26 May 2021
Our ref: JS/S1273

Matt Clarke
c/o FMF Engineering
Via email: mat@fmfengineering.com.au

Proposed Alterations and Additions – 48 Epping Drive, Frenchs Forest, NSW
Site Classification Report

1 Introduction

1.1 PROJECT DESCRIPTION

At the request of Matt Clarke, Fortify Geotech Pty Ltd carried out a site classification in accordance with AS2870 "Residential Slabs & Footings", and a qualitative slope instability risk assessment for a proposed alterations and additions at 48 Epping Drive, in Frenchs Forest. The site is located on Epping Drive.

It is understood the project involves the construction of a pool and pergola at the rear of the property. Due to the property being located in a region categorized as possessing landslide risk by the Northern Beaches Council due to flanking slopes between 5º to 25º, a geotechnical site classification and slope instability risk assessment is required.

To establish the site subsurface conditions, a handheld hydraulic push-tube was used to excavate two boreholes on the property. Borehole 1A was drilled near the proposed pool location and borehole 2A near the proposed pergola location. Two dynamic cone penetrometer (DCP) tests were also done. The subsurface profile was logged in accordance with the Unified Soil Classification System (USCS) and the log is attached to the end of this report. Figure 2 is an aerial photograph showing the approximate borehole and DCP locations.

1.2 SITE DESCRIPTION AND GEOLOGY

The site is located on 48 Epping Drive, Frenchs Forest, NSW. The ~730m^2 site is presently occupied by an existing residence towards the eastern end of the block. The groundsurface at the location of the proposed pool and pergola is grass covered and the ground surface dips is relatively flat. There is no evidence of existing site cuts or large scale placement of fill. Figure 1 shows the site locality, whilst Figure 2 is a recent aerial photograph which also shows the approximate borehole locations.

The 1:100,000 Sydney Geology map indicates the area to be underlain by Triassic age, Hawkesbury Sandstone, which consists medium to coarse grained quartz sandstone, very minor shale, and laminite lenses.

1.3 SCOPE OF INVESTIGATION

The aim of the investigation was to:

- Identify subsurface conditions including extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.
- Provide a site classification to AS2870 “Residential Slabs & Footings”.
- Recommend suitable footing systems for the buildings including types, founding depths and allowable bearing pressures.
- Slope instability risk assessment
- Advise on excavation conditions and suitability of excavated materials for use as structural fill.
- Advise on site drainage

The assessment required the development of a qualitative matrix risk assessment to people and property, in accordance with the guidelines of “Landslide Risk Management Concepts and Guidelines”, Australian Geomechanics Journal, 2007. In this instance, the residents of the house are considered as “people” and the proposed alterations and additions, as well as the surrounding houses and highway were considered as “property”.

The slope stability assessment is qualitative, based on the guidelines on landslide risk management published by the Australian Geomechanics Society. Risk assessment involves the following components: (i)Hazard identification, (ii) Likelihood of Hazards Occurring, (iii) Consequences of Hazards, and (iv) Significance of Risks. This uses a matrix approach to determine the risk level of each hazard based on the likelihood and consequences of each hazard occurrence.

2 Investigation Results

2.1 SUBSURFACE CONDITIONS

The subsurface conditions of the proposed alterations and additions were investigated by two boreholes designated 1A and 2A. The borehole logs in Appendix A can be referred to for more detail.

Investigation boreholes 1A and 2A found the subsurface profile to comprise:

TABLE 1 – Subsurface Conditions

Geological Profile	Depth Interval	Description
TOPSOIL FILL	0m to 0.15m	SILTY SAND, SILTY SANDY CLAY; medium plasticity clay, fine to coarse grained sand, brown, grass roots at surface, trace roots, medium dense, firm, dry to moist.
FILL	0.15m to 0.2m	SAND; fine to coarse grained sand, yellow to brown, trace roots, moist. This material was only encountered in borehole 2A.
ALLUVIUM	0.15m/0.2m to 0.9m/>1.5m	SAND, CLAYEY SAND/SANDY CLAY, CLAYEY SAND; fine to coarse grained sand, low to medium plasticity clay, yellow to brown, yellow to brown trace orange and grey, trace roots, trace sub angular gravels to 2mm size, medium dense to dense, medium dense, medium dense/firm, moist, moist to wet.
RESIDUAL	0.9m to 1.1m	SAND; fine to coarse grained sand, dark grey to black, some low to medium plasticity clay, trace sub angular gravels to 5mm size, medium dense, moist. This material was only encountered in borehole 2A.

Pushtube refusal occurred at 1.1m depth in borehole 2A in HW/MW sandstone bedrock , while DCP testing suggest the presence of sandstone bedrock at 2.0m depth at the borehole 1A location.

2.2 GROUNDWATER

Permanent groundwater was not encountered in the investigation boreholes; however, temporary perched seepages could be encountered at shallower depths following rainfall within the more previous soils.

2.3 DYNAMIC CONE PENETROMETER (DCP) TESTING

To determine the consistency/relative density of the encountered soils, two Dynamic Cone Penetrometer (DCP) tests were taken on 10 May 2021 in accordance with AS1289.6.3.2 “Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer test”. The DCP results are shown in Table 2 below. The tests were taken from ground surface levels, with DCP1 adjacent to borehole 1A and DCP2 adjacent to borehole 2A. The location of the DCP tests are shown on Figure 2.

TABLE 2 - DCP Testing Results

Depth below grown surface (m)	Blows per 100mm penetration	
	DCP1	DCP2
0.1	0	0
0.2	2	0
0.3	0	1
0.4	0	1
0.5	1	0
0.6	1	0
0.7	2	2
0.8	4	1
0.9	5	0
1.0	3	2
1.1	3	4
1.2	3	>30 (Refusal)
1.3	2	
1.4	3	
1.5	3	
1.6	4	
1.7	3	
1.8	2	
1.9	0	
2.0	>30 (Refusal)	

The DCP test results for the DCP tests indicate the subsurface profile to comprise loose to medium dense soil to 0.8m/1.0m depth over medium dense to dense soil to at least 1.2m/2.0m depth over HW bedrock at 1.2m/2.0m.

3 SLOPE INSTABILITY RISK ASSESSMENT

3.1 METHOD OF RISK ASSESSMENT

The following sections of the report outline the slope instability risk assessment carried out for the site. The assessment is qualitative, based on the guidelines provided in the Australian Geomechanics Journal Vol 42 March 2007, and has been adopted by the NSW Department of Infrastructure, Planning and Natural Resources. This uses a matrix approach to determine the risk level of each hazard based on the likelihood and consequences of each hazard occurring.

Risk assessment involves the following components:

(i) Identification on the potential site slope hazards that may damage property and/or cause loss of life (Hazard Identification).

(ii) Estimation of the likelihood of each hazard occurring (Likelihood of Hazards Occurring).

(iii) Assessment of the potential consequences to property and people of these hazards occurring (Consequences of Hazards).

(iv) Evaluation of the significance of the assessed risks against criteria of acceptability (Significance of Risks).

Following the risk assessment, options for the treatment of the risk are provided as a guide to the owner, administrator and regulatory authorities who will need to decide whether to avoid or accept the risk, or to treat the site to reduce the likelihood and/or consequences of the hazards.

A flowchart, included in the Australian Geomechanics Journal, Vol 42, March 2007, paper on “Landslide Risk Management Concept & Guidelines” 2007 (Reference 2), which shows the processes of risk assessment/risk management is copied here in Appendix D. Appendix E provides guidelines for hillside construction.

3.2 HAZARD IDENTIFICATION

The potential hazards to slope stability at this site were considered, and includes:

- Large Scale Translational Slide
- Small Scale Slumps in the Soil Profile
- Surface Erosion
- Failure of Retaining Wall
- Large Rockfall from Upslope

3.3 LIKELIHOOD OF HAZARDS OCCURRING

3.3.1 Large Scale Translational Slide

To our knowledge, no landslips have been recorded in this immediate vicinity. The combination of moderate slopes on the property dipping north east at 5° to 10° and a level slope at the location of proposed development, with well-established stable vegetation and good surface drainage, reduces the possibility of a major landslip occurring. The existing trees on the slope exhibit vertical or near vertical growth suggesting little to no slope movement. For a large-scale slide to happen there would need to be an extreme combination of unfavourable triggering conditions such as earthquakes, extreme rainfall, saturated soils, mass clearance of vegetation, unsupported excavations etc. Consideration of the steep slopes and a lack of previous landslides in this geological formation suggest that such an event is considered to be “Unlikely”.

3.3.2 Small-Scale Slumps in the Soil Profile

Under adverse site conditions, such as when site soils are saturated, small slumping failures of the soils could conceivably occur. However, as there does not appear to have any slippages or slumps in the past, such an event is “Possible”.

3.3.3 Failure of Retaining Wall

The cuts to be constructed on the block will be supported by well-drained, properly designed and constructed engineered retaining walls. As no failures or cracking was observed on similar retaining walls on the adjacent blocks, the likelihood or a properly drained and constructed retaining wall failure is judged to be “Rare”.

3.3.4 Surface Erosion

There are presently no signs of surface scouring on the block, probably in part due to the surface vegetation and good surface drainage. The existing road uphill of the block would also help to prevent this occurring. Nevertheless, the upper soils are quite silty, so if the vegetation was removed and surface water flow-paths were allowed to develop, surface erosion is “Unlikely”.

3.3.5 Rock Fall from Upslope

Large rockfalls from upslope could have occurred in the past. However, given the development upslope of the site (including multiple roads and properties), the risk is reduced. Therefore, this event is “Possible”.

3.4 CONSEQUENCES OF HAZARDS OCCURRING

3.4.1 Large-Scale Translational Slide

Theoretically, a large-scale slide could occur with little or no warning, and the consequences to property and people would depend on the volume of the slide material, its velocity, and whether or not people are present, or in the downslope dwelling at the time. Using the AGS table of qualitative measures of vulnerability and consequences in Appendix C, we consider the consequences of such a rare event to be “Medium”, i.e Theoretically, there is the possibility of a fatality in the dwelling and/or the imposition of moderate damage to some of the structure in the rare even of this occurring.

3.4.2 Small-Scale Slumps in the Soil Profile

The consequence to the pool and outdoor area of a small-scale slump occurring in the soil is believed to be "Minor" considering the low loads expected from the structure. However, the slope uphill or downhill might be affected, and some material may slough onto the or downslope structure. The chance or temporal probability of persons being in the area during an earth slump is low, and therefore the risk of loss of life is low. The consequences for persons is therefore rated as "Minor".

3.4.3 Failure of a Retaining Wall

If a retaining wall failed, damage may well result to the structure, depending on many factors. In general, the consequences can be rated as "Minor to Medium". The chance of persons being injured or of loss of life is low and the consequences to persons are therefore also rated as "Minor to Medium".

3.4.4 Surface Erosion

If such an event develops and occurs, small cobbles/boulders may wash out of erosion gully slides and rolled downhill. The consequential damage to a structure would be "Insignificant".

3.4.5 Rockfall from Upslope

The top of the escarpment is >300m to the south of the site with multiple other properties, a residential road and a major road in between. Therefore, any rockfalls that do occur will have slowed in velocity by the time it reaches the property or be protected by developments uphill. Therefore, the consequences are assessed as "Insignificant to Minor".

3.5 RISK ESTIMATION

A summary of estimated risk to property and life for each of the potential hazards identified in the previous sections is provided in Table 1. The resulting risk level was derived using the AGS risk analysis matrix presented in Appendix C.

TABLE 1
Risk Analysis Summary

Potential Hazard	Assessed Likelihood	Assessed Consequences	Risk Level
Large-Scale Translational Slide	Unlikely	To Dwelling - Medium	Low
		To People in/adjacent to dwelling – Medium	Low
Small-Scale Slumps in Soil	Possible	To Dwelling - Minor	Moderate
		To People in/adjacent to dwelling - Minor	Moderate
Failure of Retaining Wall	Rare	To Dwelling – Minor to Medium	Low
		To People in/adjacent to dwelling – Minor	Very Low
Surface Erosion	Possible	To Dwelling - Insignificant	Very Low
		To People in/adjacent to dwelling - Insignificant	Very Low
Rock Fall	Possible	To Dwelling – Insignificant/Minor	Low
		To People in/adjacent to dwelling – Insignificant/Minor	Low

3.6 SIGNIFICANCE OF RISKS (RISK EVALUATION)

Risk evaluation is the process by which owners, administrators and relevant regulatory authorities can decide whether the potential risks (See Table 1) are acceptable, and/or whether these can be feasibly eliminated or reduced by remedial treatment. Implications of each level of risk are described in Appendix C.

In this case, the overall risk to property and people is assessed to be “Very Low” to “Moderate”. Provided design and construction of the structure is undertaken in accordance with accepted procedures for hillside construction, and treatments are carried out to reduce the potential hazards, the risk is no higher than normally acceptable for residential development.

3.7 RISK TREATMENT

To maintain and/or reduce the risk level of slope stability during the construction of the pool and associated structures and subsequent occupation, the following measures are recommended to be implemented:

- Ensure footings are founded on adequate material, preferably on weathered bedrock.
- Limit cut-to-fill earthworks. Excavations greater than 500mm will require support through the use of a permanent retaining wall.
- All retaining walls should be properly designed and constructed, and positively drained.
- Maintain adequate drainage of the site and ensure drains are free-flowing.
- Where possible, maintain the existing vegetation cover.
- Periodic inspection of the slope uphill for signs of erosion developing, and remediate as necessary.

Some useful guidelines on hillside construction, prepared by the Australian Geomechanics Society, are presented in Appendix E.

4 Site Classification

The upper (low to medium plasticity) soils generally are moderately reactive in terms of potential shrink-swell movements that may occur due to seasonal ground moisture changes. The characteristic ground surface movement “Ys”, as defined by AS2870 for the range of extreme dry to extreme wet moisture conditions is estimated to be between 20mm and 40mm. The site is therefore Class “M” (moderately reactive).

5 Structure Footings

AS2870 provides “deemed-to-comply” footing/slab designs, which for a class “M” site includes stiffened rafts, stiffened footing slabs, waffle rafts, and strip and/or pad footings with above ground floors. Footings and slabs should be in accordance with the principles of AS2870.

Footings including thickened sections of slabs forming footings should be taken below the fill material and founded in medium dense to dense natural soils. A footing depth of up to 0.8m/1.1m depth below existing surface levels may be required. It is recommended that, bored piers founded in the underlying bedrock, expected below 1.1m/2.0m depth, should be used.

Recommended allowable end-bearing pressures and shaft adhesion values for various footing systems and likely foundation materials are provided in Table 3.

Table 3 – Recommended Allowable End-Bearing Pressures for Footings

Foundation Material Type	Depth Below Existing Surface Level	Allowable End-Bearing Pressure			Allowable Shaft Adhesion on Bored Piers and Anchors	
		Strips	Pads	Bored Piers	Downward Loading	Uplift
Newly Placed Controlled Fill	-	100kPa	125kPa	N.A	N.A	N.A
Medium Dense to Dense Alluvial and Residual Soils	0.8m/1.1m	50kPa	75kPa	100kPa	10kPa	5kPa
HW/MW & less weathered bedrock (Class IV Sandstone)	1.1m/2m	1500kPa.	2000kPa	2500kPa	250kPa	125kPa

It is recommended that footings are inspected by a geotechnical engineer prior to the pouring of concrete to ensure that footings are founded in adequate material.

6 Excavation Conditions & Use of Excavated Material

It is understood that only shallow excavations will be required, although pool excavations could extend to ~2.0m depth. The excavations will be through topsoil, fill material, alluvial and residual soils and into weathered bedrock. The fill, alluvial and residual material is readily diggable by backhoe and medium sized excavator to at least 1.1m/1.9m depth. Moderately weathered and less weathered bedrock could be encountered below 1.1m/1.9m depth and would require heavy excavator, bulldozer ripping and rock hammering.

Any low/medium plasticity residual soils can be used in controlled fill construction of building platforms. Topsoil and existing uncontrolled fill material should not be used in controlled fill construction, however, it can be used for landscaping.

If imported fill is required, a suitable select fill material would include a low or medium plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay), and no particles greater than 75mm size.

7 Site Drainage

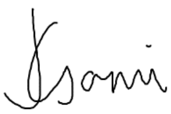
Permanent groundwater was not encountered during the investigation. The permanent groundwater table is expected to be below the proposed excavations. Temporary perched seepages may be present following rain, but should be readily controllable using pumps during construction.

Suitable surface drainage should be provided to ensure rainfall run-off or other surface water cannot pond against buildings or pavements. Drainage should be provided behind all retaining walls, and subsoil drains should be installed along the upslope sides of access roads and carparks.

Should you require any further information, please contact our office.

Yours faithfully,

Fortify Geotech Pty Ltd



Jerome Sami,
Geotechnical Engineer

SITE LOCALITY	S1273	FIGURE 1

LEGEND:

Borehole Location - ⊗
DCP Location - ☆

N

AERIAL PHOTOGRAPH AND BOREHOLE LOCATION	S1273	FIGURE 2

Figure 3: Site Photographs

Borehole Log

Borehole No.	1A
Sheet	1 of 1
Job No.	S1273

CLIENT: FMF Engineering

PROJECT: Proposed Alterations And Additions
48 Epping Drive, Frenchs Forest

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : HandHeld PushTube
Hole Diameter : 52mm

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.0–0.15		SM	SILTY SAND; fine to coarse grained sand, brown, grass roots at surface, trace roots, dry to moist	Medium Dense		TOPSOIL FILL
			0.15–0.8		SC	CLAYEY SAND; fine to coarse grained sand, low to medium plasticity clay, yellow to brown, trace roots, moist	Medium Dense		ALLUVIUM
			0.8–1.0		SC	CLAYEY SAND; fine to coarse grained sand, low to medium plasticity clay, yellow to brown trace orange and grey, trace roots, trace sub angular gravels to 2mm size, moist	Medium Dense to Dense		
			1.0–1.5		SC	CLAYEY SAND; fine to coarse grained sand, low to medium plasticity clay, yellow to brown trace grey, trace roots, trace sub angular gravels to 2mm size, moist	Medium Dense to Dense		
			1.5			BOREHOLE TERMINATED AT 1.5m At Target			
			1.7						

Logged By : JS Date : 10/5/21 Checked By : Date :

Borehole Log

Borehole No.	2A
Sheet	1 of 1
Job No.	S1273

CLIENT: FMF Engineering

PROJECT: Proposed Alterations And Additions
48 Epping Drive, Frenchs Forest

Equipment Type : HandHeld PushTube
Hole Diameter : 52mm

Location :

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Samples	Water	Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure (Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure)	Consistency or Relative Density	Field Test Results	Geological Profile
	None Encountered		0.15		CL	SILTY SANDY CLAY; medium plasticity clay, fine to coarse grained sand, brown, grass roots at surface, trace roots, dry to moist	Firm		TOPSOIL FILL
			0.2		SW	SAND; fine to coarse grained sand, yellow to brown, trace angular gravels to 10mm size, moist	Loose to Medium Dense		FILL
			0.3		SW	SAND; fine to coarse grained sand, yellow to brown, trace roots, moist	Medium Dense		ALLUVIUM
			0.9		SC	CLAYEY SAND/SANDY CLAY; fine to coarse grained sand, medium plasticity clay, yellow to brown, trace sub angular gravels to 2mm size, moist to wet	Medium Dense/ Firm		
			1.0 1.1		SW	SAND; fine to coarse grained sand, dark grey to black, some low to medium plasticity clay, trace sub angular gravels to 5mm size, moist	Medium Dense		RESIDUAL
			1.7			BOREHOLE TERMINATED AT 1.1m At Refusal			

Logged By : JS Date : 10/5/21 Checked By : Date :

ACT Geotechnical Engineers

Fortify Geotech

DESCRIPTION AND CLASSIFICATION OF SOILS

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 1993, Geotechnical site investigations. In general, descriptions cover the following properties – soil type, colour, secondary grain size, structure, inclusions, strength or density and geological description.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

Classification	**Particle Size**
Clay	Less than 0.002mm
Silt	0.002mm to 0.06mm
Sand	0.06mm to 2.00mm
Gravel	2.00mm to 60.00mm
Cobbles	60mm (63mm) to 200mm
Boulders	>200mm

Soils are also classified according to the Unified Soil Classifications System which is included in this Appendix. Rock types are classified by their geological names.

Cohesive soils are classified on the basis of strength either by laboratory testing or engineering examination. The terms are defined as follows:

Consistency	**Shear Strength su(kPa) (Representative Undrained Shear)**	
Very soft	< 12	<2 (~SPT "N")
Soft	12 - 25	2-4
Firm	25 - 50	4-8
Stiff	50 – 100	8-15
Very Stiff	100 – 200	15-30
Hard	> 200	>30

Non-cohesive soils are classified on the basis of relative density, generally from the results of in-situ standard penetration tests as below:

Term	**Relative Density (%)**	**SPT Blows/300mm 'N'**
Very loose	< 15	<4
Loose	15-35	4-10
Medium dense	35-65	10-30
Dense	65-85	30-50
Very Dense	>85	>50

SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.

2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 “Testing Soils for Engineering Purposes” Testing Soils for Engineering Purposes” – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63 kg hammer having a free fall of 750mm.

The “N” value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

DEFINITIONS OF ROCK, SOIL, AND DEGREES OF CHEMICAL WEATHERING

GENERAL DEFINITIONS – ROCK AND SOIL

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces.

Note: Since “strong” and “permanent” are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one.

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System. Three principal classes of soil recognized are:

Residual soils: soils which have been formed in-situ by the chemical weathering of parent rock. Residual soil may retain evidence of the original rock texture or fabric or, when mature, the original rock texture may be destroyed.

Transported soils: soils which have been moved from their places of origin and deposited elsewhere. The principal agents of erosion, transport and deposition are water, wind and gravity. Two important types of transported soil in engineering geology and materials investigations are:

Colluvium – a soil, often including angular rock fragments and boulders, which has been transported downslope predominantly under the action of gravity assisted by water. The principle forming process is that of soil creep in which the soil moves after it has been weakened by saturation. It may be water borne for short distances.

Alluvium – a soil which has been transported and deposited by running water. The larger particles (sand and gravel size) are water worn.

Lateritic soils: soils which have formed in situ under the effects of tropical weathering include all reddish residual and non residual soils which genetically form a chain of material ranging from decomposed rock through clay to sesqui-oxide rich crusts. The term does not necessarily imply any compositional, textural or morphological definition; all distinctions useful for engineering purposes are based on the differences in geotechnical characteristics.

ROCK WEATHERING DEFINITIONS

Extremely Weathered (EW)	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Classification System, but the texture of the original rock is still evident.
Highly Weathered (HW)	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered (MW)	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered (SW)	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite, has taken place. The colour and texture of the fresh rock is recognisable.
Fresh (Fr)	Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are weak, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

Fresh drill cores of some rock types, such as basalt and shale may disintegrate after exposure to the atmosphere due to slaking, desiccation, expansion or contraction, stress relief or a combination of any of these factors.

AN ENGINEERING CLASSIFICATION OF SEDIMENTARY ROCKS

This classification system provides a standardised terminology for the engineering description of the sandstone and shales in the Sydney area, but the terms and definitions may be used elsewhere when applicable. Where other rock types are encountered, such as in dykes, standard geological descriptions are used for rock types and the same descriptions as below are used for strength, fracturing and weathering.

Under this system rocks are classified by Rock Type, Strength, Stratification Spacing, Degree of Fracturing and Degree of Weathering. These terms do not cover the full range of engineering properties. Descriptions of rock may also need to refer to other properties (e.g. durability, abrasiveness, etc) where these are relevant.

ROCK TYPE DEFINITIONS

ROCK TYPE	DEFINITION
Conglomerate:	More than 50% of the rock consists of gravel sized (greater than 2mm) fragments.
Sandstone:	More than 50% of the rock consists of sand sized (0.06 to 2mm) grains.
Siltstone:	More than 50% of the rock consists of silt-sized (less than 0.06mm) granular particles and the rock is not laminated.
Claystone:	More than 50% of the rock consists of silt or clay sized particles and the rock is not laminated.
Shale:	More than 50% of the rock consists of silt or clay sized particles and the rock is laminated.

Rocks possessing characteristics of two groups are described by their predominant particle size with reference also to the minor constituents, e.g. clayey sandstone, sandy shale.

STRATIFICATION SPACING

Term	Separation of Stratification Planes
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

DEGREE OF FRACTURING

This classification applies to <u>diamond drill cores</u> and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Term	Description
Fragmented:	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
Highly Fractured:	Core lengths are generally less than 20mm – 40mm with occasional fragments.
Fractured:	Core lengths are mainly 30mm – 100mm with occasional shorter and longer section.
Slightly Fractured:	Core lengths are generally 300mm – 1000mm with occasional longer sections and occasional sections of 100mm – 300mm.
Unbroken:	The core does not contain any fracture.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	**Point Load Index Is(50) MPa**	**Field Guide**	**Approx qu MPa***
Extremely Weak:	0.03	Easily remoulded by hand to a material with soil properties.	0.7
Very Weak:	0.1	May be crumbled in the hand. Sandstone is “sugary” and friable.	2.4
Weak:	0.3	A piece of core 150mm long x 50mm dia. May be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	7
Medium Strong:	1	A piece of core 150mm long x 50mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.	24
Strong: (SW)	3	A piece of core 150mm long x 50mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.	70
Very Strong (SW)	10	A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	240
Extremely Strong (Fr)	>10	A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer.	>240

The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ration to the point load index of 24:1. This ratio may vary widely.

Unified Soil Classification System (Metricated)
Data for Description Indentification and Classification of Soils

Field identification (all soils): Determine approximate percentages of material over 60mm size, maximum size, shape, surface texture, hardness of material, geological description. Identify on estimated percentage mass of the various fractions. 0.05mm is about the smallest particle visible to the naked eye.

Laboratory classification: Use the gradation curve of material passing 60mm for classification of fractions according to criteria given under "Major Division".

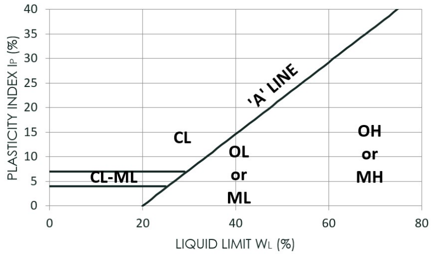
COARSE GRAINED SOILS – More than 50% by dry mass, less than 60mm is greater than 0.06mm. (Field identification: COARSE GRAINED SOILS – More than half of the material less than 60mm is larger than 0.06mm)

MAJOR DIVISIONS		Group Symbol	TYPICAL NAME	DESCRIPTIVE DATA	GRAVELS AND SANDS: GRADATIONS		NATURE OF FINES	DRY STRENGTH	Group Symbol	% (2) < 0.06mm	PLASTICITY OF FINE FRACTION			NOTES
GRAVELS	More than 50% of coarse grains are greater than 2.0mm	GW	Well graded gravels and gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition and hardness of the coarse grains, local or geological name and other perfinent descriptive information, symbols in parenthesis. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. EXAMPLE: Silty Sand, gravelly, about 20% hard, angular gravel particles, 10mm maximum size, rounded and sub angular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, light brown alluvial sand, (SM)	GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	GW	0-5	-	>4	Between 1 and 3	1. Identify Fines by the method given for fine grained soils. 2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols eg SP-SM GW-GC
GRAVELS		GP	Poorly graded gravels and gravel sand mixtures, little or no fines		POOR	Predominantly one size or range of sizes			GP	0-5	-	Fails to comply with above		
GRAVELLY SOILS		GM	Silty gravels, gravel-sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	GM	12-50	Below 'A' line and Ip >7	-	-	
GRAVELLY SOILS		GC	Clayey gravels gravel-sand-clay mixtures				Fines are plastic (1)		GC	12-50	Above 'A' line and Ip > 7	-	-	
SANDS	More than 50% of coarse grains are greater than 2.0mm	SW	Well graded sands and gravelly sands, little or no fines		GOOD	Wide range in grain size	"Clean" materials (not enough fines to band coarse grains)	None	SW	0-5	-	>6	between 1 and 3	
SANDS		SP	Poorly graded sands and gravelly sands, little or no fines		POOR	Predominantly one size or range of sizes			SP	0-5	-	Fails to comply with above		
SANDY SOILS		SM	Silty sand, sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are non-plastic (1)	None to medium	SM	12-50	Below 'A' line or Ip < 4	-	-	
SANDY SOILS		SC	Clayey sands, sand-clay mixtures				Fines are plastic (1)		SC	12-50	Above 'A' line and Ip > 7	-	-	

FINE GRAINED SOILS – More than 50% by dry mass, less than 6omm is less than 0.06mm. (Field identification: FINE GRAINED SOILS – More than half of the material less than 50mm is less than 0.06mm)

SILT AND CLAY FRACTION – Fraction smaller than 0 20mm AS sieve size

MAJOR DIVISIONS	Group Symbol	TYPICAL NAME	DESCRIPTIVE DATA	DRY STRENGTH	DILATANCY	TOUGHNESS	Group Symbol	% < 0.06mm	PLASTICITY OF FINE FRACTION
Liquid Limit less than 50%	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, colour in wet condition, odour if any, local or geological name and r pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure, stratification, consistancy in undisturbed and remoulded states, moisture and drainage conditions. EXAMPLE Clayey Silt, brown, low plasticity, small percentage of fine sand, numerous vertical root-holes, firm and dry in place, fill, (ML).	None to low	Quick to slow	None	ML	More than 50% passing 0.06mm	Below 'A' line
Liquid Limit less than 50%	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.		Medium to high	None to very slow	Medium	CL		Above 'A' line
Liquid Limit less than 50%	OL	Organic silts and organic silty clays of low plasticity		Low to medium	Slow	Low	OL		Below 'A' line
Liquid Limit more than 50%	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts.		Low to medium	Slow to none	Low to medium	MH		Below 'A' line
Liquid Limit more than 50%	CH	Inorganic clays of high plasticity, fat clays.		High to very high	None	High	CH		Above 'A' line
Liquid Limit more than 50%	OH	Organic clays of medium to high plasticity.		Medium to high	None to very slow	Low to medium	OH		Below 'A' line
	Pt	Peat muck and other highly organic soils.		Readily identified by colour, odour, spongy feel and generally by fibrous texture			Pt*	*Effervescence with H2O2	



PLASTICITY CHART
FOR CLASSIFICATION
OF FINE GRAINED SOILS

FORTIFY
GEOTECH

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

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

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

Attachment 1 – Risk Assessment Matrix

E – Extreme risk – detailed action plan required
H - High risk – needs senior management attention
M – Medium risk – specify management responsibility
L – Low risk – manage by routine procedures

High or **Extreme** risks must be reported to Senior Management and require detailed treatment plans to reduce the risk to **Low** or **Medium**.

	Consequence →				
People	Injuries or ailments not requiring medical treatment.	Minor injury or First Aid Treatment Case.	Serious injury causing hospitalisation or multiple medical treatment cases.	Life threatening injury or multiple serious injuries causing hospitalisation.	Death or multiple life threatening injuries.
Reputation	Internal Review	Scrutiny required by internal committees or internal audit to prevent escalation.	Scrutiny required by external committees or ACT Auditor General's Office, or inquest, etc.	Intense public, political and media scrutiny. Eg: front page headlines, TV, etc.	Assembly inquiry or Commission of inquiry or adverse national media.
Business Process & Systems	Minor errors in systems or processes requiring corrective action, or minor delay without impact on overall schedule.	Policy procedural rule occasionally not met or services do not fully meet needs.	One or more key accountability requirements not met. Inconvenient but not client welfare threatening.	Strategies not consistent with Government's agenda. Trends show service is degraded.	Critical system failure, bad policy advice or ongoing non-compliance. Business severely affected.
Financial	1% of Budget or <$5K	2.5% of Budget or <$50K	> 5% of Budget or <$500K	> 10% of Budget or <$5M	>25% of Budget or >$5M
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**

↑ Likelihood	Probability:	Historical:			1	2	3	4	5
	>1 in 10	Is expected to occur in most circumstances	**5**	**Almost Certain**	**M**	**H**	**H**	**E**	**E**
	1 in 10 - 100	Will probably occur	**4**	**Likely**	**M**	**M**	**H**	**H**	**E**
	1 in 100 – 1,000	Might occur at some time in the future	**3**	**Possible**	**L**	**M**	**M**	**H**	**E**
	1 in 1,000 – 10,000	Could occur but doubtful	**2**	**Unlikely**	**L**	**M**	**M**	**H**	**H**
	1 in 10,000 – 100,000	May occur but only in exceptional circumstances	**1**	**Rare**	**L**	**L**	**M**	**M**	**H**

Adapted from Standards Australia Risk Management AS/NZS 4360: 2004

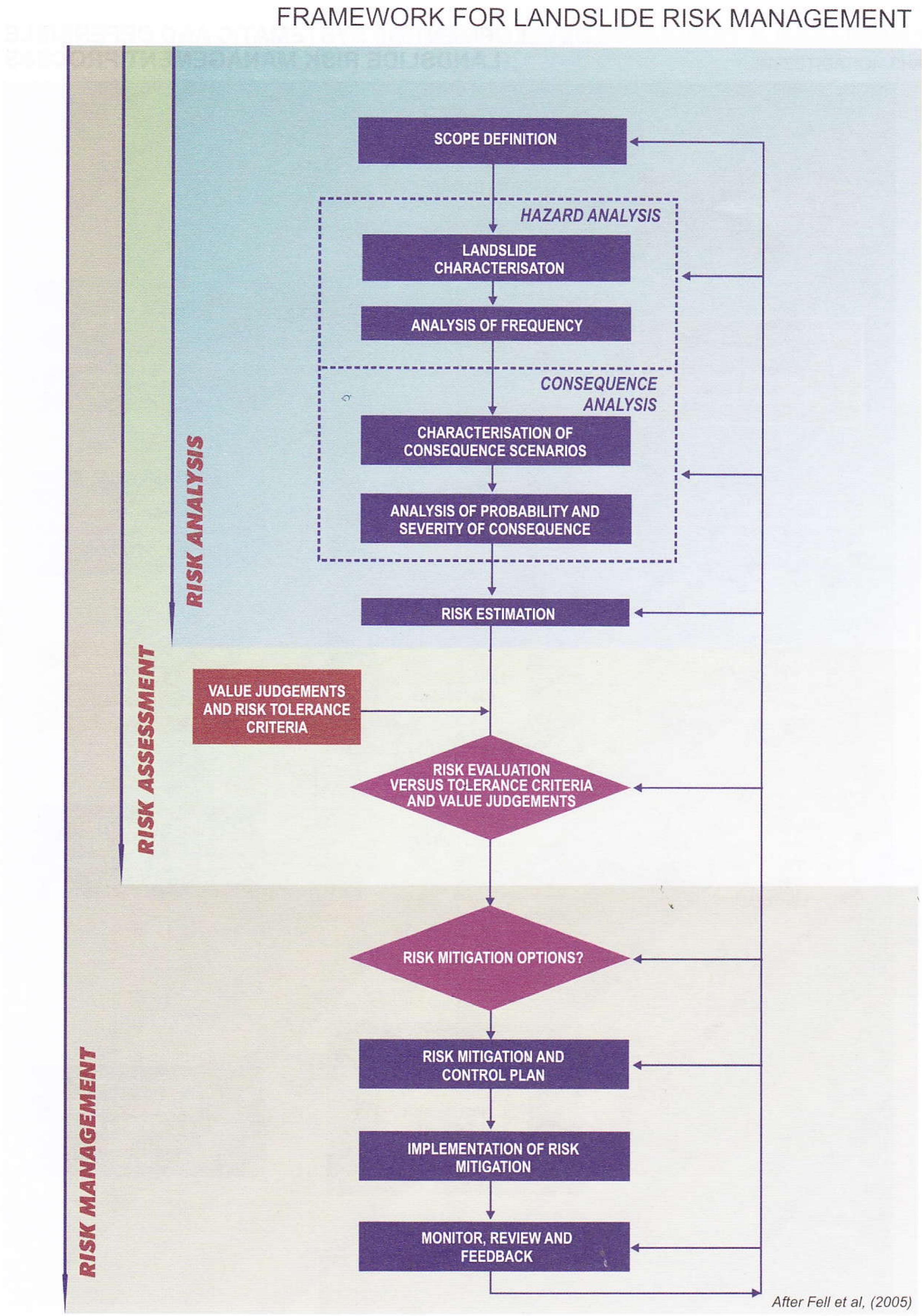
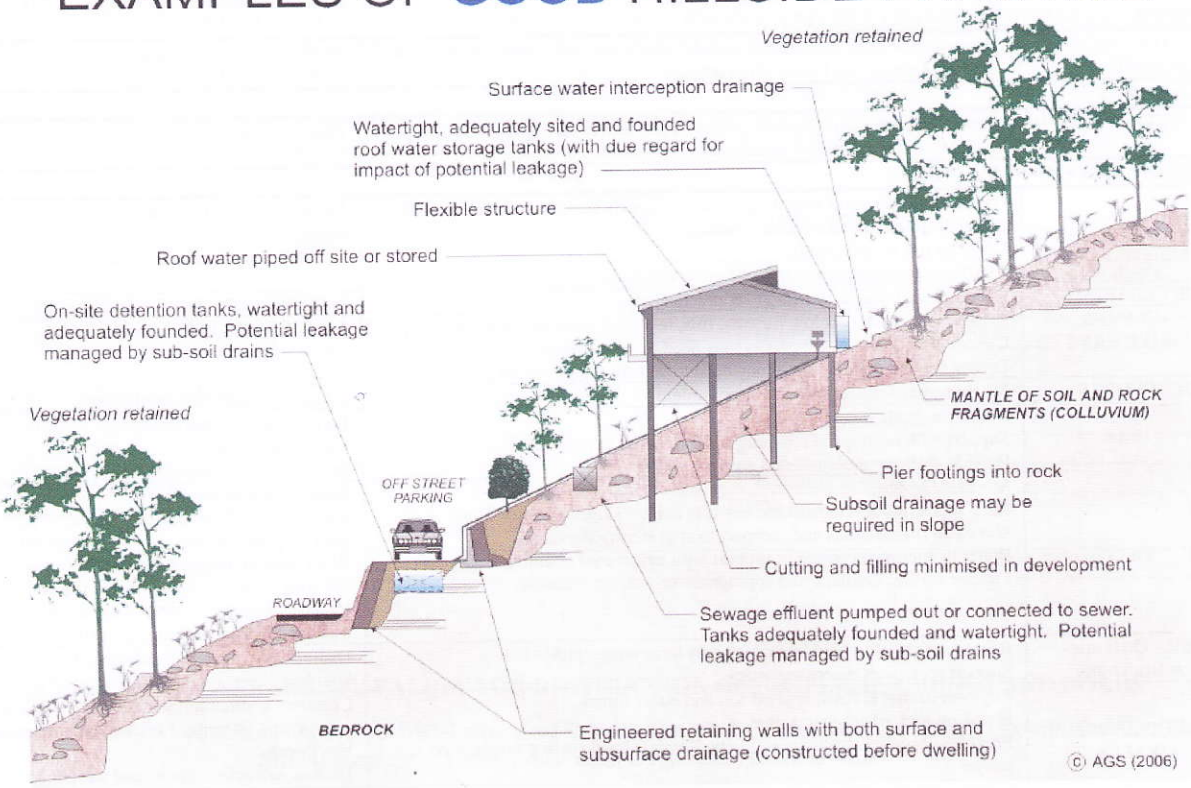


Figure 2: Abbreviated flowchart for Landslide Risk Management.
Ref: AGS (2007a, 2007c)

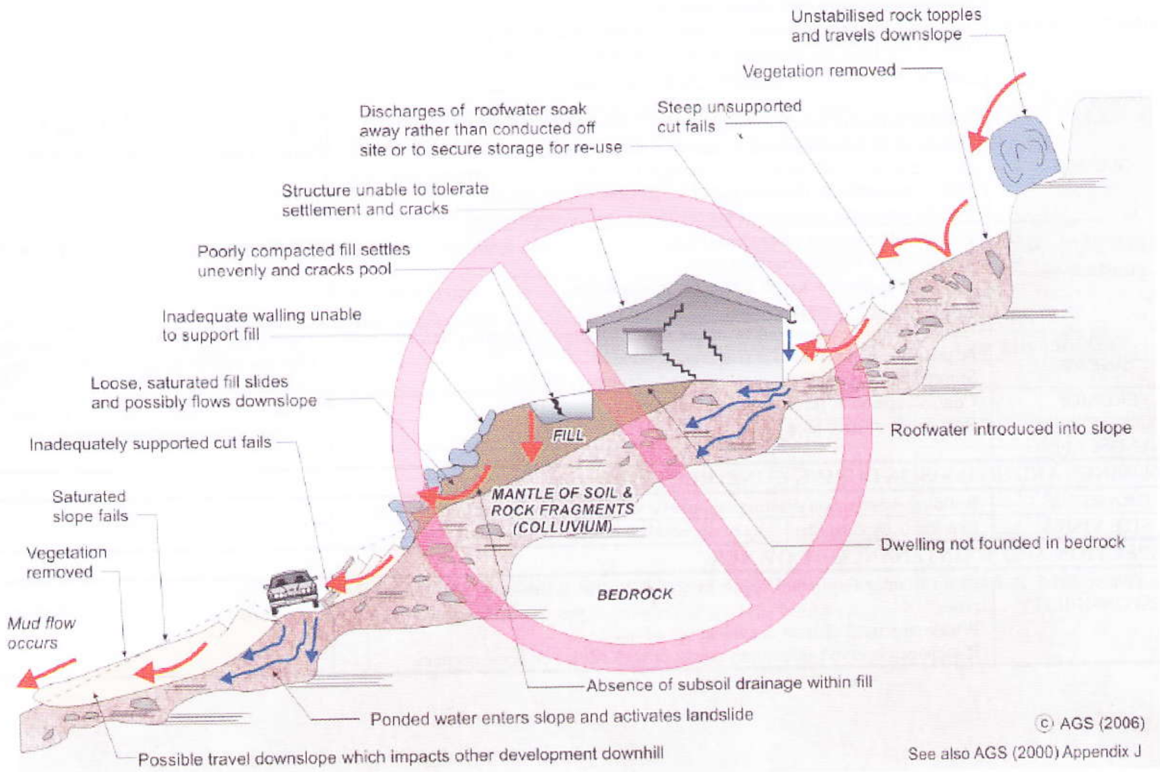
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



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Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observes in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.