowing is not widely apparent over the natural slopes within the propped building envelopes, suggesting that the rate of natural soil creep is minimal under the current conditions.

The elements most at risk from creep in natural soils include building envelopes situated on natural ground steeper than approximately 15°. The existing ground angle was measured rangining from 15° to 24° in the western portion of Lots 4 and 5 and in the northern portion of Lot 13 it was measured at 17°.

It is deemed 'unlikely' that well-designed, constructed and maintained future structures will be affected by soil creep provided that appropriate control measures are incorporated into the design and construction. Control measures for soil creep would be similar to those outlined in Section 5.3.1 for slips.

With a likelihood of 'rare' to 'unlikely' and with a 'minor' consequence due to creep to appropriate designed and constructed structures, the risk from creep is assessed as Low to Very Low.

5.3.3 Slip, Creep or Settlement of Uncontrolled Fill

It is considered 'likely' that slips, settlement or creep of the existing uncontrolled fill will affect the proposed building envelopes resulting in 'medium' consequences unless remediated.

The likelihood of uncontrolled fill impacting the future lots could be reduced to 'rare' or 'barely credible' by removing the existing uncontrolled fill from the area within or near the proposed building envelopes. Once existing fill is removed, the risk of slip, creep or settlement of uncontrolled fill to future structures on the lots and persons within is assed as Low.

Table 5-1 Qualitative Measures of Likelihood

Level	Descriptor	Description	Approximate Annual Probability
A	ALMOST CERTAIN	The event is expected to occur over the design life	10^{-1}
B	LIKELY	The event will probably occur under adverse conditions over the design life	10^{-2}
C	POSSIBLE	The event could occur under adverse conditions over the design life	10^{-3}
D	UNLIKELY	The event might occur under very adverse circumstances over the design life	10^{-4}
E	RARE	The event is conceivable but only under exceptional circumstances over the design life	10^{-5}
F	BARELY CREDIBLE	The event is inconceivable or fanciful over the design life	10^{-6}

Table 5-2 Qualitative Measures of Consequences to Property

Level	Descriptor	Description
1	CATASTROPHIC	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.
2	MAJOR	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.
3	MEDIUM	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.
4	MINOR	Limited damage to part of structure, and/or part of site requiring reinstatement stabilisation works.
5	INSIGNIFICANT	Little damage.

Table 5-3 Qualitative Risk Analysis Matrix

Likelihood		Consequence to Property				
	Approx. Annual Probability	1: Catastrophic	2: Major	3: Medium	4: Minor	5: Insignificant
A – Almost Certain	10^{-1}	VH	VH	VH	H	M / L
B - Likely	10^{-2}	VH	VH	H	M	L
C - Possible	10^{-3}	VH	H	M	M	L
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

Table 5-4 Risk Level Implications

Risk Level		Example Implications
VH	Very High	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 will likely cost more than the value of the property
H	High	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	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce risk to Low.
L	Low	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	Very Low	Acceptable. Manage by normal slope maintenance procedures.

Table 5-5 Results of Qualitative Assessment of Risk to Property

Potential Hazard	Elements at Risk	Possible Engineering Controls to Reduce Risk[1]	With Engineering Controls		
			Consequence	Likelihood of Occurrence[2]	Qualitative Risk
Slip in natural soils impacting lots from above	All Lots	None Required, however the condition of the slopes above the proposed lots should be visibly monitored for any sign of change.	Medium	Unlikely	LOW
Slip in natural soils undermining lots	All Lots	Geotechnical investigation and design recommendations specific to the proposed development are required. Control irrigation and surface drainage. Found structures into rock or as recommended by the project geotechnical engineer. Incorporate retaining structures into footing design. Found structures on cut platforms and minimise filling on the Lots.	Medium	Unlikely	LOW
Creep in natural soils	Lot 4, 5 and 13	Geotechnical investigation and design recommendations specific to the proposed development are required. Control irrigation and surface drainage. Found structures into controlled fill or rock or as recommended by the project geotechnical engineer. Incorporate retaining structures into footing design. Found structures on cut platforms and minimise filling on the Lots.	Minor	Unlikely	LOW
Creep in Natural Soils	Lots 1-3, 6-12 and 14	None required; however, implementation of the above measures is considered applicable.	Minor	Rare	VERY LOW
Slip, creep or settlement of uncontrolled fill	Lots 1, 2, 9-12	Remove and replace if necessary all uncontrolled fill within or adjacent to the proposed building envelopes.	Medium	Rare	LOW

Notes:

1. The likelihood of occurrence has been inferred based on past experience in the area and site specific observations.
2. Control measures, if required, should be designed based on the specific development concept. Alternate control measures or a combination of control measures are possible to mitigate elevated risk.

6 Conclusions

Field investigation comprising a walkover inspection and excavation of hand auger boreholes and DCP testing has revealed a subsurface profile comprising clayey natural soils and fill to the depth investigated.

Groundwater was not encountered in the hand auger holes, however minor surface flow was observed in both gullies on the site.

No large scale instability was observed within or adjacent to the site. Ground undulations visible in the cleared areas within the site are deemed to be the result of past earthworks.

Old slips and evidence of creep were observed within the two gullies that cross the site, but the gullies will be filled (along with appropriately designed drainage infrastructure) to achieve design elevations. Slips and unsuitable soils in the gullies shall be remediated as a part of normal hillside earthwork practice.

The risk from landslide, including slips and creep, within or adjacent to the subject property is assessed to be low with respect to property and life provided that normal earthworks practice for implementation of hillside residential development is undertaken.

The site has been undermined at depth, however the MSB indicates that the site is suitable for two story brick veneer residential structures on conventional footings without remedial works.

The proposed development will not negatively impact the stability of adjacent property.

7 Recommendations

7.1 Uncontrolled Fill

Uncontrolled fill is not suitable for support of structures, and presents an elevated risk to future structures from slip, creep and settlement. All uncontrolled fill within the future building envelopes shall be removed and replaced with controlled fill.

The uncontrolled fill material may be re-used to create controlled fill unless it is found to contain contaminated material, organics, rubbish or other deleterious material.

7.2 Filling and Earthworks

Any filling required should be placed, compacted and documented in accordance with AS 3798-2007, *Guidelines on Earthworks for Commercial and Residential Development* [6] and the following general guidelines.

Construction of a suitable fill platform to support structural loads such as street subgrade, footings, slabs, etc. would include the following:

> Removal of any existing uncontrolled fill, topsoil, existing structures (including subsurface structures), deleterious or over wet soils from areas where fill is to be placed. A bridging layer may be required if wet conditions are encountered in the subgrade.

> Benching of the exposed subgrade on slopes in the area where fill is to be placed if slopes are steeper than 8H:1V or approximately 7°.

> Removing all unsuitable material from the gullies including wet alluvium, uncontrolled fill or slip debris.

> Refilling all cavities resulting from removal of trees or removed structures with controlled fill.

> Proof rolling of the exposed subgrade in the presence of a geotechnical consultant to detect any weak or deforming areas of subgrade that shall be excavated and replaced with compacted fill.

> Placement of fill in horizontal layers with compaction of each layer to a minimum dry density ratio of 95% Standard Compaction (Australian Standard AS 1289 Clause 5.1.1) at moisture contents of 85 - 115% of Standard Optimum Moisture Content (SOMC).

Care is required to ensure that compaction is achieved over the entire fill area, particularly adjacent to any vertical excavated faces. This will require benching to allow compaction equipment to achieve full compaction to the edge. Alternately, the use of hand compaction equipment may be required. Fill shall be fully compacted to the batter face; overfilling and trimming back is recommended.

All fill should be supported by properly designed and constructed retaining walls or else battered at a slope of 2H:1V or flatter and protected against erosion by vegetation and the provision of adequate drainage.

Materials excavated on-site with the exception of topsoil and other deleterious materials are considered suitable for re-use as engineering fill.

If imported materials are required, it is recommended that material of reactivity similar to that of the site materials is utilised to avoid increasing the characteristic surface movement and detrimentally affecting the site classification. Low reactivity material with an $I_{ss} \leq 1.0\%$ should be sourced if imported fill is required.

Earthwork guidelines should be specific to the civil design when it becomes available.

7.3 Hillside Construction and Slope Monitoring

Future development on sloping ground should be undertaken with the usual design considerations and construction practices typical of hillside construction. Examples of good hillside construction practices are summarised in Australian Geoguide LR8 [7] included as Appendix C of this report. A qualified geotechnical consultant shall provide recommendations specific to proposed structures for each hillside allotment.

CGS recommends that the slopes are visually monitored annually or after major storm events by the future homeowners for any indications of change. Should the condition of a slope change in any way, a qualified geotechnical consultant should inspect the slopes without delay.

7.4 Site Specific Investigation

This report is not intended to replace a geotechnical investigation or site classification specific to future development concepts. Site-specific geotechnical assessment and site classification is required for all lots.

7.5 Risk Reduction Measures

Engineering controls will be required to reduce the risk to tolerable levels for future structures on several building envelopes within the proposed subdivision as summarised in Table 5-5. The suggested measures are preliminary and are not intended to form an exhaustive or exclusive list of remedial options for potential debris flow, slip or creep. Other remedial options are possible and may be more applicable for a given future development concept.

8 Limitations

Cardno Geotech Solutions (CGS) has performed investigation and consulting services for this project in general accordance with current professional and industry standards. The extent of testing and observation was limited to discrete locations and variations in ground conditions can occur between test locations that cannot be inferred or predicted.

A geotechnical consultant or qualified engineer shall provide additional investigation specific to the finalised civil design and shall provide inspections during construction to confirm assumed conditions in this assessment. If subsurface conditions encountered during construction differ from those given in this report, further advice shall be sought without delay.

Cardno Geotech Solutions, or any other reputable consultant, cannot provide unqualified warranties nor does it assume any liability for the site conditions not observed or accessible during the investigations. Site conditions may also change subsequent to the investigations and assessment due to ongoing use.

This report and associated documentation was undertaken for the specific purpose described in the report and shall not be relied on for other purposes. This report was prepared solely for the use by David Hardy and any reliance assumed by other parties on this report shall be at such parties own risk.

References

[1] Newcastle Coalfield Regional Geology Map, "1:100,000 Geological Series Sheet 9231, and part of 9131, 9132 and 9232 (Edition 1)," Geological Survey of NSW, Department of Mineral Resources, 1995.

[2] LMCC, "Property Enquiry (website)," LMCC, 2014. [Online]. Available: http://apptracking.lakemac.com.au/modules/PropertyMaster/default.aspx.

[3] LakeMacquarie City Council, *Geotechnical Engineering Policy - Part 1, File reference 284/34.*

[4] AGS Landslide Taksforce, "Commentary on Practice Note Guidelines for Landslide Risk Management 2007," *Journal and News of the Australian Geomechanics Society,* vol. 47, no. 1, pp. 115-158, 2007d.

[5] Austraslian Geomechanics Society, "Practice Note Guidelines for Landslide Risk Management (c)," *Journal and News of hte Australian Geomechanics Society,* vol. 42, no. 1, pp. 63-158, 2007.

[6] Australian Standard AS3798-2007, "Guidelines on Earthworks for Commercial and Residential Structures," Standards Australia, 2007.

[7] Australian Geoguide LR8, "Hillside Construction Practice," Australian Geomechanics journal, Volume 42, No 1, March 2007.

Proposed Subdivision - 18 Winterlake Road, Warners Bay

APPENDIX

A

DRAWINGS

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Cardno Geotech Solutions, Shaping the Future	DRAWING TITLE: SITE LOCATION AND CONTOUR PLAN	CLIENT: Michael Wratten	DRAWN BY: AS	NORTH
	PROJECT NAME: PROPSOED SUBDIVISION	PROJECT NO: CGS2708	CHECKED BY: JD	
	SITE LOCATION: 18 WINTERLAKE DRIVE,WARNERS BAY	DRAWING NO: 1	DATE: 24 June 2015	
		FILE REF: CGS2708-002-d1	OFFICE: 4/5 Arunga Dr, Beresfield NSW 2322	

NOTES:

Drawing is not to scale

Drawing adapted from untitled image supplied by client.

Approximate hand auger locations and numbers

Red indicates approximate location of uncontrolled fill.

Purple denotes location of old vehicle track

Orange indicates approximate location of slips.

Cardno Geotech Solutions Shaping the Future	DRAWING TITLE: OBSERVATION SUMMARY AND BOREHOLE LOCATION PLAN PROJECT NAME: PROPOSED SUBDIVISION, 14 LOT OPTION SITE LOCATION: 18 WINTERLAKE, WARNERS BAY	CLIENT: Michael Wratten PROJECT NO: CGS2708 DRAWING NO: 1 FILE REF: CGS2708-002-d2	DRAWN BY: JD CHECKED BY: PB DATE: 24 July 2015 OFFICE: 4/5 Arunga Dr, Beresfield NSW 2322

NOTES:

Drawing is not to scale

Drawing adapted from untitled image supplied by the client.

Cardno Geotech Solutions Shaping the Future	DRAWING TITLE: 12 LOT OPTION PROJECT NAME: PROPOOSED SUBDIVISION SITE LOCATION: 18 WINTERLAKE, WARNERS BAY	CLIENT: Michael Wratten PROJECT NO: CGS2708 DRAWING NO: 3 FILE REF: CGS2708-002-d3
DRAWN BY: JD CHECKED BY: PB DATE: 24 July 2015 OFFICE: 4/5 Arunga Dr, Beresfield NSW 2322	NORTH	

Proposed Subdivision - 18 Winterlake Road, Warners Bay

APPENDIX

B

ENGINEERING LOGS

Cardno Geotech Solutions
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BOREHOLE LOG

CLIENT : *Michael Wratten*
PROJECT : *18 Winterlake Road*
LOCATION : *Warners Bay*

HOLE NO : HA01
PROJECT REF : CGS2708
SHEET : 1 OF 1

RIG TYPE : Hand Auger | METHOD : 50mm Hand Auger | CONTRACTOR : na | DRILLER :

DATE STARTED : 25/6/15 | DATE COMPLETED : 25/6/15 | DATE LOGGED : 25/6/15 | LOGGED BY : JD | CHECKED BY : PB

LOCATION : See Drawing for location

METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
	Not Encountered			0.0			Topsoil: Clayey SILT, low plasticity, dark grey.	M to W	S to F	
				0.20m			Residual Soil: CLAY with Silt, medium to high plasticity, grey mottled orange.	M	St	
							Trace of Siltstone fragments, angular, 2-4mm diameter.			
				1.0						
				1.40m			Borehole HA01 terminated at 1.40 m Refusal Possible bedrock			
				2.0						

WATER / MOISTURE	SAMPLES & FIELD TESTS	CONSISTENCY	RELATIVE DENSITY	ROCK STRENGTH	ROCK WEATHERING
D - Dry	U - Undisturbed Sample	VS - Very Soft	VL - Very Loose	EL - Extremely low	RS - Residual soil
M - Moist	D - Disturbed Sample	S - Soft	L - Loose	VL - Very low	XW - Extremely weathered
W - Wet	ES - Environmental sample	F - Firm	MD - Medium Dense	L - Low	DW - Distinctly weathered
OMC - Optimum MC	B - Bulk Disturbed Sample	St - Stiff	D - Dense	M - Medium	SW - Slightly weathered
PL - Plastic Limit	SPT - Standard Penetration Test	VSt - Very Stiff	VD - Very Dense	H - High	FR - Fresh rock
Water inflow	HP - Hand/Pocket Penetrometer	H - Hard		VH - Very high	
				EH - Extremely high	

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO GEOTECH SOLUTIONS

BOREHOLE LOG

CLIENT : Michael Wratten
PROJECT : 18 Winterlake Road
LOCATION : Warners Bay

HOLE NO : HA02
PROJECT REF : CGS2708
SHEET : 1 OF 1

RIG TYPE : Hand Auger	METHOD :	CONTRACTOR :	DRILLER :	
DATE STARTED : 25/6/15	DATE COMPLETED : 25/6/15	DATE LOGGED : 25/6/15	LOGGED BY : JD	CHECKED BY : PB

LOCATION : See Drawing for location

DRILLING					MATERIAL					
METHOD	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	RL (m)	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, plasticity or particle characteristic, colour Rock Type, grain size, colour Secondary and minor components	MOISTURE / WEATHERING	CONSISTENCY / REL DENSITY / ROCK STRENGTH	STRUCTURE & Other Observations
	Not Encountered			0.0			Topsoil: Silty CLAY, medium plasticity, dark grey.	W	L	
				0.10m			Fill: Clayey SILT / Silty CLAY, medium plasticity, dark grey, with rounded to angular rock fragments of varying compositon to 20mm diameter.	M to W	F	
				1.0						
				1.20m			Borehole HA02 terminated at 1.20 m Refusal Obstruction.			
				2.0						

WATER / MOISTURE	SAMPLES & FIELD TESTS	CONSISTENCY	RELATIVE DENSITY	ROCK STRENGTH	ROCK WEATHERING
D - Dry	U - Undisturbed Sample	VS - Very Soft	VL - Very Loose	EL - Extremely low	RS - Residual soil
M - Moist	D - Disturbed Sample	S - Soft	L - Loose	VL - Very low	XW - Extremely weathered
W - Wet	ES - Environmental sample	F - Firm	MD - Medium Dense	L - Low	DW - Distinctly weathered
OMC - Optimum MC	B - Bulk Disturbed Sample	St - Stiff	D - Dense	M - Medium	SW - Slightly weathered
PL - Plastic Limit	SPT - Standard Penetration Test	VSt - Very Stiff	VD - Very Dense	H - High	FR - Fresh rock
▶ Water inflow	HP - Hand/Pocket Penetrometer	H - Hard		VH - Very high	
				EH - Extremely high	

See Explanatory Notes for details of abbreviations & basis of descriptions.

CARDNO GEOTECH SOLUTIONS

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Explanatory Notes

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS1726-1993 Geotechnical Site Investigations. Material descriptions are deduced from field observation or engineering examination, and may be appended or confirmed by in situ or laboratory testing. The information is dependent on the scope of investigation, the extent of sampling and testing, and the inherent variability of the conditions encountered.

Subsurface investigation may be conducted by one or a combination of the following methods.

Method	
Test Pitting: excavation/trench	
BH	Backhoe bucket
EX	Excavator bucket
X	Existing excavation
Natural Exposure: existing natural rock or soil exposure	
Manual drilling: hand operated tools	
HA	Hand Auger
Continuous sample drilling	
PT	Push tube
Hammer drilling	
AH	Air hammer
AT	Air track
Spiral flight auger drilling	
AS	Large diameter short spiral auger
AD/V	Continuous spiral flight auger: V-Bit
AD/T	Continuous spiral flight auger: TC-Bit
Hollow flight auger drilling	
HFA	Continuous hollow flight auger
Rotary non-core drilling	
WS	Washbore (mud drilling)
RR	Rock roller
Rotary core drilling	
HQ	63mm diamond-tipped core barrel
NMLC	52mm diamond-tipped core barrel
NQ	47mm diamond-tipped core barrel
Concrete coring	
DT	Diatube

Sampling is conducted to facilitate further assessment of selected materials encountered.

Sampling method	
Disturbed sampling	
B	Bulk disturbed sample
D	Disturbed sample
ES	Environmental soil sample
Undisturbed sampling	
SPT	Standard Penetration Test sample
U	Thin wall tube 'undisturbed' sample
Water samples	
EW	Environmental water sample

Field testing may be conducted as a means of assessment of the in situ conditions of materials.

Field testing	
SPT	Standard Penetration Test (blows/150mm)
HP/PP	Hand/Pocket Penetrometer
Dynamic Penetrometers (generally blows/150mm)	
DCP	Dynamic Cone Penetrometer
PSP	Perth Sand Penetrometer
MC	Moisture Content
VS	Vane Shear
PBT	Plate Bearing Test
PID	Photo Ionization Detector

If encountered, refusal (R) or virtual refusal (VR) of SPT or dynamic penetrometers may be noted.

The quality of the rock can be assessed be the degree of fracturing and the following.

Rock quality description	
TCR	Total Core Recovery (%) (length of core recovered divided by the length of core run)
RQD	Rock Quality Designation (%) (sum of axial lengths of core greater than 100mm long divided by the length of core run)

Notes on groundwater conditions encountered may include.

Groundwater	
Not Encountered	Excavation is dry in the short term
Not Observed	Water level observation not possible
Seepage	Water seeping into hole
Inflow	Water flowing/flooding into hole

Perched groundwater may result in a misleading indication of the depth to the true water table. Groundwater levels are also likely to fluctuate with variations in climatic and site conditions.

Notes on the stability of excavations may include.

Excavation conditions	
Stable	No obvious/gross short term instability noted
Spalling	Material falling into excavation (minor/major)
Unstable	Collapse of the majority, or one or more face of the excavation

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Explanatory Notes: General Soil Description

The methods of description and classification of soils used in this report are based on Australian Standard AS1726-1993 Geotechnical Site Investigations. In practice, a material is described as a soil if it can be remoulded by hand in its field condition or in water. The dominant component is shown in upper case, with secondary components in lower case. In general descriptions cover: soil type, plasticity or particle size/shape, colour, strength or density, moisture and inclusions.

In general, soil types are classified according to the dominant particle on the basis of the following particle sizes.

Soil Classification		Particle Size
CLAY		< 0.002mm
SILT		0.002mm 0.075mm
SAND	fine	0.075mm to 0.2mm
	medium	0.2mm to 0.6mm
	coarse	0.6mm to 2.36mm
GRAVEL	fine	2.36mm to 6mm
	medium	6mm to 20mm
	coarse	20mm to 63mm
COBBLES		63mm to 200mm
BOULDERS		> 200mm

Soil types are qualified by the presence of minor components on the basis of field examination or the particle size distribution.

Description	Percentage of minor component
Trace	< 5% in coarse grained soils
	< 15% in fine grained soils
With	5% to 12% in coarse grained soils
	15% to 30% in fine grained soils

The strength of cohesive soils is classified by engineering assessment or field/laboratory testing as follows.

Strength	Symbol	Undrained shear strength
Very Soft	VS	< 12kPa
Soft	S	12kPa to 25kPa
Firm	F	25kPa to 50kPa
Stiff	St	50kPa to 100kPa
Very Stiff	VSt	100kPa to 200kPa
Hard	H	> 200kPa

Cohesionless soils are classified on the basis of relative density as follows.

Relative Density	Symbol	Density Index
Very Loose	VL	< 15%
Loose	L	15% to 35%
Medium Dense	MD	35% to 65%
Dense	D	65% to 85%
Very Dense	VD	> 85%

The moisture condition of soil is described by appearance and feel and may be described in relation to the Plastic Limit (PL) or Optimum Moisture Content (OMC).

Moisture condition and description	
Dry	Cohesive soils: hard, friable, dry of plastic limit. Granular soils: cohesionless and free-running
Moist	Cool feel and darkened colour: Cohesive soils can be moulded. Granular soils tend to cohere
Wet	Cool feel and darkened colour: Cohesive soils usually weakened and free water forms when handling. Granular soils tend to cohere

The plasticity of cohesive soils is defined as follows.

Plasticity	Liquid Limit
Low plasticity	≤ 35%
Medium plasticity	> 35% ≤ 50%
High plasticity	> 50%

The structure of the soil may be described as follows.

Zoning	Description
Layer	Continuous across exposure or sample
Lens	Discontinuous layer (lenticular shape)
Pocket	Irregular inclusion of different material

The structure of soil layers may include: defects such as softened zones, fissures, cracks, joints and root-holes; and coarse grained soils may be described as strongly or weakly cemented.

The soil origin may also be noted if possible to deduce.

Soil origin and description	
Fill	Man-made deposits or disturbed material
Topsoil	Material affected by roots and root fibres
Colluvial	Transported down slopes by gravity
Aeolian	Transported and deposited by wind
Alluvial	Deposited by rivers
Lacustrine	Deposited by lakes
Marine	Deposits in beaches, bays and estuaries
Residual	Developed on weathered rock

The origin of the soil generally cannot be deduced on the appearance of the material only and may be determined based on further geological evidence or other field observation.

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Explanatory Notes: General Rock Description

The methods of description and classification of rocks used in this report are based on Australian Standard AS1726-1993 Geotechnical Site Investigations. In practice, if a material cannot be remoulded by hand in its field condition or in water, it is described as a rock. In general, descriptions cover: rock type, grain size, structure, colour, degree of weathering, strength, minor components or inclusions, and where applicable, the defect types, shape, roughness and coating/infill.

Sedimentary rock types are generally described according to the predominant grain size as follows.

Rock Type	Description
CONGLOMERATE	Rounded gravel sized fragments (>2mm) cemented in a finer matrix
SANDSTONE	Sand size particles defined by the following grain sizes: fine 0.06mm to 0.2mm medium 0.2mm to 0.6mm coarse 0.6mm to 2mm
SILTSTONE	Predominately silt sized particles
SHALE	Fine particles (silt or clay) and fissile
CLAYSTONE	Predominately clay sized particles

The classification of rock weathering is described based on definitions in AS1726 and summarised as follows.

Term and symbol		Definition
Residual Soil	RS	Soil developed on rock with the mass structure and substance of the parent rock no longer evident
Extremely weathered	XW	Weathered to such an extent that the rock has 'soil-like' properties
Distinctly weathered	DW	The strength is usually changed and may be highly discoloured. Porosity may be increased by leaching, or decreased due to deposition in pores
Slightly weathered	SW	Slightly discoloured; little or no change of strength from fresh rock
Fresh Rock	FR	The rock shows no sign of decomposition or staining

The rock material strength can be defined based on the point load index as follows.

Term and symbol		Point Load Index I_s50
Extremely low	EL	< 0.03MPa
Very Low	VL	0.03MPa to 0.1MPa
Low	L	0.1MPa to 0.3MPa
Medium	M	0.3MPa to 1MPa
High	H	1MPa to 3MPa
Very High	VH	3MPa to 10MPa
Extremely High	EH	> 10MPa

It is important to note that the rock material strength as above is distinct from the rock mass strength which can be significantly weaker due to the effect of defects.

A preliminary assessment of rock strength may be made using the field guide detailed in AS1726, and this is conducted in the absence of point load testing.

The defect spacing and bedding thickness, measured normal to defects of the same set or bedding, is described as follows.

Definition	Defect Spacing
Thinly laminated	< 6mm
Laminated	6mm to 20mm
Very thinly bedded	20mm to 60mm
Thinly bedded	60mm to 0.2m
Medium bedded	0.2m to 0.6m
Thickly bedded	0.6m to 2m
Very thickly bedded	> 2m

Terms for describing rock and defects are as follows.

Terms			
Joint	JT	Sheared zone	SZ
Bed Parting	BP	Sheared surface	SS
Contact	CO	Seam	SM
Dyke	DK	Crushed Seam	CS
Decomposed Zone	DZ	Infilled Seam	IS
Fracture	FC	Foliation	FL
Fracture Zone	FZ	Vein	VN

The shape and roughness of defects in the rock mass are described using the following terms.

Planarity		Roughness	
Planar	PR	Very Rough	VR
Curved	CU	Rough	RF
Undulating	U	Smooth	S
Irregular	IR	Polished	POL
Stepped	ST	Slickensides	SL

The coating or infill associated with defects in the rock mass are described as follows.

Definition	Description
Clean	No visible coating or infilling
Stain	No visible coating or infilling; surfaces discoloured by mineral staining
Veneer	Visible coating or infilling of soil or mineral substance (<1mm). If discontinuous over the plane; patchy veneer
Coating	Visible coating or infilling of soil or mineral substance (>1mm)

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Graphic Symbols Index

Clays

- CLAY
- Silty CLAY
- Sandy CLAY
- Gravelly CLAY

Silts

- SILT
- Clayey SILT
- Sandy SILT
- Gravelly SILT

Sands

- SAND
- Clayey SAND
- Silty SAND
- Gravelly SAND

Gravels

- GRAVEL
- Clayey GRAVEL
- Silty GRAVEL
- Sandy GRAVEL

Sedimentary Rock

- CONGLOMERATE
- BRECCIA
- SANDSTONE
- SILTSTONE
- SHALE
- MUDSTONE, CLAYSTONE
- COAL
- LIMESTONE

Metamorphic Rock

- SLATE, PHYLLITE, SHIST
- GNEISS
- QUARTZITE, MARBLE

Igneous Rock

- GRANITE
- RHYOLITE
- BASALT, DOLERITE
- IGNIMBRITE
- TUFF, VOLCANIC BRECCIA

Other Soils

- TOPSOIL
- ORGANIC SOILS
- COBBLES, BOULDERS

Fill Strata

- FILL
- ASPHALT
- CONCRETE
- ROADBASE
- BALLAST

Piezometer Symbols

- Screen Section
- Casing: sand backfill
- Casing: gravel backfill
- Casing: spoil backfill
- Bentonite Seal
- Cement Seal
- Spoil Backfill
- Cement Backfill

Proposed Subdivision - 18 Winterlake Road, Warners Bay

APPENDIX

C

AUSTRALIAN GEOGUIDE LR8

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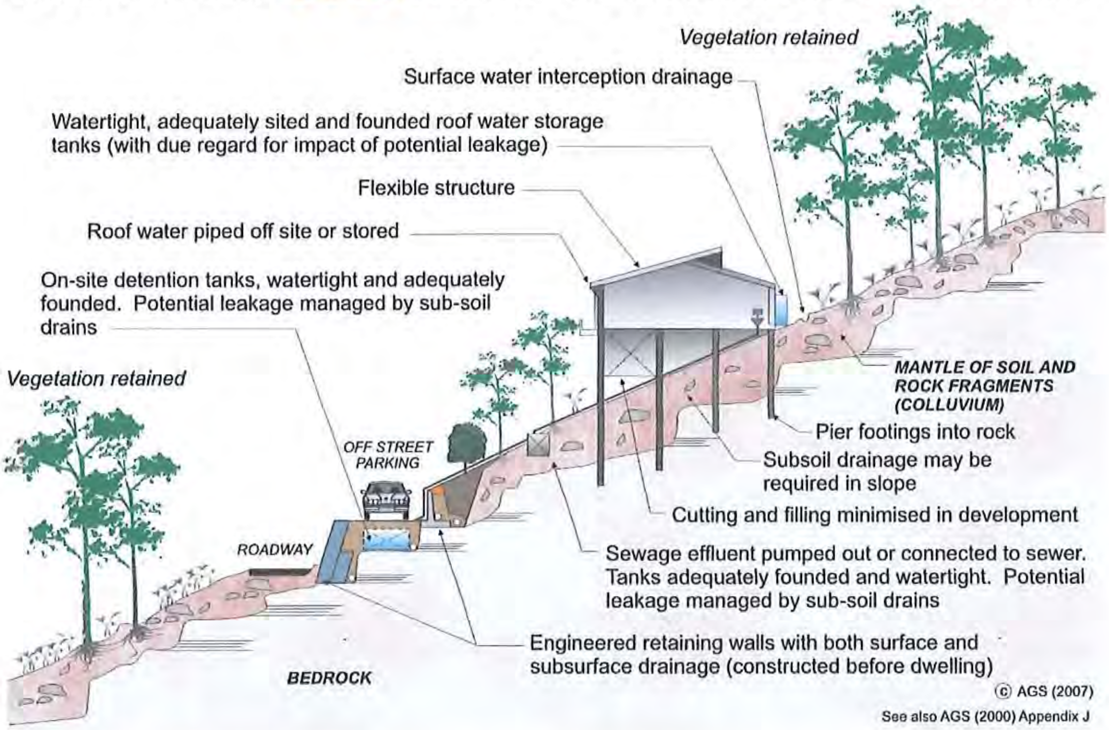
AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

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

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

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

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

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

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

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

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

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

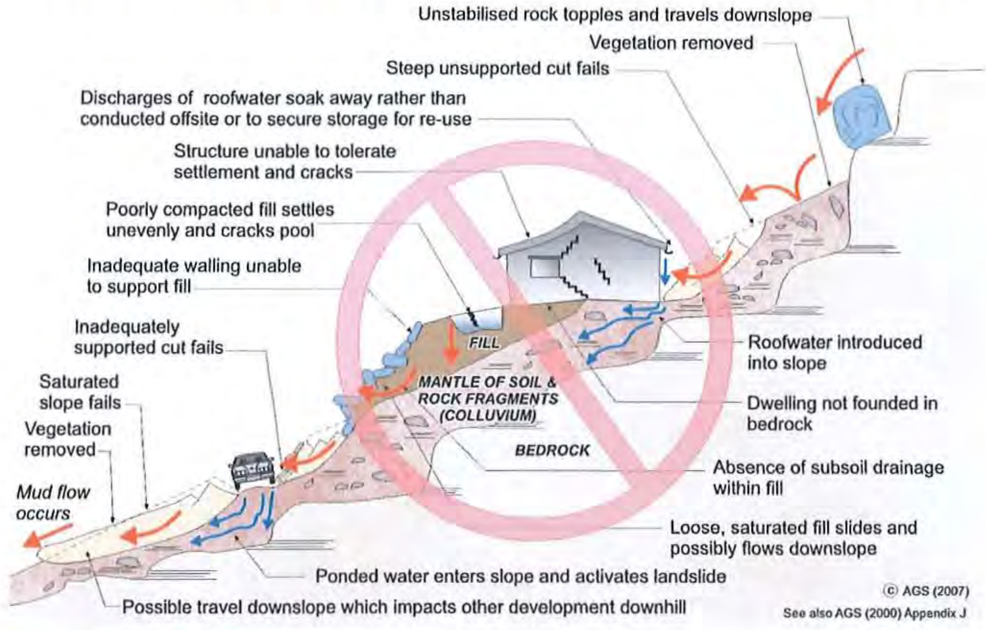
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

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

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

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

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

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

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

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

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

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

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