REPORT ON

PRELIMINARY GEOTECHNICAL INVESTIGATION

FOR

PROPOSED REZONING DEVELOPMENT

AT

NO.225 TERRANORA ROAD, TERRANORA

DESCRIBED AS LOT 16 ON DP 856265

PREPARED FOR

WRENN PTY LTD

PROJECT REF: GI 3953-B

31 JANUARY 2019

geotech INVESTIGATIONS PTY LTD

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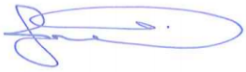
The undersigned, for and on behalf of Geotechnical Investigations Pty Ltd, confirm that this document and all attached drawings, logs, and test results prepared by Geotech Investigations Pty Ltd have been checked and reviewed for errors, omissions and inaccuracies.

Yours faithfully
For and on behalf of
Geotech Investigations Pty Ltd



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APPENDICES:-

1. INTRODUCTION

As requested, Geotech Investigations Pty Ltd (GI) has completed a preliminary geotechnical investigation for the rezoning application at No.225 Terranora Road, Terranora described as Lot 16 on DP 856265.

The scope of the geotechnical services was provided in a detailed proposal by GI, referenced: JW:GI P17 2058-a dated 17 November 2017. The scope of works are directed towards evaluating the following items to assist the design civil engineers, developer, town planner associated with the Development Application to Tweed Shire Council:-

- Subsurface conditions, including groundwater;
- Stability risk assessment in accordance with Australian Geomechanics Society Guidelines. Depending upon the results of this initial assessment, more detailed investigations may be required in the future for each individual site.
- Earthworks, excavations, site preparation, compaction, re-use of excavated materials for fill;
- Suitable batter slopes for cut and fill embankments (temporary and permanent);
- Shrink-swell movements and indicative Site Classification in accordance with AS2870-2011.
- Geotechnical constraints that may be encountered for future development.

Initial investigations were completed by GI, in a report entitled 'Preliminary Geotechnical Investigation' referenced: GI 3953-a dated 24 September 2019. These investigations have been included within this report.

2. SITE DESCRIPTION AND OBSERVATIONS

A site visit was carried out on the 13th of March and later on the 21st of December 2018 by a Senior Geotechnical Engineer from our office, with the purpose of viewing the northern large rectangular shaped portion of the site (the subject site) and making observations with regard to the local geology, existing vegetation, geomorphology and topography. The subject site was previously used as a rock quarry, typically extracting basalt. It must be noted that the extent of earthworks completed on the site obscured the natural slopes.

For the purpose of delineation, the southern portion of the site is described as the portion of the site which funnels down from the eastern side towards Old Ferry Road. This portion of the site was not walked over nor investigated and has not been further discussed.

In general, the subject site is most elevated along the entrance off Terranora Road between No.223 and No.227. From the south eastern corner of No.227, the subject site extends down to two main large platforms which were likely formed as part of the closure of the quarry. A relatively high steep embankment forms the majority of the northern site boundary which grades down from the adjacent properties along Terranora Road and The Parapet. A large overgrown fill batter was located between the two main platforms typically from test pit TP 4 towards TP 7.

A drainage or natural gully was located in the north eastern section of the site extending down towards Old Ferry Road. The southern boundary of the upper level extends steeply down towards the south and is heavily vegetated.

The site coverage is typically grass, low lying weeds and shrubs and isolated pockets of more matured trees, typically along the western and eastern sections of the site.

3. REGIONAL GEOLOGY

Reference to geological mapping by the Geological Survey of New South Wales 1:250,000 series 'Tweed Heads' sheet indicates the site is underlain by soils from the Tertiary aged (23 million years old) Lamington Volcanics, which typically comprise *"basalt with members of rhyolite, trachyte, tuff, agglomerate and conglomerate"*. These materials often cap the much older (460 million years) Neranleigh Fernvale Beds.

As previously discussed, the subject site was previously used as a rock quarry, typically extracting basalt. Following the completion of the extraction activities, it is understood and further confirmed with these investigations, the subject site was extensively filled and reshaped to form the current topography.

4. SITE INVESTIGATION

4.1 Field Work Methodology

Fieldwork was undertaken on the 13th of March 2018 with additional investigations completed on the 21st of December 2018. The investigations comprised the excavation of 14 test pits in total, designated TP 1 to TP 14, using a 5.5 t hydraulic excavator. The test pits were undertaken at accessible locations spread over the general subject site area to termination depths between 0.6 m and 3.5 m. The approximate locations of the test pits are shown on Site Plan S01 attached in Appendix A with hand held GPS locations shown on the attached engineering logs.

This investigation has been carried out generally in accordance with AS 1726 – 2017[1] in terms of soil description. The fieldwork was carried out by an experienced senior Geotechnical Engineer who positioned and logged the materials encountered in the test pits. At the completion of the investigation, the test pits were backfilled with excavated spoil.

4.2 Field Work Results

The results of the fieldwork are described in the form of Engineering Logs in Appendix B, along with explanatory notes in Appendix C. In summary, the subsurface conditions encountered in the boreholes can be described as 'uncontrolled' **fill**, residual **soils** and weathered **rock,** described as basalt. Table 1 has summarised the typical depths of these layers at each test pit location.

[1] Australian Standard AS 1726-2017 *'Geotechnical site investigations'*, Standards Australia

Table 1: Summary of Subsurface Materials

Test Pit No.	Uncontrolled Fill (m)	Residual Soils (m)	Rock (m)	T.D. (m)
TP 1	0 – 1.8	1.8 – 2.3	NE	2.3
TP 2	0 – 1.3	NE	1.3 – 1.8	1.8(1)
TP 3	0 – 3.2	NE	3.2 – 3.4	3.4
TP 4	0 – 0.6	0.6 – 2.1	NE	2.1
TP 5	0 – 3.5	NE	NE	3.5
TP 6	0 – 2.1	NE	NE	2.1(1)
TP 7	0 – 0.4	NE	0.4 – 0.6	0.6(1)
TP 8	NE	0 – 0.4	0.4 -1.7	0.7(1)
TP 9	0 – 1.6	NE	1.6 – 1.7	1.7(1)
TP 10	0 – 0.7	0.7 – 0.9	0.9 – 1.1	1.1(1)
TP 11	NE	0 – 2.8	NE	2.8
TP 12	0 – 2.9	NE	NE	2.9
TP 13	0 – 2.1	2.1 – 2.8	NE	2.8
TP 14	NE	0 – 2.4	NE	2.4

Notes: (1) Slow penetration to practical refusal

NE - Not Encountered

4.3 Groundwater

Standing groundwater and seepage was observed while the test pits remained open, refer to Table 2. It was evident in the test pits that the groundwater would generally sit at the interface between the fill and natural or above the basalt rock.

Table 2: Ground Water Summary

Test Pit No.	Seepage Level (m BSL)	Standing Water Level (m BSL)
TP 1	1.8	NM
TP 5	3.2	NM
TP 9	1.6	1.6
TP 10	0.9	NM

Notes: BSL – Below Existing Surface Levels

NM – Not Measured

It should be noted that groundwater is affected by climatic conditions, varying soil permeability, and will therefore vary over time.

5. RESULTS AND DISCUSSION

5.1 Proposed Development

The proposed development is understood to comprise the re- rezoning of the existing allotments for the purpose of future residential development. Detailed development plans have not been provided at this date, however a conceptual layout plan indicates a series of larger residential type allotments of a minimum 4000 m^2 each and an internal access road servicing these allotments.

5.2 Discussion on Subsurface and Surface Conditions

The results of the fieldwork and surface assessment indicate the conditions encountered in the location of the proposed rezoning area can be summarised as follows:-

Previous Site History: The site was previously used as a 'basalt' rock quarry. Experience with similar geology in the area and based on knowledge of the quarry, it is understood the site was excavated of the overlying vegetation and soils, typically considered 'overburden'. The basalt rock is then extracted and exported for various uses. Following the cease of use for the quarry, the overburden was spread back over the site to form the existing topography. The test pit investigation further confirms these understandings. As a result of these works, significant and varying depths of 'uncontrolled' fill exists over the site.

Basalt: Basalt was encountered at TP 2, TP 3 and TP 7 to TP 10. The basalt was typically described as highly to moderately weathered and is low to medium strength, as a guide only.

Drainage: A relatively steep gully traverses from the north eastern section of the site (below the existing shed) and extends down towards Old Ferry Road. The gully provides significant drainage and surface water runoff for the overland flow on the site and there are some localised steep slopes within the gully. The northern areas of the site are typically poorly drained.

Table 2, Section 4.3 of the report provides details of the existing seepage and groundwater levels encountered during the investigations. The groundwater is likely a result of natural springs, commonly encountered in the area and surface water seeping through the fill. The seepage layers were typically encountered at the interface of the existing fill and natural soils or above the basalt.

5.3 Key Geotechnical Constraints

A summary of the key geotechnical constraints outlined within this report are detailed below:-

1. ***Uncontrolled Filling:*** The site has been extensively filled and the fill is described as typically poorly compacted containing traces of deleterious materials and oversized materials. If left insitu, shallow footing systems and 'standard' residential type development, infrastructure and service

construction would not be possible due to unacceptable levels of risk against settlement and movement. There are common engineering solutions and construction options that can be considered as mitigation to such risks which are further detailed in Section 5.5.

2. ***Slope Stability:*** Based on experience with similar fill soils at slopes of greater than about 12 degrees there is an unacceptable level of risk against slope movement for areas within residential development. Localised gullies, steeper slopes and any areas of potential past and present instability (such as creep movement) will limit building locations, amongst possible other constraints associated with the development. Section 6 provides a detailed landslide susceptibility assessment along with possible mitigation options for areas of risk to instability.
3. ***Road and Infrastructure:*** Due to risk of irregular settlements of uncontrolled fill, roads, services and other infrastructure could not be supported within the existing uncontrolled fill. There are common engineering solutions and construction options that can be considered as mitigation to such risks which are further detailed in Section 5.5.
4. ***Subsurface and Surface Drainage Control:*** Further investigations to be completed to assist with a clear understanding on the best methodology to control drainage within the specific building envelopes and any future roads.

5.4 Uncontrolled Filling

For the purpose of this report, uncontrolled fill refers to the placement of materials without technical and control requirements as specified in AS 3798 – 2007[2]. If documentation can be provided to reflect such requirements have been met this report will need to be revised, however the presence of deleterious materials throughout the fill would cast doubt that such documentation is available.

The proposed rezoning of the subject site is understood to be for the use of residential land development consisting of large lots with access provided through an internal road. It is also understood that infrastructure will require stormwater and electricity, however sewerage will consist of onsite wastewater. The depth and extent of the uncontrolled fill encountered during the site investigation exhibits a level of risk to structures such as roads, dwellings and services and potentially adjoining land.

Through engineering design and flexible planning, there are solutions to control such risks. These options are detailed in Section 5.5.

5.5 Remediation Options

The following summarised mitigation options are provided as a guide to assist the developer, design engineers and planning consultants with reducing the risk of damage to roads, infrastructure, services and future dwellings caused by potential settlements of the uncontrolled fill. These alternative methods are to

[2] Australian Standard AS 3798-2007 *'Guidelines on earthworks for residential and commercial developments'*, Standards Australia

be used for discussion and conceptual planning purposes and it must be noted further detailed geotechnical design advice will be required during the detailed civil design and prior to any construction.

5.5.1 Remove and Replace (Option 1)

This option requires full removal and replacement of all uncontrolled fill and provides the development with the lowest risk of all options for potential movement associated with standard construction techniques. Refer to Section 5.5 for the required details of site preparation and fill placement to achieve this option.

5.5.2 Partial Remove and Replacement (Option 2)

This option requires localised removal and replacement of all uncontrolled fill within the building envelopes, road easements and under stormwater water service trenches. Refer to Section 5.5 for the required details of fill placement to achieve this option.

5.5.3 Ground Treatment (Option 3)

This option requires removal of the upper 1.5 m of uncontrolled fill over the site or a minimum 1.5 m below the design level (whichever is the greater). The exposed ground surface can then be compacted using 'impact rolling' techniques or conventional earthworks. Due to the high loads imposed by the impact rollers and the resulting higher compactive effort, this option is preferred and is likely to provide a more suitable foundation for filling over. Removal of natural ground, where encountered is not required and excavations may cease at this level at the discretion of GI consulting engineers.

5.5.4 Piled Structures and Removal and Replacement (Option 4)

This option requires removal and replacement of fill under roads and infrastructure and services, unless these can be designed for the potential movements. All buildings and other movement sensitive structures (retaining walls, etc) located in areas of uncontrolled fill will need to be supported using a piled foundation.

5.6 Earthworks

5.6.1 Site Preparation and Fill Placement

It must be noted, the scope of any earthworks program is dependent upon the choice of remediation option to be adopted in Section 5.5. Generally, all earthworks are to be carried out in accordance with AS 3798 – 2007[3].

The placement of fill can be broadly based on the following guidelines, however the design engineer must detail the actual earthworks guidelines and should comply with AS 3798 – 2007.

- The building and pavement areas, and areas to accept new fill, should be prepared by removing any unsuitable "uncontrolled" fill, loose debris, soils that are wet, or contain vegetation or deleterious materials. The extent of removal of uncontrolled fill will be dependent on the remediation option selected in Section 5.5.
-

[3] Australian Standard AS 3798-2007 *'Guidelines on earthworks for residential and commercial developments'*, Standards Australia

- It is expected that the existing clays and silts could be re-used for fill, depending upon the performance requirements, moisture control and conditioning, and ensuring any oversize particles are removed. The use of silty soils can be difficult as they are susceptible to moisture.
- The exposed subgrade should be test rolled using a 12 tonne roller (or similar), loaded water truck or dump truck to determine the presence of any soft spots, which should be excavated out and replaced with compacted select fill. The surface should be tyned to 0.2 m depth, moisture conditioned and then compacted.
- Structural fill for earthworks should be uniformly compacted to 95% Standard MDD (or higher), with moisture content within 2% wet or dry of OMC for cohesive material. Layer thickness depends on the compaction equipment, however 200 mm to 250 mm loose layer thickness is generally considered suitable for most mechanical compaction equipment. Where backfill for service trenches is carried out, the above layer thickness applies however if vibrating plates are used, the layers are to be placed in 100mm loose thickness.
- Field testing must be carried out to confirm the standard of compaction achieved and the moisture content during the construction. The test frequency and extent of testing is to be carried out as per AS 3798, Section 8.0 and compaction testing is to be carried out by a NATA accredited laboratory.
- The placement of fill material to support building loads and pavements must be placed and compacted under 'Level 1' full-time geotechnical inspections and testing.

5.6.2 Suitability of Excavated Material for Various Uses

The natural materials encountered on the site are considered suitable for use as engineered fill subject to the construction requirements described in Section 5.6.1 and the civil design engineers specification. Where the existing fill is to be removed and replaced consideration is required for careful management of fill including the requirements for removal of any deleterious materials, oversized materials or organics.

Consideration to contaminated land is beyond the scope of this report and consultation with a suitably qualified contaminated land consultant is required.

5.6.3 Batter Slopes

Stable batter angles in soils are strongly dependent upon fill type and compaction, soil type and strength, strength of underlying soils, slope angle / height and surcharge loadings. For the purpose of preliminary design, the batter slopes presented in Table 3 are considered to be suitable for the different soil and rock conditions encountered on the site. Where soil / rock conditions vary from those presented in Table 3, GI may provide guidance and alternative slope angles on site during construction. At these batter slopes, some movement at and behind the slope crest, as well as some localised slumping of batter faces may occur.

If batter heights exceed 3 m, then this will require batters to be separated by a minimum horizontal bench width of 1 m, which is to slope away at 1V:10H to promote drainage. The batter slopes assume that no surcharge loadings will be applied to the crest of the slope, and that no seepage out of the batter is present. If seepage is encountered or present at any stage, site specific geotechnical advice on batter stability should be obtained, and likely positive support options considered. All permanent batter slopes are to be protected from erosion and scour by use of appropriate drainage and vegetation.

Table 3: Slopes Angles for Batter Heights < 3 m (Unsurcharged, Horizontal Ground Behind Crest) [(1)]

Material Description	Short Term (Maximum)	Long Term (Maximum)[(1)]
Uncontrolled Fill	1V:2H (26°)	1V:4H (14 °)
Controlled Fill [(2)]	1V:1H (45°)	1V:2H (26°)
Residual Soils	1V:1H (45°)	1V:2H (26°)
Very Low Strength (or better) Rock [(3)]	1V:0.5H (63°)	1V: 1H (45°)

Notes:
[(1)] A geotechnical engineer from GI is required to be on site during excavations of embankments and placement of fill batters to confirm safe batter slopes. These slopes assume the batters are not underlain by lower bearing strata.
[(2)] All 'controlled' fill batters should be overfilled, compacted and cut back at a maximum angle given in Table 3 for filled batters. These slope angles are dependent on the fill material used and must not be underlain with uncontrolled fill.
[(3)] The stability of excavations in rock is often governed by the presence of geological structures such as bedding planes, joints and faults. A suitably experienced Engineering Geologist/Geotechnical Engineer must inspect the excavations at the time of construction to assess whether the slope angles recommended in Table 3 are appropriate for the exposed conditions.

5.7 Preliminary Site Classification

At this stage of the development and considering the existing conditions, typically the site must be classified as **'Class P'** in accordance with the provisions of AS 2870 due to the presence of 'uncontrolled' fill material and risk to slope movement. Where remediation options are completed, the individual sites may then be investigated along with site specific Site Classifications.

6. ASSESSMENT OF THE LIKELIHOOD OF SLOPE INSTABILITY USING AGS GUIDELINES

6.1 Discussion

Natural hill slopes are formed by processes which reflect the site geology, climate and environment. The natural process can be influenced by human intervention in the form of earthworks, construction or other related activities. The risk associated in hill side construction is far greater than level construction. Good hill side building practices should be adopted to decrease the risk associated with it. Figures on good and bad hillside construction are presented in Appendix D of this report.

To define a slope as being 'stable' or 'unstable' is not technically feasible, however assessing the likelihood of slope movement can help in defining the stability of the site. Several methods can be adopted to assess the likelihood of slope movement including existing surface features supplemented with knowledge of the subsurface profile and experience gained on similar sites.

A five-fold subdivision of landside likelihood categories has been developed by the Australian Geomechanics Society-Sydney Group (AGS-SG) and is described in their 1985 paper on "Geotechnical Risk Associated with Hillside Development". In March 2003, the AGS Sub-Committee on landslide Risk Management subsequently published "Landslide Risk Management Concepts and Guidelines" which review the earlier publication and the most current review in the 2007 publications.

The guidelines typically is to define and assess the "risk" as a function of the likelihood or probability of an event occurring (i.e. landslide, batter failure etc.) and the damage that this event may have (i.e. damage to property, loss of life etc.). Landslide and hazard risk zoning is a method of identifying different areas on a

site with regard to the potential of a hazard or risk and incorporating this risk into local planning and development. The risk assessment process involves answering the following question:-

- What might happen?
- How likely is it?
- What damage or injury may result?
- How important is it?
- What can be done about it?

It is normal to carry out a preliminary assessment of the first two points and is generally based on the site observations and soil profiles.

The causes of slope instability are well documented in the above mentioned literature and include the following factors:-

- Slope angle;
- Underlying geology and soil types;
- Vegetation cover;
- Variable and transient factors such as rainfall intensity, overland water flows, groundwater flows, piezometric pressures and seismic vibrations;
- Presence of soil masses in an unstable condition (ie. past movement);
- Man made factors such as construction activity including earthworks, removal of vegetation and changes to the surface and subsurface drainage, retaining walls, etc.

For any given area some of the above factors can be identified, while other possible contributing factors can be considered. From studying existing slope instabilities and the failure mechanisms, it is possible to make an assessment of the potential, relative likelihood of similar conditions arising in other areas. Slope instabilities can also be induced from man made factors including:-

- The construction of fill slopes;

- Undermining of steep slopes;
- Changing of water flow paths, in particular at the toe of slopes;
- Concentrated stormwater flow onto building platforms;
- Inadequate design and/or construction of retaining walls; and
- Saturation of soil below septic waste disposal absorption fields.

The terminology of the AGS Guidelines has been employed in the descriptions of hazards and the qualitative assessment of the likelihood, consequence and risk of slope instability. The following guidelines can be used for describing the likelihood of slope movement;

Likelihood	**Probability**	**Qualitative Risk**	**Significance**
Barely Credible	10^{-6}	Very Low	Acceptable
Rare	10^{-5}	Low	Usually Acceptable
Unlikely	10^{-4}	Moderate	May be tolerated
Possible	10^{-3}	High	Unacceptable
Likely	10^{-2}	Very High	Unacceptable
Almost Certain	10^{-1}	Extremely High	Unacceptable

Any proposed residential development should generally include works which result in 'acceptable' or 'usually acceptable' risk level to the property after construction. In some cases, subject to appropriate monitoring and maintenance programs, a 'may be tolerated' risk may be accepted. Definitions of acceptable and tolerable risk included in the AGS Guidelines are attached as Appendix C.

6.1.1 Risk Categorisation

The site has been qualitatively classified in accordance with the methods of the AGS.

The effect of these hazards on the site has been summarised in Table 4, together with a qualitative assessment of likelihood, consequence and risk to the property in its proposed conditions.

Table 4: Hazard and Risk Summary for Proposed Multi-Dwelling Development

Hazard	Likelihood	Possible Consequence	Risk Category
Landslip in "uncontrolled" fill batters at greater than 14°	Possible	• Moderate damage to proposed structures, services and proposed roads. • Injury to person/s.	Moderate
Landslip in 'natural' soils sloping at less than 18°	Rare	• Moderate damage to proposed structures, buried services and parked vehicles.	Low

Hazard	Likelihood	Possible Consequence	Risk Category
		• Injury to person/s.	
Landslip in 'natural' soils sloping between 18° and 26°	Unlikely	• Moderate damage to proposed structures, buried services and parked vehicles. • Injury to person/s.	Moderate
Surface water from ridgeline / upper slopes weakening founding soils	Unlikely	• Minor damage to structures and retaining walls for repair.	Low

The analysis summarised in Table 4 indicates **"moderate"** risks which are unacceptable for residential development and additional mitigation measures must be put in place to reduce the risk to more tolerable or acceptable levels.

6.2 Suggestions to Maintain and Reduce Risk of Instability

The risk mitigation will need to concentrate on maintaining the 'low' risk categories within the proposed building areas with specific mitigation required for areas within the 'moderate' risk categories.

The recommendations in Table 5 below are designed to maintain or reduce the risk of slope instability to an acceptable level for future development of the site.

Table 5: Risk Mitigation Measures for Proposed Dwellings

Hazard	Hazard Mitigation Measures	Risk Category
Landslip in "uncontrolled" fill batters at greater than 18°	• Locate all footings for the dwellings and retaining walls in the natural clays or better (rock). • (Option 1) Retain Existing Uncontrolled Filled Batters using engineered designed retaining walls. • (Option 2) Flatten Existing Uncontrolled Fill batters in accordance with Section 5.6.2.	Low
Landslip in 'natural' soils sloping at less than 18°	• Any development in these areas requires site specific investigations and will be dependent on Remediation Options as outlined in Section 5.5.	TBC
Landslip in 'natural' soils sloping between 18°and 26°	• As above, however any development in these areas should be avoided.	TBC
Surface water from ridgeline / upper slopes weakening founding soils	• All surface water from the upper areas is collected and / or diverted away from the building envelopes, into the stormwater system or approved stormwater discharge point. Preventing additional	Low

Hazard	Hazard Mitigation Measures	Risk Category
	runoff on the site is essential in maintaining and improving the existing risk of instability.	

Notes: TBC – Additional site specific investigations would be required for such areas of the site and would be highly dependent on the chosen remediation options as per Section 5.5.

The following recommendations are a summary and also aimed to assist with reducing or maintaining the risk of slope instability within the proposed building area:-

- Gravity retaining walls such as boulder, gabion and crib are not recommended, where underlain with existing fill.
- Embankment protection is to be placed on the embankment faces (e.g. mulching, planting vegetation) to limit the degree of rill erosion from water runoff and drying out / cracking if left exposed, as these will influence the potential for inducing landslips.
- Ensure all stormwater management plans and drainage plans are adhered to, particularly in relation to ensuring that all surface water is collected and diverted away from the building envelopes, top of batters and retaining walls. Preventing additional runoff on the site is essential in maintaining and improving the existing risk of instability.
- Maintain good vegetation over the remainder of the site and provide additional vegetation with good root systems for any batters and cut embankments.

7. LIMITS OF INVESTIGATION

Recommendations given in this report are based on the information supplied in conjunction with the findings of the investigation. Any change in the information provided (plans, allotment layouts, development use etc) may require additional testing and/or make recommendations invalid.

Every reasonable effort has been made to locate test sites so that the test pits are representative of the general soil conditions within the rezoning area to be investigated, as outlined by the client, however it must be noted that this assessment is a preliminary geotechnical investigation with the expectation that further discussions and rectification options will be discussed with GI during the detailed design phase.

APPENDIX A

SITE PLAN S01

GeoTech INVESTIGATIONS PTY LTD

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CLIENT: WRENN PTY LTD

PROJECT: PROPOSED RESIDENTIAL DEVELOPMENT AT No.225 TERRANORA ROAD, BANORA POINT

DRAWING REF: S01: SITE PLAN

LEGEND:
Approximate Test Pit Locations (refer to GPS locations on Engineering Logs)

Site Plan provided by Google Earth

APPROXIMATE NORTH

NORTH

DATE: 21.12.2018

OUR REF / JOB No.: GI 3953-b sp

DRAWN BY: JDW

Drawing not to scale. Printed dimensions only.

APPENDIX B

ENGINEERING LOGS – TEST PITS PROFILES TP 1 TO TP 14

GEOTECH INVESTIGATIONS PTY LTD

Unit 3/42 Machinery Drive, Tweed Heads South NSW 2486
Ph: 0755 233 979 Fax: 0755 233 981

ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.235641	E:	153.532198

CLIENT: WRENN PTY LTD — **TEST PIT I.D. :** TP 1

PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT — **JOB No.:** GI 3953-a

EQUIPMENT TYPE: 5.5 TONNE KUBOTA — **BUCKET SIZE:** 450mm — **PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CH) Silty CLAY: High plasticity, With gravel, With cobbles and boulders throughout, Moist ($w>w_p$), Dark red/brown and grey	F - St	PP = 110 - 130		FILL *PP's difficult to complete due to coarse materials and friable nature of clay *Boulders up to 0.6m dia.
	►	1.0						
		1.5						
		2.0		(CH) Silty CLAY: High plasticity, With gravel and boulders, With cobbles throughout, Moist ($w>w_p$), Red/brown	St			RESIDUAL
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 1 TERMINATED AT 2.3m – LIMIT OF INVESTIGATION DUE TO DIFFICULT PENETRATION THROUGH COBBLES

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: JDW	Date: 13/03/18	Checked By:	Date:

GEOTECH INVESTIGATIONS PTY LTD

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.235315	E:	153.531518

CLIENT: WRENN PTY LTD | **TEST PIT I.D. :** TP 2

PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT | **JOB No.:** GI 3953-a

EQUIPMENT TYPE: 5.5 TONNE KUBOTA | **BUCKET SIZE:** 450mm | **PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CH) Silty CLAY: High plasticity, With gravel, With cobbles and Weathered basalt boulders throughout, Wet to very moist ($w>w_p$), Dark red/brown and grey	F - St			FILL ? *PP's difficult to complete due to coarse materials
		1.0						
		1.5		(HW) BASALT and layers of (XW) BASALT mixed with medium to high plasticity silty clay: Red, dark orange/brown and grey	VLw			RESIDUAL
				(HW-MW) BASALT: Fine grained, Grey, dark grey and red/brown	Lw			
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 2 TERMINATED AT 1.8m – LIMIT OF INVESTIGATION DUE TO VERY SLOW PENETRATION

METHOD

AD	Auger Drilling
C	Casing
MS	Mud Support
NMLC	Rock Coring
RR	Rock Roller
TB	Toothed Bucket
TC	Tri Cone
WB	Wash Bore

WATER

▼	Water Level
►	Water Seepage

WEATHERING

EW	Extremely
HW	Highly
DW	Distinctly
MW	Moderately
SW	Slightly
F	Fresh

CONSISTENCY / DENSITY / ROCK STRENGTH

VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS

U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: JDW	Date: 13/03/18	Checked By:	Date:

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.235063	E:	153.530866

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 3
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-a
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CH) Silty CLAY: High plasticity, With gravel, With cobbles and boulders throughout, Wet to very moist ($w>w_P$), Dark red/brown and grey	F - St			FILL *PP's not possible with Cobbles throughout
		1.0						
		1.5						
		2.0						
		2.5						Trace of building Material and grease cartridge
		3.0						
				(HW) BASALT and layers of (XW) BASALT mixed with medium to high plasticity silty clay: Red, dark orange/brown and grey	VLw			RESIDUAL
		3.5						
		4.0						
		4.5						

TP 3 TERMINATED AT 3.4m – LIMIT OF REACH

METHOD		WEATHERING		CONSISTENCY / DENSITY / ROCK STRENGTH				SAMPLES / TESTS	
AD	Auger Drilling	EW	Extremely	VS	Very Soft	D	Dense	U( )	Undisturbed (size in mm)
C	Casing	HW	Highly	S	Soft	VD	Very Dense	D	Disturbed
MS	Mud Support	DW	Distinctly	F	Firm	Fb	Friable	BS	Bulk Sample
NMLC	Rock Coring	MW	Moderately	St	Stiff	ELw	Extremely Low	DCP	Dynamic Cone Penetrometer
RR	Rock Roller	SW	Slightly	VSt	Very Stiff	VLw	Very Low	SPT	Standard Penetrometer Test
TB	Toothed Bucket	F	Fresh	Hd	Hard	Lw	Low	N	Number of blows for SPT / 300mm
TC	Tri Cone			VL	Very Loose	M	Medium	VS	Vane Shear
WB	Wash Bore			L	Loose	H	High	A	Acid Sulfate Sample
WATER				MD	Medium Dense	VH	Very High	PP	Pocket Penetrometer (kPa)
▼	Water Level								
►	Water Seepage								

Logged By:	JDW	Date:	13/03/18	Checked By:		Date:	

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.234886	E:	153.530287

CLIENT: WRENN PTY LTD | **TEST PIT I.D. :** TP 4

PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT | **JOB No.:** GI 3953-a

EQUIPMENT TYPE: 5.5 TONNE KUBOTA | **BUCKET SIZE:** 450mm | **PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.0		(CH) Silty CLAY: High plasticity, With gravel, With cobbles and boulders, Moist ($w>w_p$), Dark red/brown	F			FILL *Boulders up to 0.6m dia.
		0.5		(GP) GRAVEL: With clay and cobbles,	L			
				(CH) Silty CLAY: High plasticity, With gravel, With cobbles and boulders, Moist ($w>w_p$), Dark red/brown				RESIDUAL ? POSSIBLE FILL *Boulders up to 1m dia.
		1.0						
		1.5						
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 4 TERMINATED AT 2.1m – ???

METHOD		WEATHERING		CONSISTENCY / DENSITY / ROCK STRENGTH				SAMPLES / TESTS	
AD	Auger Drilling	EW	Extremely	VS	Very Soft	D	Dense	U( )	Undisturbed (size in mm)
C	Casing	HW	Highly	S	Soft	VD	Very Dense	D	Disturbed
MS	Mud Support	DW	Distinctly	F	Firm	Fb	Friable	BS	Bulk Sample
NMLC	Rock Coring	MW	Moderately	St	Stiff	ELw	Extremely Low	DCP	Dynamic Cone Penetrometer
RR	Rock Roller	SW	Slightly	VSt	Very Stiff	VLw	Very Low	SPT	Standard Penetrometer Test
TB	Toothed Bucket	F	Fresh	Hd	Hard	Lw	Low	N	Number of blows for SPT / 300mm
TC	Tri Cone			VL	Very Loose	M	Medium	VS	Vane Shear
WB	Wash Bore			L	Loose	H	High	A	Acid Sulfate Sample
				MD	Medium Dense	VH	Very High	PP	Pocket Penetrometer (kPa)

WATER	
▼	Water Level
►	Water Seepage

Logged By:	JDW	Date:	13/03/18	Checked By:		Date:	

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.234981	E:	153.531520

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 5
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-a
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CH) Silty CLAY: High plasticity, With gravel, With cobbles and boulders, Very moist ($w>w_p$), Red/brown	F - St	PP = 80 - 120		FILL
		1.0						
		1.5						
		2.0		(MH/CH) Clayey SILT/Silty CLAY: High plasticity, Trace of cobbles, Wet ($w>w_p$), Dark grey	F	PP < 80		*PP's difficult as Material was crumbling
		2.5						
		3.0						
	▶	3.5		(MH/CH) Clayey SILT/Silty CLAY: High plasticity, With gravel, Tree roots and rubbish, Wet ($w>w_p$), Dark grey				
		4.0						
		4.5						

TP 5 TERMINATED AT 3.5m – LIMIT OF REACH

METHOD		WEATHERING		CONSISTENCY / DENSITY / ROCK STRENGTH				SAMPLES / TESTS	
AD	Auger Drilling	EW	Extremely	VS	Very Soft	D	Dense	U( )	Undisturbed (size in mm)
C	Casing	HW	Highly	S	Soft	VD	Very Dense	D	Disturbed
MS	Mud Support	DW	Distinctly	F	Firm	Fb	Friable	BS	Bulk Sample
NMLC	Rock Coring	MW	Moderately	St	Stiff	ELw	Extremely Low	DCP	Dynamic Cone Penetrometer
RR	Rock Roller	SW	Slightly	VSt	Very Stiff	VLw	Very Low	SPT	Standard Penetrometer Test
TB	Toothed Bucket	F	Fresh	Hd	Hard	Lw	Low	N	Number of blows for SPT / 300mm
TC	Tri Cone			VL	Very Loose	M	Medium	VS	Vane Shear
WB	Wash Bore			L	Loose	H	High	A	Acid Sulfate Sample
WATER				MD	Medium Dense	VH	Very High	PP	Pocket Penetrometer (kPa)
▼	Water Level								
►	Water Seepage								

Logged By:	JDW	Date:	13/03/18	Checked By:		Date:	

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.235479	E:	153.530789

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 6
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-a
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0		(GP) GRAVEL: Fine to coarse gravel, Moist, Dark grey	L			FILL
		0.5		(GP) GRAVEL: Fine to coarse gravel, With sand and clay throughout, With cobbles and boulders, Moist, Dark grey				*Boulders up to 0.8m dia.
		1.0						
		1.5						
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 6 TERMINATED AT 2.1m – TERMINATED DUE TO LIMIT OF INVESTIGATION AND SLOW EXCAVATION

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: JDW	Date: 13/03/18	Checked By:	Date:

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	-28.235950	E:	153.531665

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 7
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-a
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.0		(CH) Silty CLAY: High plasticity, Trace of gravel, Moist ($w>w_p$), Dark red/brown	F - St			FILL
				(GP) Sandy GRAVEL: Fine to coarse gravel, Moist, Grey				
		0.5		(HW) BASALT: Fine grained, Dark grey				RESIDUAL
		1.0						
		1.5						
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 7 TERMINATED AT 0.6m – EXCAVATOR REFUSAL

METHOD

AD	Auger Drilling
C	Casing
MS	Mud Support
NMLC	Rock Coring
RR	Rock Roller
TB	Toothed Bucket
TC	Tri Cone
WB	Wash Bore

WATER

▼	Water Level
►	Water Seepage

WEATHERING

EW	Extremely
HW	Highly
DW	Distinctly
MW	Moderately
SW	Slightly
F	Fresh

CONSISTENCY / DENSITY / ROCK STRENGTH

VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS

U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: JDW	Date: 13/03/18	Checked By:	Date:

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235130	E:	153.533190

CLIENT: WRENN PTY LTD — **TEST PIT I.D. :** TP 8

PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT — **JOB No.:** GI 3953-b

EQUIPMENT TYPE: 5.5 TONNE KUBOTA — **BUCKET SIZE:** 450mm x 2.1m — **PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0		(Cl) Gravelly CLAY: Medium plasticity, Dry, Red/brown				RESIDUAL
				(Cl) Sandy CLAY: Medium plasticity, With silt, Trace of gravel, Dry ($w<w_p$), Red/brown	VSt - Hd	PP = 300 - 450		Organic material throughout
		0.5		(HW) BASALT: Fine grained, Very fractured, Dry, Dark red/brown, orange/brown and grey	Vlw ↓ Lw			
		1.0						
		1.5						
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 8 TERMINATED AT 0.7m – EXCAVATOR REFUSAL ON ROCK

METHOD

AD	Auger Drilling
C	Casing
MS	Mud Support
NMLC	Rock Coring
RR	Rock Roller
TB	Toothed Bucket
TC	Tri Cone
WB	Wash Bore

WATER

▼	Water Level
►	Water Seepage

WEATHERING

EW	Extremely
HW	Highly
DW	Distinctly
MW	Moderately
SW	Slightly
F	Fresh

CONSISTENCY / DENSITY / ROCK STRENGTH

VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS

U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235015°	E:	153.532526°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 9
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm X 2.8m	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(SC) Clayey SAND: Fine to coarse sand, With gravel and boulders, Wet, Dark red/brown and grey				FILL
		1.0						Large >1.0m boulders
	▼ ►	1.5		(CI-CH) Sandy CLAY: Medium to high plasticity, With gravel, Wet, Dark orange/brown	F			
				(HW) BASALT: Fine grained, Very fractured, Dry, Dark red/brown, orange/brown and grey	Lw - M			RESIDUAL
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						

TP 9 TERMINATED AT 1.7m – EXCAVATOR REFUSAL ON ROCK

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235214°	E:	153.531991°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 10
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm x 2.5m	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CI-CH) Sandy CLAY: Medium to high plasticity, With gravel, Wet, Dark orange/brown	F - St			FILL
	►			(CI-CH) Sandy CLAY: Medium to high plasticity, Trace of gravel, Wet, Dark orange/brown				RESIDUAL
		1.0		(HW) BASALT: Fine grained, Very fractured, Dry, Dark grey	Lw - M			
		1.5						
		2.0						
		2.5						
		3.0						
		3.5						
		4.0						
		4.5						

TP 10 TERMINATED AT 1.1m – EXCAVATOR REFUSAL ON ROCK

METHOD		WEATHERING		CONSISTENCY / DENSITY / ROCK STRENGTH				SAMPLES / TESTS	
AD	Auger Drilling	EW	Extremely	VS	Very Soft	D	Dense	U( )	Undisturbed (size in mm)
C	Casing	HW	Highly	S	Soft	VD	Very Dense	D	Disturbed
MS	Mud Support	DW	Distinctly	F	Firm	Fb	Friable	BS	Bulk Sample
NMLC	Rock Coring	MW	Moderately	St	Stiff	ELw	Extremely Low	DCP	Dynamic Cone Penetrometer
RR	Rock Roller	SW	Slightly	VSt	Very Stiff	VLw	Very Low	SPT	Standard Penetrometer Test
TB	Toothed Bucket	F	Fresh	Hd	Hard	Lw	Low	N	Number of blows for SPT / 300mm
TC	Tri Cone			VL	Very Loose	M	Medium	VS	Vane Shear
WB	Wash Bore			L	Loose	H	High	A	Acid Sulfate Sample
WATER				MD	Medium Dense	VH	Very High	PP	Pocket Penetrometer (kPa)
▼	Water Level								
►	Water Seepage								

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

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ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235635°	E:	153.531748°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 11
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm x 3.0m	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(CH) Silty CLAY: High plasticity, With sand, Trace of boulders, Moist ($w>w_p$), Dark red/brown	VSt	PP = 300		RESIDUAL Grass roots at surface Trace of organic material.
		1.0				PP = 350		
		1.5						
		2.0						
		2.5		(CH) Silty CLAY: High plasticity, With sand, Trace of boulders, Moist ($w>w_p$), Dark grey and red/brown	St - VSt			
		3.0						
		3.5						
		4.0						
		4.5						

TP 11 TERMINATED AT 2.8m – HIT A BOULDER AND REFUSED

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

GEOTECH INVESTIGATIONS PTY LTD

Unit 3/42 Machinery Drive, Tweed Heads South NSW 2486
Ph: 0755 233 979 Fax: 0755 233 981

ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235240°	E:	153.531027°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 12
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 400mm x 1.0m	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5, 1.0, 1.5, 2.0		(CI-CH) Sandy Silty CLAY: Medium to high plasticity, Dry (w<wp), Red/brown				FILL
		2.5		Boulders and cobbles (crushed and angular)				
		3.0, 3.5, 4.0, 4.5						

TP 12 TERMINATED AT 2.9m – LIMIT OF EXCAVATION DUE TO CONTINUAL CAVE IN

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

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Unit 3/42 Machinery Drive, Tweed Heads South NSW 2486
Ph: 0755 233 979 Fax: 0755 233 981

ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235237°	E:	153.530449°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 13
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm x 3.5m	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5		(GC) Clayey GRAVEL: Fine to coarse gravel, With sand, Cobbles throughout, Moist, Grey/brown	L - MD			FILL
		1.0		(GP) Sandy GRAVEL: Fine to coarse gravel, With cobbles throughout, Dry, Grey				
		1.5						
		2.0		(Cl) Sandy CLAY: Medium plasticity, Fine to coarse sand, With gravel, Moist, Dark red/brown and orange/brown	St - VSt			
		2.5		(Cl) Silty CLAY: Medium plasticity, With sand, Moist ($w \approx w_p$), Dark red/brown and dark orange/brown				RESIDUAL
		3.0						
		3.5						
		4.0						
		4.5						

TP 13 TERMINATED AT 2.8m – LIMIT OF INVESTIGATION

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

GEOTECH INVESTIGATIONS PTY LTD

Unit 3/42 Machinery Drive, Tweed Heads South NSW 2486
Ph: 0755 233 979 Fax: 0755 233 981

ENGINEERING LOG – TEST PIT PROFILE

GPS:	S:	28.235516°	E:	153.529928°

CLIENT: WRENN PTY LTD	**TEST PIT I.D. :** TP 14
PROJECT: LOT 16 (No.225) TERRANORA ROAD, BANORA POINT	**JOB No.:** GI 3953-b
EQUIPMENT TYPE: 5.5 TONNE KUBOTA / **BUCKET SIZE:** 450mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
TB		0.5, 1.0, 1.5, 2.0		(CI) Silty CLAY: Medium plasticity, Trace of sand and cobbles and boulders, Moist ($w<w_P$),Dark orange/brown and red/brown				RESIDUAL
		2.5, 3.0, 3.5, 4.0, 4.5						

TP 14 TERMINATED AT 2.4m – LIMIT OF INVESTIGATION

METHOD		WEATHERING	
AD	Auger Drilling	EW	Extremely
C	Casing	HW	Highly
MS	Mud Support	DW	Distinctly
NMLC	Rock Coring	MW	Moderately
RR	Rock Roller	SW	Slightly
TB	Toothed Bucket	F	Fresh
TC	Tri Cone		
WB	Wash Bore		

WATER	
▼	Water Level
►	Water Seepage

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By:	JDW	Date:	21/12/18	Checked By:	JW	Date:	31/01/19

APPENDIX C

GEOTECHNICAL REPORT STANDARD NOTES

SCOPE These standard notes may be of assistance when understanding terms and recommendations given in this report. These notes are for general conditions and not all terms given may be of concern to the report attached. The descriptive terms adopted by Geotech Investigations Pty Ltd are given below and are largely consistent with Australian Standards AS1726-1993 'Geotechnical Site Investigations'.

CLIENT can be described and is limited to the financier of this geotechnical investigation.

LEGALITY and privacy of this document is based on communication between Geotech Investigations Pty Ltd and the client. Unless indicated otherwise the report was prepared specifically for the client involved and for the purposes indicated by the client. Use by any other party for any purpose, or by the client for a different purpose, will result in recommendations becoming invalid and Geotech Investigations Pty Ltd will hold no responsibility for problems which may arise.

GEOTECHNICAL REPORTS are predominantly derived using professional estimates determined from the results of fieldwork, in-situ and laboratory testing and experience from previous investigations in the area, from which geotechnical engineers then formulate an opinion about overall subsurface conditions. The client must be made aware that the investigations are undertaken to ensure minimal site impact using test-pits or small diameter boreholes and soil conditions on-site may vary from those encountered during the investigation.

CLIENTS RESPONSIBILITY to notify this office should there be adjustments in proposed structure/location or inconsistencies with material descriptions given in this report and those encountered on site. Geotech Investigations Pty Ltd is able to provide a range of services from on-site inspections to full project supervision to confirm recommendations given in the report.

CSIRO Publication BTF 18 'Foundation Maintenance and Footing Performance: A Homeowner's Guide' explains how to adequately maintain drainage during and post construction which lies as the responsibility of the client. Suitable drainage ensures recommendations given in this report remain valid.

INVESTIGATION METHODS adopted by Geotech Investigations Pty Ltd are designed to incorporate individual project-specific factors to obtain information on the physical properties of soil and rock around a site to design earthworks and foundations for proposed structures. The following methods of investigation currently adopted by this company are summarised below:-

HAND AUGER – investigations enable field work to be undertaken where access is limited. The materials must have sufficient cohesion to stand unsupported in an unlined borehole and there must be no large cobbles boulders or other obstructions which would prevent rotation of the auger.

TEST-PITS – investigations are carried out with an excavator or backhoe, allowing a visual inspection of sub-surface material in-situ and from samples removed. The limit of investigation is restricted by the reach of the excavator or backhoe.

CONTINUOUS SPIRAL FLIGHT AUGERING TECHNIQUES – investigations are advanced by pushing a 100mm diameter spiral into the sub-surface and withdrawing it at regular intervals to allow sampling or testing as it emerges.

WASH BORING – investigations are advanced by removing the loosened soil from the borehole by a stream of water or drilling mud issuing from the lower end of the wash pipe which is worked up and down or rotated by hand in the borehole. The water or mud carries the soil up the borehole where it overflows at ground level where the soil in suspension is allowed to settle in a pond or tank and the fluid is re-circulated or discharged to waste as required.

NON-CORE ROTARY DRILLING – investigations are advanced using a rotary bit with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from feel and rate of penetration.

ROTARY MUD DRILLING – is carried out as above using mud as support and circulating fluid for the borehole drilling. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling.

CONTINUOUS CORE DRILLING – investigations are carried out in rock material, specimens of rock in the form of cylindrical cores are recovered from the drill holes by the means of core barrel. The core barrel is provided at its lower end with a detachable core bit which carries industrial diamond chips in a matrix of metal. Rotation of the barrel by means of the drill rods causes the core bit to cut an annulus in the rock, the cuttings being washed to the surface by a stream of pumped down the hollow drill rods.

TESTING METHODS adopted by Geotech Investigations Pty Ltd to determine soil properties include but not limited to the following:-

U50 – Undisturbed samples are obtained by inserting a 50mm diameter thin-walled steel tube into the material and withdrawing with a sample of the soil in a moderately undisturbed condition.

PP – Pocket Penetrometer tests are commonly used on thin walled tube samples of cohesive soils to evaluate consistency and approximate unconfined compressive strength of saturated cohesive soils. They may also be used for the same purpose in freshly excavated trenches.

VS – Vane Shear test are commonly used in-situ or on thin walled tube samples of cohesive soils by introducing the vane into the material where the measurement of the undrained shear strength is required. Then the vane is rotated and the torsional force required to cause shearing is calculated.

DCP – Dynamic Cone Penetrometer tests are commonly used in-situ to measure the strength attributes of penetrability and compaction of sub-surface materials.

SPT – Standard Penetration Tests are commonly used to determine the density of granular deposits but are occasionally used in cohesive material as a means of determining strength and also of obtaining a relatively unmixed sample. Samples and results are obtained by driving a 50mm diameter split tube through blows from a slide hammer with a weight of 63.5kg falling through a distance of 760mm. Blow counts are recorded for 150mm intervals with the sum of the number of blows required for the second and third 150mm of penetration is termed the "standard penetration resistance" or the "N-value".

GEOLOGICAL ORIGINS of sub-surface material plays a considerable role in the development of engineering parameters and have been summarised as follows:-

FILL – materials are man made deposits, which may be significantly more variable between test locations than naturally occurring soils.

RESIDUAL – soils are present in a region because of weathering over the geological time scale.

COLLUVIAL – soils have been deposited recently, on the geological time scale, as soils being transported slowly down slope due to gravitational creep.

ALLUVIAL – soils have been deposited recently, on the geological time scale, as water borne materials.

AEOLIAN – soils have been deposited recently, on the geological time scale, as wind borne materials.

SOIL DESCRIPTION is based on an assessment of disturbed samples, as recovered from boreholes and excavations, and from undisturbed materials. Soil descriptions adopted by Geotech Investigations Pty Ltd are largely consistent with AS 1726-2017 '*Geotechnical Site Investigation'.* Soil types are described according to the predominating particle size and behaviour, qualified by the grading of other particles present on the following bases detailed in Table 1.

COHESIVE SOILS ability to hold moisture known as its liquid limit is the state of a soil when it goes from a solid state to a liquid state described in Table 2

TABLE 1

Soil Classification	Particle Size
Clay	< 0.002 mm
Silt	0.002 – 0.06 mm
Sand	0.06 – 2.00 mm
Gravel	2.00 – 60.0 mm

TABLE 2

Descriptive Type	Range of Liquid Limit %
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

Furthermore to soil description cohesive soils are described on their strength (assessed in conjunction with penetration tests) and liquid limit. Non-cohesive soil strengths are described by their density index. With descriptions for cohesive and non-cohesive soils summarised in Table 3.

TABLE 3

COHESIVE SOILS		NON-COHESIVE SOILS	
Term	**Undrained Shear Strength kPa**	**Term**	**Density Index %**
Very soft	≤ 12	Very Loose	≤15
Soft	> 12 ≤25	Loose	> 15 ≤35
Firm	> 25 ≤50	Medium Dense	> 35 ≤65
Stiff	> 50 ≤100	Dense	> 65 ≤85
Very Stiff	> 100 ≤200	Very Dense	> 85
Hard	> 200		

Description of terms used to describe material portion are summarised in Table 4.

TABLE 4

COARSE GRAINIED SOILS		FINE GRAINED SOILS	
% Fines	**Modifier**	**% Coarse**	**Modifier**
≤ 5	Omit or 'trace'	≤ 15	Omit or 'trace'
> 5 ≤12	Describe as 'with'	> 15 ≤30	Describe as 'with'
> 12	Prefix soil as 'silty/clayey'	> 30	Prefix soil as 'sandy/gravelly'

ROCK DESCRIPTIONS are determined from disturbed samples or specimens collected during field investigations. A rocks presence of defects and the effects of weathering are likely to have a great influence on engineering behaviour.

Rock Material Weathering Classification is summarised in Table 5.

TABLE 5

Term	Symbol	Definition
Residual Soils	-	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported
Extremely Weathered Rock	XW	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water
Distinctly Weathered Rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to decomposition of weathering products in pores
Slightly Weathered Rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh rock	FR	Rock shows no signs of decomposition or staining

Rock Material Strength Classification is summarised in Table 6.

TABLE 6

Term	Symbol	Point load index (MPa) I_s50	Field guide to strength
Extremely Low	EL	≤0.03	Easily remoulded by hand to a material with soil properties
Very Low	VL	>0.03 ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 3cm thick can be broken by finger pressure
Low	L	>0.1 ≤0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling
Medium	M	>0.3 ≤1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty
High	H	>1.0 ≤3.0	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer
Very High	VH	>3.0 ≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer
Extremely High	EH	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer

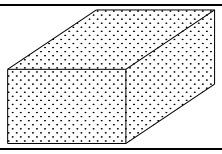
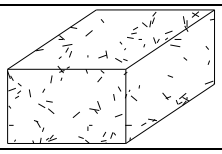
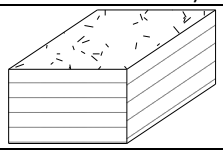
Rock Material Defect Shapes are summarised in Table 7.

TABLE 7

Term	Description
Planar	The defect does not vary in orientation.
Curved	The defect has a gradual change in orientation
Undulating	The defect has a wavy surface
Stepped	The defect has one or more well defined steps.
Irregular	The defect has many sharp changes of orientation
Smooth	The defect has a flat even finish
Rough	The defect has a irregular disoriented finish

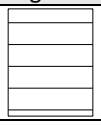
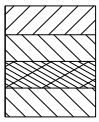
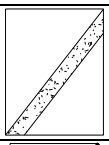
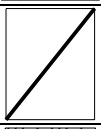
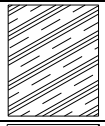
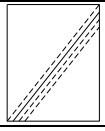
Rock Material Texture and Fabric are summarised in Table 8.

TABLE 8

Geological Description	Massive		Layered (Bedded foliate cleaved)
Diagram			
Fabric Type	Effectively homogenous and isotropic. Bulky or equi-dimensional grains uniformly distributed	Effectively homogeneous and isotropic. Elongated	Effective homogeneous with planar anisotropy. Elongated or tabular grains or pores in a layered arrangement

Rock Material Defect Type is summarised in Table 9

TABLE 9

Term	Definition	Diagram
Bedding	Signifying existence of beds or laminate. Planes dividing sedimentary rocks of the same or different lithology. Structure occurring in granite and similar rocks evident in a tendency to split more or less horizontally to the land surface	
Cross Bedding	Also called cross-lamination or false bedding. The structure commonly present in granular sedimentary rocks, which consists of tabular, irregularly lenticular or wedge-shaped bodies lying essentially parallel to the general stratification and which them selves show pronounced lamination structure in which the laminae are steeply inclined to the general bedding.	
Crushed Seam	A fracture at a more or less acute angle to applied force generally with some pulverized material along its surface	
Joint	A fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.	
Parting	A small joint in rock or a layered rock where the tendency of crystals to separate along certain planes that are not true cleavage planes.	
Sheared Zone	A fracture that results from stresses which tend to shear one part of a specimen past the adjacent part	

APPENDIX D

AGS AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)
GUIDELINES TO GOOD AND BAD HILLSIDE PRACTICES

LANDSLIDE RISK

Concept of Risk

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

Landslide Risk Assessment

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

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

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

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

Risk to Property

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

TABLE 2: LIKELIHOOD

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

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

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

TABLE 1: RISK TO PROPERTY

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

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

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

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

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

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

TABLE 3: RISK TO LIFE

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

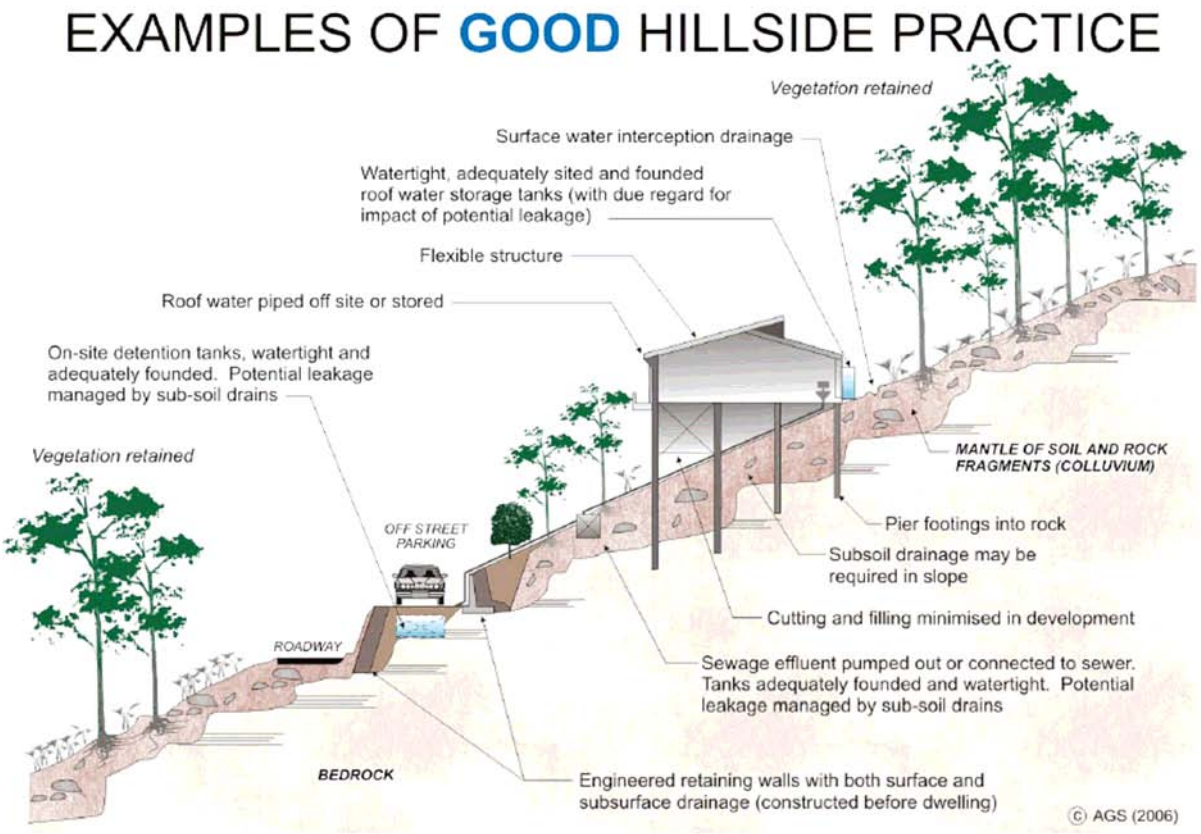
More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

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

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

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

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


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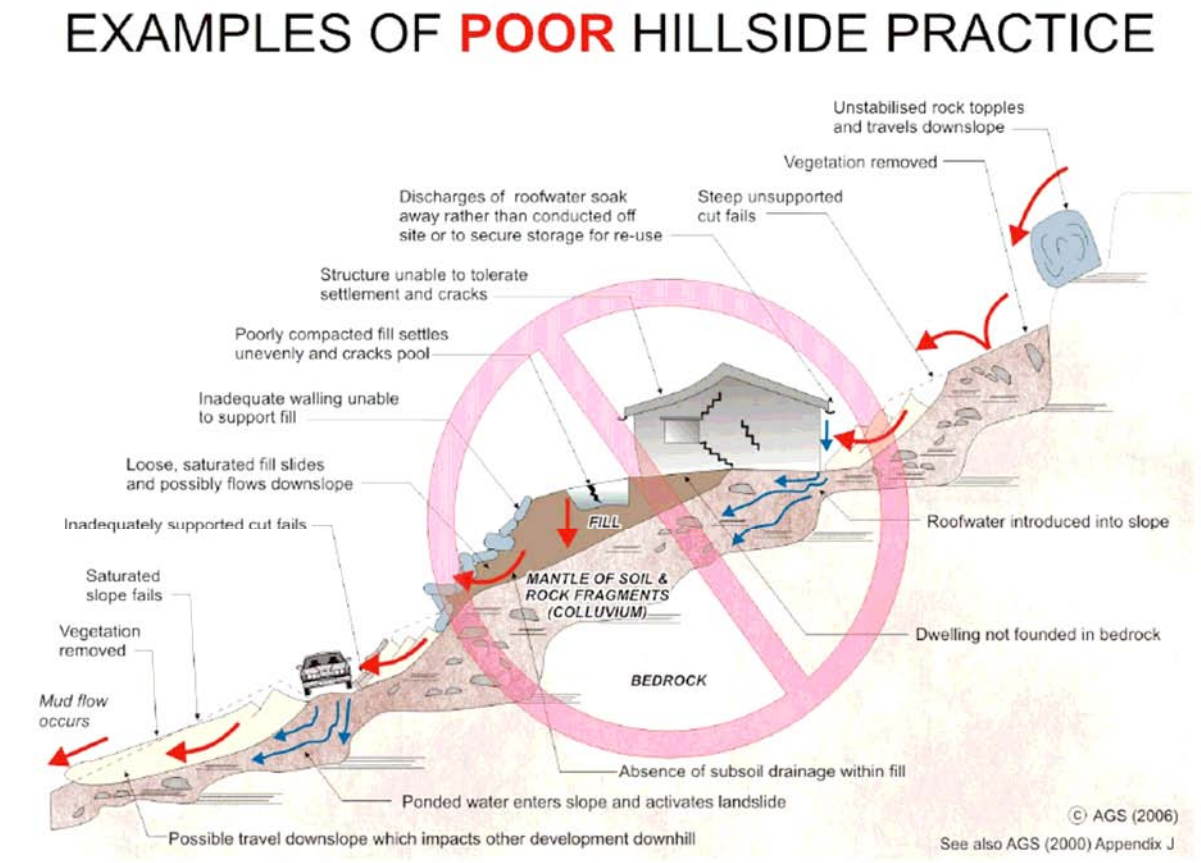
EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles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