GREYWACKE
GEOTECHNICS

13 March 2020

To	**Antonio Todarello**		
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From	Kadir Oncu	Tel	0434 837 859
Subject	**Slope Risk Assessment** Proposed Stormwater System 731 Great Western Highway, Faulconbridge NSW	Job no.	ANTT0396 - GEO AA Rev01

1 Introduction

This report details the results of a slope risk assessment carried out by Greywacke Geotechnics (Greywacke) for a proposed stormwater system along the top of existing embankment located adjacent to the northern boundary of the hardstand within the site mentioned above. The location of the proposed stormwater system is marked on the **Figure 1** found in **Appendix B**.

The area inspected is located within 731 Great Western Highway (Lot 9, D.P.656879), Faulconbridge NSW 2776 and currently occupied by a commercial property and other related structures. The assessment was commissioned by Antonio Todarello (client) and prepared by an experienced geotechnical engineer from Greywacke.

On the 11th February 2019, Local and Environment Court of New South Wales has issued *Notice of Orders Made* for the case between Antonio Todarello and Blue Mountains City Council (BMCC), case number 2017/00358563.

This assessment is carried out to address the conditions stated under **Section 2** - ***Site Plan and additional information, item 7*** of *Notice of Orders Made* by Local and Environment Court of New South Wales. The conditions stated in item 7 of Section 2 includes the following:

- Provide details to demonstrate long term embankment stability can be achieved with the proposed stormwater system. Details to include any additional works required including any retaining structure(s) and/or stabilisation work and landscaping. This shall be supported by an updated geotechnical assessment.

This report must be read in accordance with General Notes found in **Appendix A**.

2 Scope of Work

A geotechnical field assessment was undertaken on the 24th September 2019 and comprised a visual assessment of the current stability of the existing embankment within the proposed site, a desktop study, review of the available documents such as geotechnical reports, development conditions and plans of the proposed works for the site.

This assessment includes the following:

- Review of *Preliminary Geotechnical Investigation and Stability Assessment* report prepared and issued by **envirotech** (Environmental and Engineering Consultancy Services) for *731 Great*

Western Highway, Faulconbridge, *Reference No.: REP-321516-A, Issue Date: 3rd May 2016*.

- Review of *Notice of Orders Made* issued by **Local and Environment Court of New South Wales,** *Case No.: 2017/00358563*, dated *11 February 2019*.
- Review of the engineering plan - *Site Stormwater Drainage Layout and Details & Sediment and Erosion Control Details*, *Drawing No.: 2019/104/SW1*, dated *March, 2020,* prepared by **Williams Consulting Engineers Australia P/L**.
- A visual and tactile observation of the existing embankment and surrounding area.
- Identify potential geotechnical constraints for the proposed stormwater system and retaining wall;
- The long-term stability assessment of the existing embankment with the proposed stormwater system.
- Identify the potential embankment/slope instability issues that may occur after construction of the proposed stormwater system and provide relevant geotechnical advice for long term stability of the embankment.

3 Environmental Setting

Topography

Imagery available on the Department of Lands and Spatial Information Exchange website and the site survey plan provided indicates that the allotment is within elevation (reduced levels) of RL480m and RL490m in accordance with Australian Height Datum (AHD). The allotment has a triangular shape, bounded by Great Western Highway along the southern and south-eastern boundary with boundary length of approximately 153m. Neighbouring lots occupy areas adjacent to the northern and western extents.

The topography of the surrounding area is generally rugged, with rolling, moderate and steep hills. The elevations of the area surrounding the northern extent of the site appears to slope downwards to an elevation of approximately RL400m within 250m north of the site.

Based on the information provided, the embankment inspected during our site visit was constructed many years ago by using imported material comprising primarily railway ballast. The embankment is constructed within the northern extent of the allotment and separated by a metal fence from the developed area. The height of the embankment inspected is approximately 3.0m and slopes downwards towards north with slopes up to 15 degrees.

Regional Geology

Reference to the 1:100, 000 scale Penrith Geological Series Sheet 9030 (Edition 1 - 1991) indicates that the proposed development site is underlain by Hawkesbury Sandstone of the Wianamatta Group. This stratum occurs extensively across the Sydney Basin and comprises medium to coarse grained quartz, very minor shale and laminite lenses.

The 1:100,000 Penrith Soil Landscape Map indicates that the site is within Falconbridge soil group comprises primarily earthy sands. This landscape characterised by shallow, highly permeable soil, rock outcrop and very low soil fertility.

4 Site Observations and Field Assessment

The site is currently occupied by a single level commercial building located within the centre of the allotment and concrete pavement (hardstand) surrounding the commercial building. The developed area within the site is relatively flat and fenced along northern and western boundary lines.

The embankment inspected is located within the northern end of the allotment, adjacent to the northern boundary of the existing hardstand. As mentioned previously, the height of the embankment inspected is approximately 3.0m and slopes downwards towards north with slopes up to 15 degrees.

Observations made during the site assessment are presented below. Selected photos, as referenced below, are presented in **Table 1**.

- The allotment is currently occupied by an existing single level commercial property/structure located in the centre of the lot (**Photo 1**). The structure appears in good condition with no visual signs of structural damage. It is envisaged that the foundations of this structure are likely supported on sandstone bedrock.
- The area surrounding the commercial building is covered with concrete pavement (hardstand). The hardstand covers the majority of the site area and provides access and parking facilities for vehicles. The hardstand appears fairly flat and consistent, and fenced along the northern and western boundary (**Photo2**).
- The surface of the embankment is covered with vegetation and appears to be in stable condition. No evidence of previous slope movement was observed during our field assessment (**Photo 4**).
- Areas adjacent to northern extent of the embankment comprised moderately to steep side slopes with inclination between 15 degrees to 20 degrees and stepped/benched rocky outcrops (**Photo 3** and **Photo 4**). The rear of the allotment is mostly open grassed area which is slightly vegetated including vegetable patches/gardens.
- Persistent surface bedrock outcrops were evident around the site (**Photo 5**). Where exposed, the bedrock comprised sandstone and was generally observed to brown-grey with surface staining, massive with minor to moderate bedding planes, moderately weathered to slightly weathered, medium to coarse grained, medium to high strength.
- No seepage/groundwater observed within the areas inspected.

Table 1 - ***Selected Site Photos***

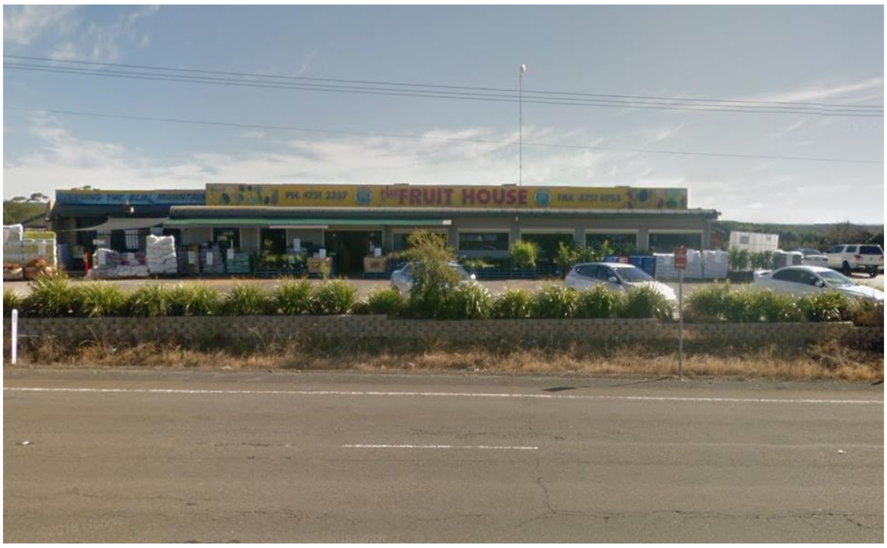

Photo 1: View looking west from the Great Western Highway showing the existing commercial building.

Photo 2: Photo of the hardstand. Looking East towards the carpark exit.

Photo 3: View looking east from the northern end of the site. Natural slope adjacent to the embankment with exposed sandstone outcrop at the bottom of the slope.

Photo 4: Surface of the embankment is covered with vegetation.

Photo 5: Persistent bedrock surface outcrop along the northern boundary line.

5 Proposed Works and Objective

The proposed works within the site will include a stormwater system along the top of existing embankment located within the northern extent of the site. Based on the stormwater drainage plans provided (refer to Section 2), the proposed stormwater drainage system will comprise a 1.5m wide and 250mm deep grassed swale with 300mm clay bed and supported with galvinised 100 'UC' posts driven into sandstone, at 1800mm centres with 70mm treated pine sleepers across the northern embankment.

This assessment was carried out to assess the potential embankment/slope instability issues that may occur after construction of the proposed stormwater system and provide relevant geotechnical advice for long term stability of the embankment.

6 Geotechnical Assessment

6.1 Review of Geotechnical Report

The geotechnical site investigation carried out by Envirotech (Refer to Section 2) comprised the drilling of two (2) hand augured boreholes to 0.3m depth below existing ground level and four (4) Dynamic Cone Penetration (DCP) at selected locations within accessible locations. Upon completion of the borehole drilling, two (2) constant head field permeameter tests were carried out using Talsma-Hallam method (AS1547-2012) at each borehole location.

The outcome of this field investigation indicates that the subsurface conditions of the sloping area is made of soils layer comprising topsoil, fill and residual soil overlaying sandstone bedrock. This sequence is consistent with our expectations, based on the geological conditions described in **Section 3**.

A preliminary slope stability assessment carried out during this investigation found no previous or existing slope issues within the site. The geotechnical assessment also indicates that the risk of potential adverse impact on the stability of embankment due to construction of the proposed stormwater system is very low, provided that at least 300mm clay layer with particle diameter of <0.001mm is adopted to underlie the proposed channel.

The more pertinent aspects of the environmental and geological conditions at the site (i.e. location, topography, geology, subsurface materials across the site etc.), geotechnical assessment and recommendations are presented in the geotechnical investigation report, as such, will not be discussed further in this report.

6.2 Slope Stability Assessment

This slope risk/stability assessment is based on a detailed visual inspection of the topographic, surface drainage and geological conditions and environmental conditions in the vicinity of the proposed site and the relevant geotechnical information provided in the geotechnical report supplied.

The embankment inspected is constructed during filling of the site many years ago (refer to Section 3) and the proposed swale drain will be constructed within this filled area. It is understood that the filling within the site was carried out in uncontrolled manner and the properties and characteristics of the fill material may vary throughout the filled area.

The surface of the embankment/sloping area inspected was covered with dense overgrown vegetation and scattered small to medium size trees. Due to presence of dense vegetation cover, majority of the slope surface was not observed, and the extent of this field assessment was limited to areas with exposed soil/bedrock.

The principal site features used in this slope stability assessment are as follows:

- Surface contours and ground features across the site;
- The presence of shallow topsoil/fill materials and residual soil;

- Well defined and competent bedrock profile within the surrounding area (i.e. shallow and medium to high strength bedrock);
- Lack of key indicators of recent or impending slope instability such as slope slumping or tension cracks on the slope surface and in the vicinity of the proposed site;
- Presence of dense vegetation and scattered trees on the slope surface;

The proposed drainage system for the site includes a 1.5m wide and 250mm deep grassed swale with 300mm of clay bed and treated pine edging supported by galvinised 100 'UC' posts driven into sandstone, at 1800mm centres with 70mm treated pine sleepers. Swale drains are shallow, broad and vegetated channels designed to store and/or convey runoff and remove pollutants.

The key indicators of slope instability were not evident across the site during the fieldwork (e.g. rock falls / topples, block slides on weak layers, wedge failures along bedrock discontinuities, mass soil / rock movement etc.). Also, it appears that the trunks of the mature trees in the immediate vicinity of the proposed site are generally upright and straight, indicating a relatively well drained stable slope conditions.

As mentioned previously, the surface of the embankment/sloping area inspected was covered with dense overgrown vegetation and scattered small to medium size trees. The presence of vegetation cover on the embankment reduces the risk of slope instability by increasing the shear strength of the underlaying soil and causing negative pore pressure.

Furthermore, it is understood that parts of the hardstand area adjacent the northern side of the proposed swale drain will be converted into green space as per Notice of Orders Made (Refer to Section 2) and this may further stabilise the embankment with increased vegetation cover surrounding the embankment. This will also create an exclusion zone along the edge of the embankment for heavy vehicles/machinery and minimise the potential impacts of surcharge loads on the embankment stability.

6.3 Conclusion and Recommendations

Based on our field inspection, review of the available information and the nature of the proposed swale drain, the risk of potential adverse impact on the stability of embankment due to construction of the proposed stormwater system is assessed to be **very low**.

A 50mm treated pine edging/retaining wall supported with galvinised 100 'UC' posts driven into sandstone bedrock along the northern side of the proposed swale drain and 300mm clay bed underlying the channel will minimise the potential adverse impacts of the swale drain, specifically within close proximity to slope grades over 20 degrees.

The proposed retaining wall must be constructed in accordance with the **good hillside practice** guidelines **(refer to Appendix C).** Additionally, vegetation cover on the slope surface must be maintained for erosion control and long term stability of the embankment.

An experienced professional engineer should confirm the foundation conditions during construction of the proposed retaining wall for quality and design verification purposes.

Due to the presence of uncontrolled fill and limited field observations made during this assessment, care will need to be exercised during construction related activities. It would be prudent to undertake geotechnical inspection of the construction area during works to identify any loose or unstable soil or rock mass that may potentially impact on the construction site in the short term and the proposed new structure in the long term.

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In conclusion, the proposed stormwater drain is considered **suitable** for construction. The recommendations provided in this report must be adopted for long term stability of the embankment.

7 Limitations

This report has been prepared for the particular project described above and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the sub-surface conditions at the site or geometry of the deformed soil mass described in the report then all recommendations should be reviewed

We trust that this report is satisfactory for your current needs. Should you have any queries or wish to discuss the assessment and recommendations further, please do not hesitate to contact the undersigned.

For and on behalf of
Greywacke Geotechnics

Kadir Oncu
Senior Geotechnical Engineer

Appendix A – General Notes

GENERAL NOTES

GREYWACKE GEOTECHNICS

This report contains the results of a geotechnical investigation conducted for a specific purpose and client. The results should not be used by other parties, or for any other purposes, as they may contain neither adequate nor appropriate information. In particular, the investigation does not cover contamination issues unless specifically required to do so by the client.

TEST HOLE LOGGING

The information on the test hole logs (boreholes, test pits, exposures etc.) is based on a visual and tactile assessment, except at discrete locations where test information is available (field and/or laboratory results). The test hole logs include both factual data and inferred information. Moreover, the location of test holes should be considered approximate, unless noted otherwise (refer report). Reference should also be made to the relevant standard sheets for the explanation of logging procedures (Soil and Rock Descriptions, Core Log Sheet Notes etc.).

GROUNDWATER

Unless otherwise indicated, the water levels presented on the test hole logs are the levels of free water or seepage in the test hole recorded at the given time of measuring. The actual groundwater level may differ from this recorded level depending on material permeabilities (i.e. depending on response time of the measuring instrument). Further, variations of this level could occur with time due to such effects as seasonal, environmental and tidal fluctuations or construction activities. Confirmation of groundwater levels, phreatic surfaces or piezometric pressures can only be made by appropriate instrumentation techniques and monitoring programmes.

INTERPRETATION OF RESULTS

The discussion or recommendations contained within this report are normally based on a site evaluation from discrete test hole data, often with only approximate locations (e.g. GPS). Generalised, idealised or inferred subsurface conditions (including any geotechnical cross-sections) have been assumed or prepared by interpolation and/or extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in the generalised ground conditions do occur in the natural environment, particularly between discrete test hole locations. Additionally, certain design or construction procedures may have been assumed in assessing the soil-structure interaction behaviour of the site. Furthermore, conditions may change at the site from those encountered at the time of the geotechnical investigation through construction activities and constantly changing natural forces.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed or reported should be referred to this company for appropriate assessment and comment.

GEOTECHNICAL VERIFICATION

Verification of the geotechnical assumptions and/or model is an integral part of the design process - investigation, construction verification, and performance monitoring. Variability is a feature of the natural environment and, in many instances, verification of soil or rock quality, or foundation levels, is required. There may be a requirement to extend foundation depths, to modify a foundation system and/or to conduct monitoring as a result of this natural variability. Allowance for verification by appropriate geotechnical personnel must be recognised and programmed for construction.

FOUNDATION

Where referred to in the report, the soil or rock quality, or the recommended depth of any foundation (piles, caissons, footings etc.) is an engineering estimate. The estimate is influenced, and perhaps limited, by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The material quality and/or foundation depth remains, however, an estimate and therefore liable to variation. Foundation drawings, design and specifications should provide for variations in the final depth, depending upon the ground conditions at each point of support, and allow for geotechnical verification.

REPRODUCTION OF REPORTS

Where it is desired to reproduce the information contained in our geotechnical report, or other technical information, for the inclusion in contract documents or engineering specification of the subject development, such reproductions must include at least all of the relevant test hole and test data, together with appropriate Standard Description sheets and remarks made in the written report of a factual or descriptive nature.

Reports are the subject of copyright and shall not be reproduced either totally or in part without the express permission of Greywacke Geotechnics.

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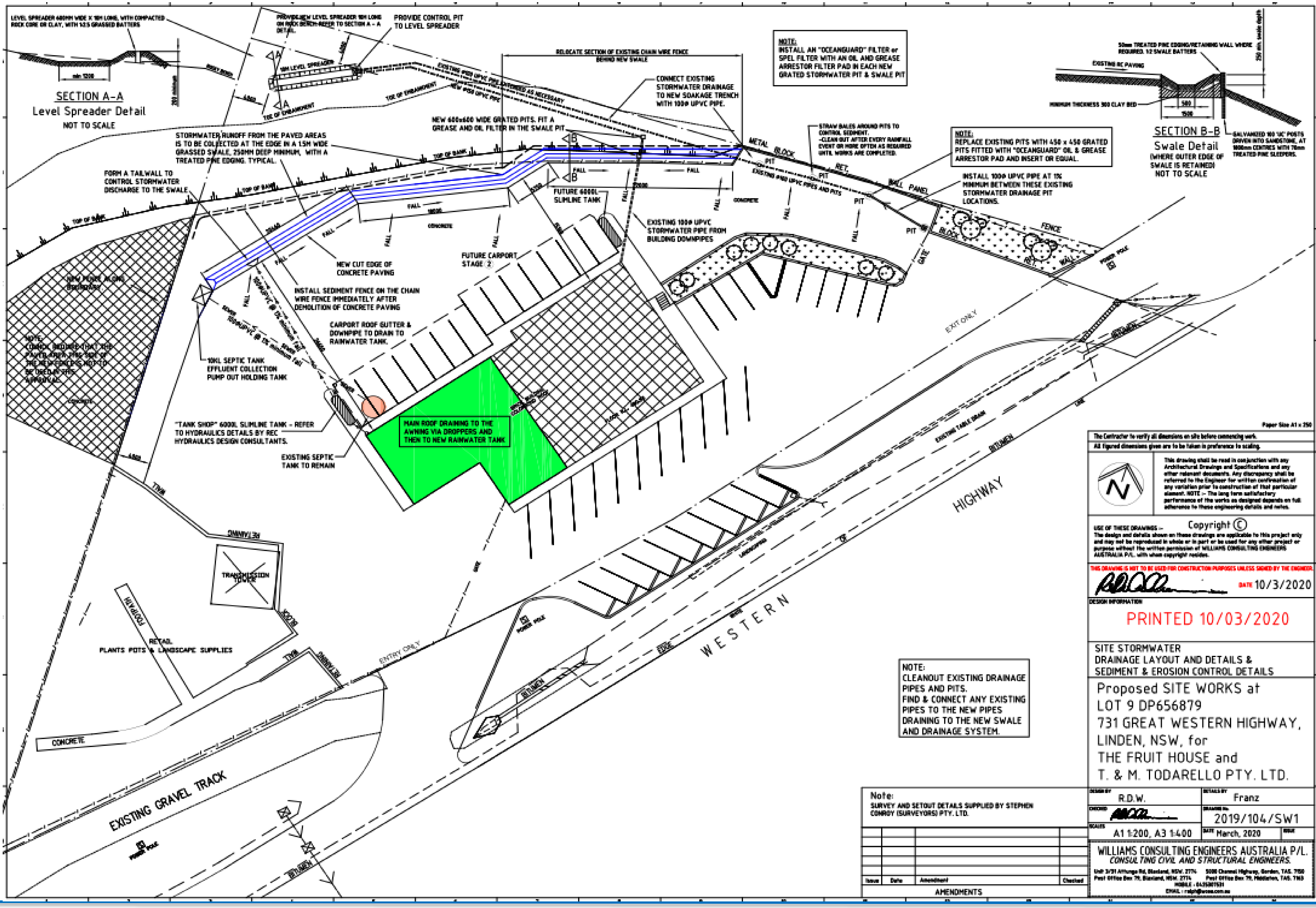
Appendix B – Figures



Paper Size A3 Scale NTS Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 56	**LEGEND** Location of theProposed Swale	GREYWACKE GEOTECHNICS	**Antonio Todarello** **Geotechnical Site Assessment** 731 Great Western Highway Faulconbridge NSW

Job Number	ANTT0396
Revision	1
Date	13-Mar-20
Source	Supplied

TEST LOCATION PLAN

Figure 1

Appendix C – Extracts from the Australian Geomechanics Society Landslide Risk Management Guideline

WATER, DRAINAGE & SURFACE PROTECTION

One way or another, water usually plays a critical part in initiating a landslide (GeoGuide LR2). For this reason, it is a key factor to be controlled on sites with more than a low landslide risk (GeoGuide LR7).

Groundwater and Groundwater Flow

The ground is permeable and water flows through it as illustrated in Figure 1. When rain falls on the ground, some of it runs along the surface ("surface water run-off") and some soaks in, becoming groundwater. Groundwater seeps downwards along any path it can find until it meets the water table: the local level below which the ground is saturated. If it reaches the water table, groundwater either comes to a halt in what is effectively underground storage, or it continues to flow downwards, often towards a spring where it can seep out and become surface water again. Above the water table the ground is said to be "partially saturated", because it contains both water and air. Suctions can develop in the partially saturated zone which have the effect of holding the ground together and reducing the risk of a landslide. Vegetation and trees in particular draw large quantities of water out of the ground on a daily basis from the partially saturated zone. This lowers the water table and increases suctions, both of which reduce the likelihood of a landslide occurring.

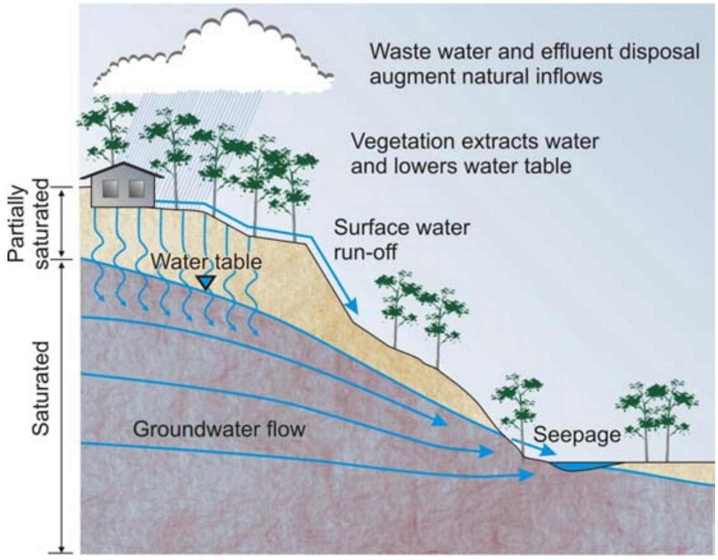


Figure 1 - Groundwater flow

Groundwater Flow and Landslides

The landslide risk in a hillside can be affected by increase in soak-away drainage or the construction of retaining walls which inhibit groundwater flow. The groundwater is likely to rise after heavy rain, but it can also rise when human interference upsets the delicate natural balance. Activities such as felling trees and earthworks can lead to:

- a reduction in the beneficial suctions in the partially saturated zone above the water table.
- increased static water pressures below the water table,
- increased hydraulic pressures due to groundwater flow,
- loss of strength, or softening, of clay rich strata,
- loss of natural cementing in some strata,
- transportation of soil particles.

Any of these effects, or a combination of them, can lead to landslides like those illustrated in GeoGuides LR2, LR3 and LR4.

Limiting the Effect of Water

Site clearance and construction must be carefully considered if changes in groundwater conditions are to be limited. GeoGuide LR8 considers good and poor development practices. Not surprisingly much of the advice relates to sensible treatment of water and is not repeated here. Adoption of appropriate techniques should make it possible to either maintain the current ground water table, or even cause it to drop, by limiting inflow to the ground.

If drainage measures and surface protection are relied on to keep the risk of a landslide to a tolerable level, it is important that they are inspected routinely and maintained (GeoGuide LR11).

The following techniques may be considered to limit the destabilising effects of rising groundwater due to development and are illustrated in Figure 2.

AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

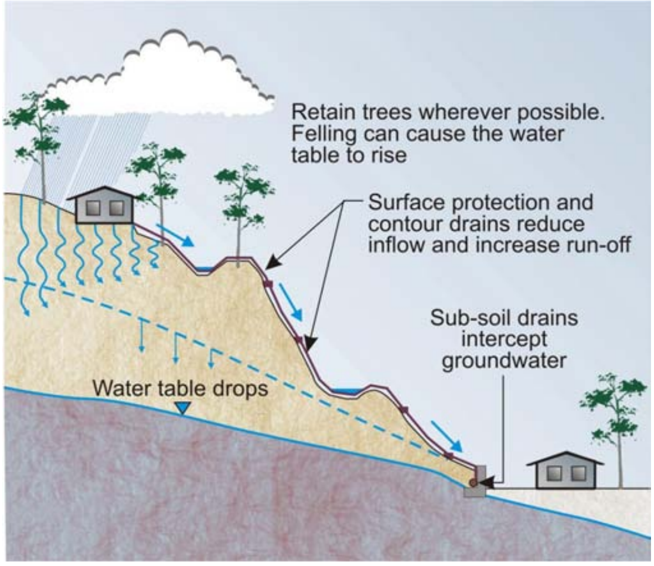


Figure 2 - Techniques used to control groundwater flow

Surface water drains (dish drains, or table drains) - are often used to prevent scour and limit inflow to a slope. Other than in rock, they are relatively ineffective unless they have an impermeable lining. You should clear them regularly, and as required, and not less than once a year. If you live in an area with seasonal rainfall, it is best to do this near the end of the dry season. If you notice that soil or rock debris is falling from the slope above, determine the source and take appropriate action. This may mean you have to seek advice from a geotechnical practitioner.

Surface protection - is sometimes used in addition to surface water drainage to prevent scour and minimise water inflow to a slope. You should inspect concrete, shotcrete or stone pitching for cracking and other signs of deterioration at least once a year. Make sure that weepholes are free of obstructions and able to drain. If the protection is deteriorating, you should seek advice from a geotechnical practitioner.

Sub-soil drains - are often constructed behind retaining walls and on hillsides to intercept groundwater. Their function is to remove water from the ground through an appropriate outlet. It is important that subsoil drains are designed to complement other measures being used. They should be laid in a sand, or gravel, bed and protected with a graded stone or geotextile filter to reduce the chance of clogging. Sub-soil drains should always be laid to a fall of at least 1 vertical on 100 horizontal. Ideally the high end should be brought to the surface, so it can be flushed with water from time to time as part of routine maintenance procedures.

Deep, underground drains - are usually only used in extreme circumstances, where the landslide risk is assessed as not being tolerable and other stabilisation measures are considered to be impractical. They work by permanently lowering the water table in a slope. They are not often used in domestic scale developments, but if you have any on your site be aware that professional maintenance is essential. If they are not maintained and stop working, the water table will rise and a landslide may even occur during normal weather conditions. Both an increase or a reduction in the normal flow from deep drains could indicate a problem if it appears to be unrelated to recent rainfall. If changes of this sort are observed, you should have the drains and your site checked by a geotechnical practitioner.

Documentation - design drawings and specifications for geotechnical measures intended to minimise landslide risk can be of great assistance to a geotechnical specialist, or structural engineer, called in to inspect and report on them. Copies of available documentation should be retained and passed to the new owner when the property is sold (GeoGuide LR11). You should also request details of an appropriate maintenance program for drainage works from the designer and keep that information with other relevant documentation and maintenance records.

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 LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

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

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

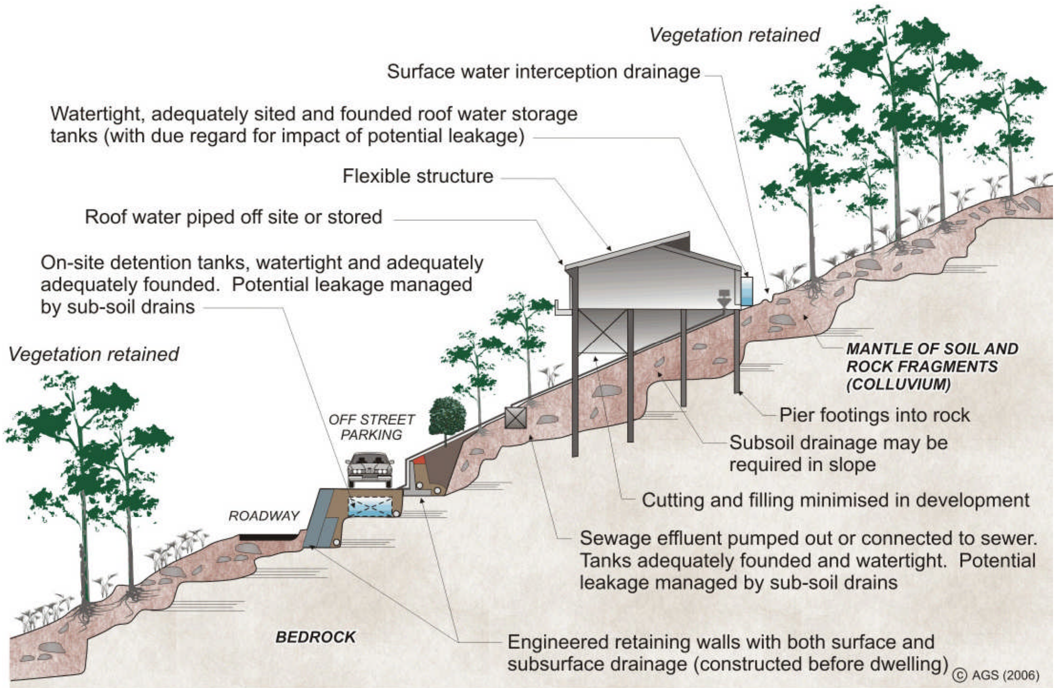
	GOOD ENGINEERING PRACTICE	POOR ENGINEERING PRACTICE
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having 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.	Indiscriminant 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 properties 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 bedrock 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 bedrock 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 generous 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 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 of roof run-off 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 of 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 a 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 seek advice. If seepage observed, determine cause or seek advice on consequences.	

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 FOR **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 due to 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 fulfill the same purpose (GeoGuide LR5).

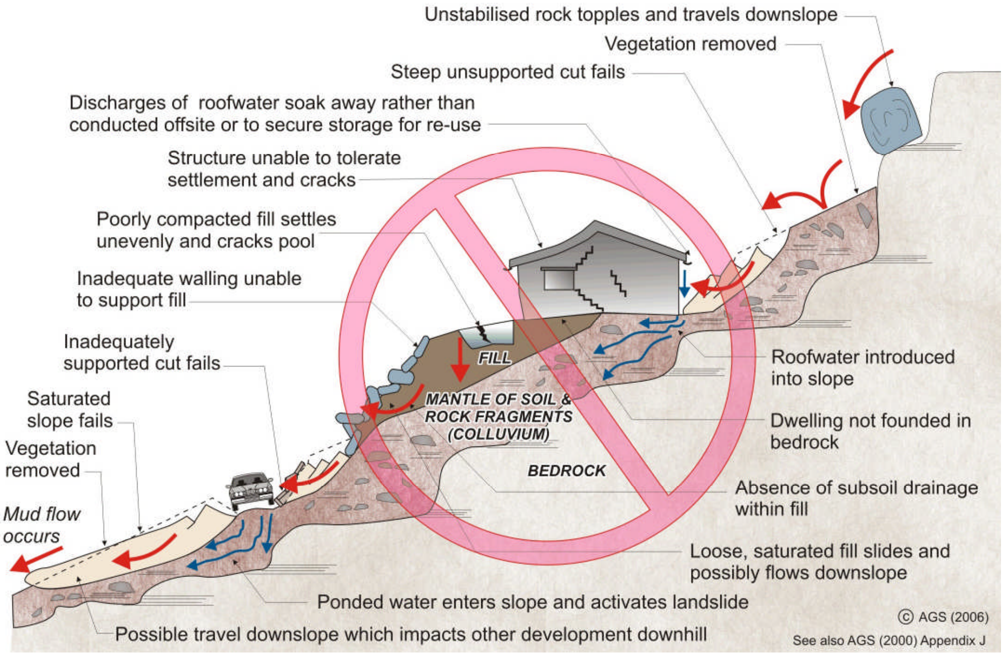
Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide 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.

EXAMPLES FOR **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 soaks 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 herringbone, 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

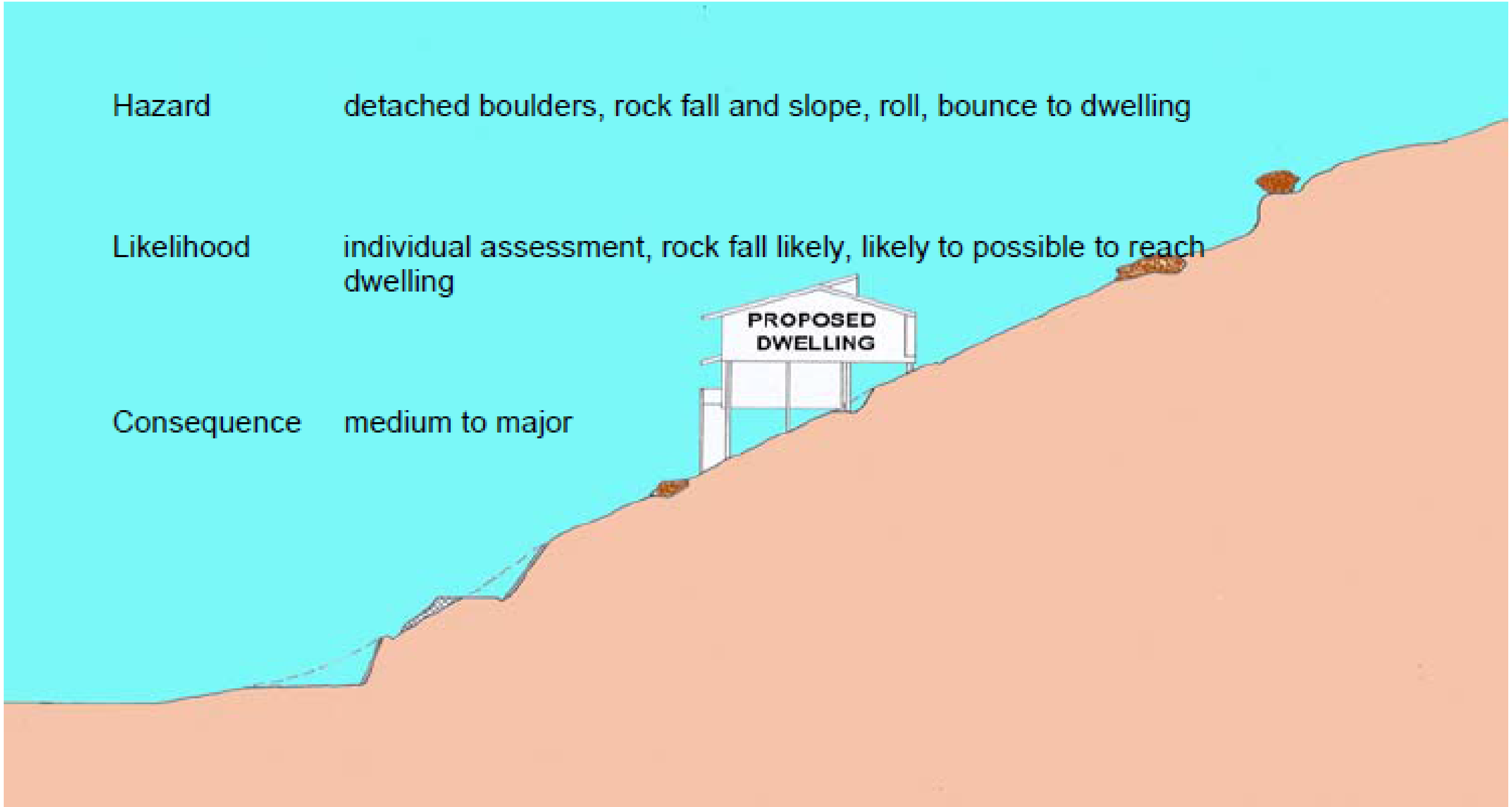
More information relevant to your particular situation may be found in other Australian GeoGuides:

- 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.

Landslide Risk Assessment Process

Example - Qualitative landslide risk assessment for property (Source: Walker (2002))



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