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REPORT ON GEOTECHNICAL SITE INVESTIGATION

for

PROPOSED NEW STRUCTURES AND ALTERATIONS TO THE EXISTING

at

70 SOUTH CREEK ROAD, COLLAROY, NSW

Prepared For

The Pittwater House School

Project No.: 2019-120

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GEOTECHNICAL REPORT FOR DEVELOPMENT APPLICATION
FOR PROPOSED NEW STRUCTURES AND ALTERATIONS TO THE EXISTING
THE PITTWATER HOUSE SCHOOL, 70 SOUTH CREEK ROAD, COLLAROY, NSW

1. INTRODUCTION:

This report details the results of a geotechnical investigation carried out for proposed new structures and alterations to the existing structures at The Pittwater House School, 70 South Creek Road, Collaroy, NSW. The investigation was undertaken by Crozier Geotechnical Consultants (CGC) at the request of Cantilever Consulting Engineers on behalf of The Pittwater House School. This report has been prepared to fulfill Northern Beaches Councils Development Application (DA) requirements.

Northern Beaches (Warringah) Councilôs 2011 LEP and DCP require that all building development applications within an area potentially affected by landslip hazards must be accompanied by a geotechnical landslip assessment. Developments within Class óAô, óBô and óDô landslip risk zone may require a preliminary assessment only where excavation/fill is <2.0m depth, however Class óCô and óEô require a geotechnical report.

This site is located within landslip risk Class óAô with a narrow zone of Class óDô along the rear northern boundary according to the Landslip Risk Map-Sheet LSR_009. A review of the preliminary checklist and the proposed works indicates that due to the excavation works adjacent to the South Wing building (>2.0m) that the Development Application (DA) involves works which exceed the preliminary assessment guidelines. Therefore, a geotechnical report in support of the DA that includes a risk assessment for the excavation is required.

This report forms part of a geotechnical investigation requested by the client to provide information for the structural design and construction works in addition to fulfilling DA submission requirements. A fee proposal was accepted by the client (Fee Proposal P19-235.3, Dated: 8th August 2019) to complete the nominated scope of work as proposed. However, to fulfill Council DA requirements and meet necessary submission deadlines, reporting has been divided and this report contains only the elements of the proposed investigation/works relevant to the DA submission including:

a) A detailed geotechnical inspection and mapping of the site and adjacent properties by a Senior Engineering Geologist.
b) A photographic record of existing site conditions.
c) The results of geotechnical boreholes and site testing undertaken
d) A risk assessment (if applicable) in accordance with the Australian Geomechanics Society (AGS) guidelines
e) Preliminary design and construction parameters for the lift and reconfigured access to South and West Wing (see Section 2).

The following documents have been supplied in regard to the request:

ŏ Drawings ï Consultant Briefing Report, Neeson Murcutt Architects, Issue: 17 04 2019

ŏ Survey Drawing ï CMS Surveyors, Ref: 4883G, Issue: 3, Pages: 12, dated 04/04/16 and 23/04/18

ŏ Scope of Works ï Cantilever letter ôRequest for Geotechnical Engineering Fee Proposalô dated: 28th June 2019

2. PROPOSED DEVELOPMENT:

Based on the information provided it is understood the works are to comprise:

- Construction of a new two storey school building/extension to the south of Block M which will require some minor cut and fill
- A new road with drop-off access from South Creek Road to the area between South Wing and the Sports Hall
- A new lift and reconfigured access between South and West Wing
- Altered parking area for buses off Westmoreland Avenue
- New car park pavement at south-east corner of school, adjacent to South Creek Road

It is further understood that the only bulk excavation proposed will be to accommodate the new lift pit directly to the north of the South Wing building and that all other excavations will be for new footings only. Proposed fill of less than 1.0m depth is anticipated under the new M building to facilitate the construction of a ground bearing floor slab.

3. SITE FEATURES:

3.1. Description:

The site is irregular in shape and occupies a parcel of land covering approximately 3.5 hectares. The northern boundary of the site lies on the low south side of Westmoreland Street. The western boundary is generally delineated by the rear boundaries of residential properties on the east side of Parkes Road. The southern boundary of the site lies on the high north side of South Creek Road. Residential properties and additional school grounds lie to the east of the site.

The site is located within gently south dipping topography. To the north of the site lies a moderately dipping (13°) slope, the crest of which is approximately 150m to the north of the north site boundary.

An aerial image of the site, immediate surrounds and the broad location of the proposed lift/access excavation are shown in Photograph 1, obtained from the NSW Government Six Maps website.

Photograph 1: Aerial view of the site, immediate surrounds and vicinity of the proposed lift excavation.

The south of the site contains several ôlargeô teaching blocks which are typically of brick construction and connected via a series of pedestrian walkways. In addition to the teaching blocks, the southern portion of the site also contains numerous single-storey brick or weatherboard structures (equipment storage, shops, small teaching facilities, canteen etc.), bus park, a playground, dining/seating areas and a swimming pool. The main staff car park/student drop off zone (shown in Photograph 2) is located within the south of the site and is accessed directly from South Creek Road.

Photograph 2: View of the car park looking south to west from the eastern side of the existing staff car park.

Within the location of the proposed new road an area of green space which dips gently from the north to the south is present and is shown in Photograph 3.

Photograph 3: View of the proposed new road location looking broadly north.

The northern portion of the site is predominantly occupied by the school sports field and the óGreat Hallô with a visitor car park near Westmoreland Avenue adjacent to the northern site boundary. A view of the northern portion of the site is provided in Photograph 4.

Photograph 4: View of the school playing field facing broadly east from the Great Hall.

3.2. Geology:

Reference to the Sydney 1:100,000 Geological Series sheet (9130) indicates that the south of the site is underlain by Quaternary deposits described as silty to peaty quartz sand, silt and clay. Ferruginous and humic cementation in places. Common shell layers (Qha).

Underlying the north of the site deposits of the Upper Narrabeen Group (Rnn-Newport Formation) are shown. Newport Formation comprise interbedded laminite, shale and quartz to lithic quartz sandstone and pink clay pellet sandstone. An extract from the 9130 Sydney Series sheet is provided below.

Extract 1: Extract from the 9130 Sydney Series sheet with site (in blue) overlain

Above the site to the north, deposits of the Hawkesbury Sandstone are shown. Morphological features often associated with the weathering of Hawkesbury Sandstone are the formation of near flat ridge tops with steep angular side slopes. These slopes often consist of sandstone terraces and cliffs with steep colluvial slopes below. The terraced areas above these cliffs often contain thin sandy (low plasticity) soil profiles with intervening rock (ledge) outcrops.

The outline of the cliff areas are often rectilinear in plan, controlled by large bed thickness and wide spaced near vertical joint pattern, many cliff areas are undercut by differential weathering. Slopes below these cliffs are often steep 15 to 23° with moderately thick sandy colluvial soil profile that are randomly covered by sandstone boulders.

Narrabeen Group rocks are dominated by shales and thin siltstone beds and often form rounded convex ridge tops with moderate angle (<20°) side slopes. These side slopes can be either concave or convex depending on geology, internally they comprise shale beds with close spaced bedding partings that have either close spaced vertical joints or in extreme cases, large space convex joints. The shale often forms deeply weathered silty clay soil profiles (medium to high plasticity) with thin silty colluvial cover.

4. FIELD WORK:

4.1. Methods:

The field investigation comprised a walk over inspection of the site and adjacent properties on the 24th September 2019 by a Senior Engineering Geologist. It involved a photographic record of site conditions as well as geotechnical/geomorphological mapping of the site and adjacent land with examination of soil slopes, vegetation and existing structures for stability. It also included the drilling of eight boreholes (with an additional four yet to be completed) within the site at nominated locations. BH10 was drilled adjacent to the proposed lift shaft to a depth of 7.0m to investigate sub-surface conditions and the other boreholes were drilled for pavement design purposes. The boreholes were drilled using a restricted access drill rig operating solid stem spiral flight augers in conjunction with a tungsten carbide bit.

Dynamic Cone Penetrometer (DCP) testing was carried out through and adjacent to the boreholes in accordance with AS1289.6.3.2 ï 1997, ñDetermination of the penetration resistance of a soil ï 9kg dynamic cone penetrometerò to estimate near surface soil conditions.

Underground service location was undertaken by an accredited service locator prior to commencement of drilling/testing. On completion the boreholes were backfilled with arisings and the surface reinstated.

Explanatory notes detailing terminology used in this report are included in Appendix: 1. Mapping information and test locations are shown on Figure: 1, Appendix: 2 along with detailed Borehole Log and DCP Test Results sheets

.

4.2. Ground Conditions:

The only significant excavation occurring within the site is required within the vicinity of the lift shaft excavation and a description of the subsurface conditions encountered within the borehole drilled in this location (BH10) is provided below.

- **SILTY SAND/SAND** ï Underlying a paved surface very loose dark grey silty sand was encountered to a depth of 0.80m and was underlain by medium dense sand to 1.60m that has been interpreted as alluvium.
- **GRAVELLY SAND** ï Underlying the sand, medium dense gravelly sand was encountered to 2.40m depth and has been interpreted as representing the base of the alluvial soils.
- **SANDY CLAY** ï Stiff to very stiff clay was encountered in the borehole and has been interpreted as a residual deposit. This soil remained until the base of the borehole at 7.0m depth and no indications of bedrock were observed.

The remaining boreholes within the site generally comprised stiff sandy clay with localized fill. Within BH1 to BH4 (within the footprint of the new extension to the M building), the ground conditions were relatively uniform and comprised stiff to very stiff clay to a depth of at least 10m below the ground surface level.

Groundwater was not encountered within BH10 (where the excavation is proposed) to the base of the borehole at 7.0m (RL11.5m). A perched water seepage within sandy horizons was encountered within BH1 to BH4 generally at around 6.0m below the existing ground surface (approximately RL8.0m).

4.3. Field Observations:

Observations made of the existing school buildings did not indicate any signs of cracking or distress in the external brickwork and the paved walkways within the site appeared to be in good condition. The north of the site is predominantly occupied by the school sports field and is elevated above the south of the site. The surface of the field appears to be irregular which may be due to use or it may be the result of placement and subsequent settlement of fill underlying the sports field and not related to landslip.

Within the north of the site and in the vicinity of BH12, a treed embankment was present adjacent to Westmoreland Avenue. Closer inspection of the embankment revealed that the external surface comprised fill. The embankment sloped gently from the north site boundary and did not display any signs of movement (tension cracks, rotating trees etc.). A view of the embankment looking broadly south is shown in Photograph 5.

Photograph 5: View of the embankment adjacent to Westmoreland Avenue looking broadly south.

To the north of Westmoreland Avenue and within the front garden of one of the residential properties, bedrock was observed in outcrop which appeared to comprise massive sandstone. Bedrock was also observed adjacent to the property within a drainage channel/stream bed which is understood to pass under Westmoreland Avenue and through the site via a culvert. Westmoreland Avenue appeared in good condition where it passed the north site boundary.

The properties that surround the site to the south, west and east contain residential properties or additional school facilities (to the east). No evidence of instability or potential instability was observed within either the roads, road easements or within the surrounding properties.

The neighbouring buildings and properties were only inspected from within the site or from the road reserve and the visible aspects did not show any significant signs of large-scale slope instability or other major geotechnical concerns which would impact the site.

5. COMMENTS:

5.1. Landslip Risk Assessment:

Based on the requirements of Warringah Councils 2011 LEP Planning Rules a preliminary assessment undertaken in accordance with Form E10 would result in the following:

• History of Landslip	No
• Proposed Excavation/Fill >2m	Yes
• Site developed	Yes
• Existing Fill >1m	Possibly
• Site Steeper than 1V:4H	No
• Existing Excavation >2m	No
• Natural Cliffs >3m	No

Therefore it is likely that a detailed Landslip Risk Assessment would be required for this development following the flow chart provided on Form E10. However, it is also considered that based on the distance of the proposed excavation from the surrounding properties (>50m) and the limited size of the excavation there is no mechanism which can be identified which could result in instability impacting the adjoining properties.

There exists a low probability that excavation instability could be encountered prior to the construction of the lift pit and following excavation however this is not considered relevant where the methodology outlined in AGS 2007 Guidelines is applied.

Therefore when the criteria of AGS is applied to the proposed development and the recommendations of this report are implemented including the installation of engineered support around the lift pit if necessary during excavation the Risk to Life and Risk to Property are óAcceptableô when assessed against the criteria of the AGS. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

5.2. Preliminary Geotechnical Assessment:

The investigation did not identify any likely landslip hazards which may impact the properties adjacent to the development site for the lift pit excavation or any other proposed development works. The ground conditions encountered with BH10 comprised silty sands/sands to a depth of 1.6m underlain by gravelly sand to 2.4m depth. Below the granular soils, stiff to very stiff sandy clay was encountered which is likely to be exposed within the base of the lift pit excavation (RL15.6m). Groundwater was not encountered within BH10 which extended to 4.0m below the proposed excavation and is not anticipated in excavation.

The proposed works involve an excavation that it is anticipated will extend up to approximately 3.0m depth below the existing level of the access walkway on the north side of the South Wing. The proposed excavation will be directly adjacent to the existing South Wing building as such it will be necessary to confirm the depth of the existing footing prior to excavation. Where the excavation is to extend below the existing footings, support/underpinning would be required to be installed prior to excavation to ensure movement of the existing footings does not occur. Where existing footings found below maximum excavation depths, safe batter slopes may be adopted subject to geotechnical inspection.

It is envisaged that standard mechanical plant (e.g. hydraulic excavator fitted with bucket) will be sufficient to complete the basement excavation.

Fill was encountered within BH12 to a depth of 2.0m. Where the existing pavement surface is to be replaced removal and re-compaction of the upper 1.0m of fill soils is recommended in this area.

Whilst there were no stability hazards identified in the investigation, there is a potential for undermining of existing site structures. Through selection of suitable excavation equipment, geotechnical inspection and mapping during the excavation works along with the installation of support measures as determined necessary by the inspections, the risk from the proposed works can be maintained within óAcceptableô levels for all situations

The recommendations and conclusions in this report are based on an investigation utilising only surface observations and a limited number of boreholes therefore some minor variation to the interpreted sub-surface conditions is possible, especially between test locations. The results of the investigation provide a reasonable basis for the DA analysis. It is considered that the proposed development is suitable for the ground conditions underlying the site.

5.3. Design & Construction Recommendations:

Design and the construction recommendations are tabulated below:

5.3.1. New Footings:	
Site Classification as per AS2870 ï 2011 for new footing design	Class óMô for footings founded in sandy clay
Type of Footing	Strip/Pad, Pile or Slab at base of excavation
Sub-grade material and Maximum Allowable Bearing Capacity	Very Stiff Sandy Clayï 150kPa
Site sub-soil classification as per *Structural design actions AS1170.4 – 2007, Part 4: Earthquake actions in Australia*	C_e ï shallow soil site

Remarks: All new footings must be inspected and tested by an experienced geotechnical professional before concrete or steel are placed to verify the bearing capacity and the in-situ nature of the founding strata due to its easily disturbed state. This is mandatory to allow them to be ćertifiedô at the end of the project. All new footings be founded within material of similar strength to reduce the potential differential settlement.

5.3.2. Excavation:	
Depth of Excavation	Up to 3.00m approximately for lift pit only
Distance of Excavation to Neighbouring Properties/structures	All surrounding properties are >50m from the proposed excavation
Type of Material to be Excavated	Pavers/fill soils
	Sandy/gravelly soils (up to 2.40m depth)
	Stiff to Very Stiff Sandy Clay (to base of excavation)
Guidelines for un-surcharged batter slopes for general information are tabulated below:	

Material	Safe Batter Slope (H:V)	
	Short Term/ Temporary	Long Term/ Permanent
Superficial Sands/gravel	1.5:1	2.5:1
Stiff to Very Stiff Sandy Clay	1:1	2:1

Remarks: Seepage through soils can also reduce the stability of batter slopes and invoke the need to implement additional support measures. Where safe batter slopes are not implemented the stability of the excavation cannot be guaranteed until the installation of permanent support measures. This should also be considered with respect to safe working conditions. Geotechnical inspection of batters will be required at regular intervals. Sub-vertical batter slopes in clayey soils can stand unsupported over very short time frames however CGC cannot certify or recommend this approach.

Equipment for Excavation	Topsoil, fills and natural sand/clay soils	Excavator with bucket
Recommended Vibration Limits (Maximum Peak Particle Velocity (PPV))	Not applicable unless rock is encountered	
Vibration Calibration Tests Required	Not required	
Full time vibration Monitoring Required	Not required	
Geotechnical Inspection Requirement	Yes, recommended that these inspections be undertaken as per below mentioned sequence:	

	• For assessment of proposed and constructed batter slopes • Where unexpected ground conditions are identified or any other concerns are held. • Following footing excavations to confirm founding material strength
Dilapidation Surveys Requirement	Not required
Remarks: Water ingress into exposed excavations can result in erosion and stability concerns in soils. Drainage measures will need to be in place during excavation works to divert any surface flow away from the excavation crest and any batter slope, whilst any groundwater seepage must be controlled within the excavation and prevented from ponding or saturating slopes/batters.	

5.3.3. Retaining Structures:	
Required	It is envisaged retaining walls will be required where insufficient space exists for the creation of temporary batter slopes (e.g. where existing footings found above the excavation base).
Types	Steel reinforced concrete/concrete block walls post excavation or pre excavation piles/piers if required designed in accordance with Australian Standards AS4678-2002 Earth Retaining Structures.
Parameters for calculating pressures acting on retaining walls for the materials likely to be retained:	

Material	Unit Weight (kN/m3)	Long Term (Drained)	Earth Pressure Coefficients		Passive Earth Pressure Coefficient *
			Active (Ka)	At Rest (K_0)	
Fill/natural sand/gravel soils	18	$\phi' = 29°$	0.35	0.52	N/A
Sandy Clay	20	$\phi' = 30°$	0.33	0.47	3.25

Remarks: In suggesting these parameters it is assumed that the retaining walls will be fully drained with suitable subsoil drains provided at the rear of the wall footings. If this is not done, then the walls should be designed to support full hydrostatic pressure in addition to pressures due to the soil backfill. It is suggested that the retaining walls should be back filled with free-draining granular material (preferably not recycled concrete) which is only lightly compacted in order to minimize horizontal stresses.

Retaining structures near site boundaries or existing structures should be designed with the use of at rest (K_0) earth pressure coefficients to reduce the risk of movement in the excavation support and resulting surface movement in adjoining areas. Backfilled retaining walls within the site, away from site boundaries or existing structures, that may deflect can utilize active earth pressure coefficients (Ka).

5.3.4. Drainage and Hydrogeology		
Groundwater Table or Seepage identified in Investigation		No
Excavation likely to intersect	Water Table	No
	Seepage	No
Site Location and Topography		High north side of the road, within Gently south sloping topography
Impact of development on local hydrogeology		Negligible
Onsite Stormwater Disposal		No considered necessary
Remarks: Trenches, as well as all new building gutters, down pipes and stormwater intercept trenches should be connected to a stormwater system designed by a Hydraulic Engineer which discharges to the Councilôs stormwater system off site.		

6. CONCLUSION:

Within the location of the lift pit natural granular soils are anticipated until approximately 2.40m depth under which stiff to very stiff sandy clay is anticipated to the base of the lift pit excavation (3.0m depth). Underlying the M building extension firm to very stiff clay is envisaged to at least 10m depth and a variety of footing types would be adequate.

Groundwater is not anticipated in any excavation within the site.

Where existing footing found above the level of the proposed lift pit it will be necessary to ensure they are not undermined as a result of the excavation. However, the excavation is well away from property boundaries an cannot impact adjacent properties or structure.

The Risk to Life and Risk to Property are óAcceptableô when assessed against the criteria of the AGS. As such the project is considered suitable for the site provided the recommendations of this report are implemented.

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7. REFERENCES:

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2. Geological Society Engineering Group Working Party 1972, ñThe preparation of maps and plans in terms of engineering geologyò Quarterly Journal Engineering Geology, Volume 5, Pages 295 - 382.
3. C. W. Fetter 1995, ñApplied Hydrologyò by Prentice Hall. V. Gardiner & R. Dackombe 1983, ñGeomorphological Field Manualò by George Allen & Unwin
4. Australian Standard AS 2870 ï 2011, Residential Slabs and Footings ï Construction
5. Australian Standard AS1170.4 ï 2007, Part 4: Earthquake actions in Australia

Appendix 1

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NOTES RELATING TO THIS REPORT

Introduction

These notes have been provided to amplify the geotechnical report in regard to classification methods, specialist field procedures and certain matters relating to the Discussion and Comments section. Not all, of course, are necessarily relevant to all reports.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, Geotechnical Site Investigation Code. In general, descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions.

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (eg. Sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	less than 0.002 mm
Silt	0.002 to 0.06 mm
Sand	0.06 to 2.00 mm
Gravel	2.00 to 60.00mm

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

Classification	Undrained Shear Strength kPa
Very soft	Less than 12
Soft	12 - 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	100 - 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT) as below:

Relative Density	SPT “N” Value (blows/300mm)	CPT Cone Value (Qc – MPa)
Very loose	less than 5	less than 2
Loose	5 – 10	2 – 5
Medium dense	10 – 30	5 -15
Dense	30 – 50	15 – 25
Very dense	greater than 50	greater than 25

Rock types are classified by their geological names. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling

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

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

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Drilling Methods

The following is a brief summary of drilling methods currently adopted by the company and some comments on their use and application.

Test Pits – these are excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descent into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (eg. Pengo) – the hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling – the hole is advanced by pushing a 100mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling soils, since moisture content is unchanged and soil structure, strength, etc. is only marginally affected.

Continuous Spiral Flight Augers – the hole is advanced using 90 – 115mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPT's or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is advanced by 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 – similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. From SPT).

Continuous Core Drilling – a continuous core sample is obtained using a diamond-tipped core barrel, usually 50mm internal diameter. Provided full core recovery is achieved (which is not always possible in very weak rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

Standard Penetration Tests

Standard penetration tests (abbreviated as SPT) are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample. The test procedures is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150mm of say 4, 6 and 7
  as 4, 6, 7 then N = 13
- In the case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm then as 15, 30/40mm.

The results of the test can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50mm diameter thin wall sample tubes in clay. In such circumstances, the test results are shown on the borelogs in brackets.

Cone Penetrometer Testing and Interpretation

Cone penetrometer testing (sometimes referred to as Dutch Cone – abbreviated as CPT) described in this report has been carried out using an electrical friction cone penetrometer. The test is described in Australia Standard 1289, Test 6.4.1.

In tests, a 35mm diameter rod with a cone-tipped end is pushed continually into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separte 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected buy electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) their information is plotted on a computer screen and at the end of the test is stored on the computer for later plotting of the results.

The information provided on the plotted results comprises: -

- Cone resistance – the actual end bearing force divided by the cross-sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower scale (0 – 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main scale (0 – 50 MPa) is less sensitive and is shown as a full line. The ratios of the sleeve friction to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios 1% - 2% are commonly encountered in sands and very soft clays rising to 4% - 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range: -

Q_c (MPa) = (0.4 to 0.6) N blows (blows per 300mm)

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range: -

$Q_c = (12 \text{ to } 18)\, C_u$

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculations of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes, etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

Dynamic Penetrometers

Dynamic penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods.

Two relatively similar tests are used.

- Perth sand penetrometer – a 16mm diameter flattened rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test 6.3.3). The test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.
- Cone penetrometer (sometimes known as Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS 1289, Test 6.3.2). The test was developed initially for pavement sub-grade investigations, and published correlations of the test results with California bearing ratio have been published by various Road Authorities.

Laboratory Testing

Laboratory testing is generally carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedure used are given on the individual report forms.

Borehole Logs

The bore logs presented herein are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable, or possible to justify on economic grounds. In any case, the boreholes represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes, the frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Details of the type and method of sampling are given in the report and the following sample codes are on the borehole logs where applicable:

D	Disturbed Sample	E	Environmental sample	DT	Diatube
B	Bulk Sample	PP	Pocket Penetrometer Test		
U50	50mm Undisturbed Tube Sample	SPT	Standard Penetration Test		
U63	63mm " " " " "	C	Core		

Ground Water

Where ground water levels are measured in boreholes there are several potential problems:

- In low permeability soils, ground water although present, may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made. More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be interference from a perched water table.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. A three-storey building), the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty-storey building). If this happens, the Company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface condition, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency,
- changes in policy or interpretation of policy by statutory authorities,
- the actions of contractors responding to commercial pressures,

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies

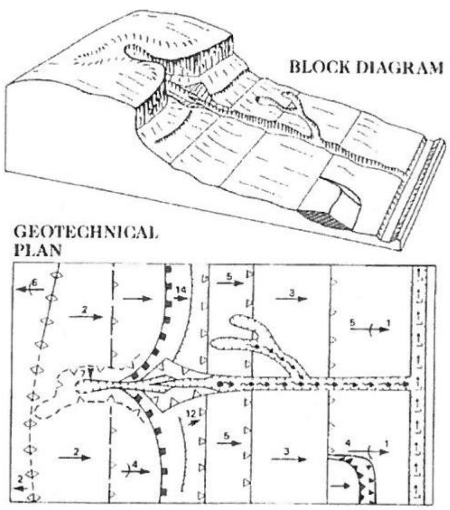
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the Company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed than at some later stage, well after the event.

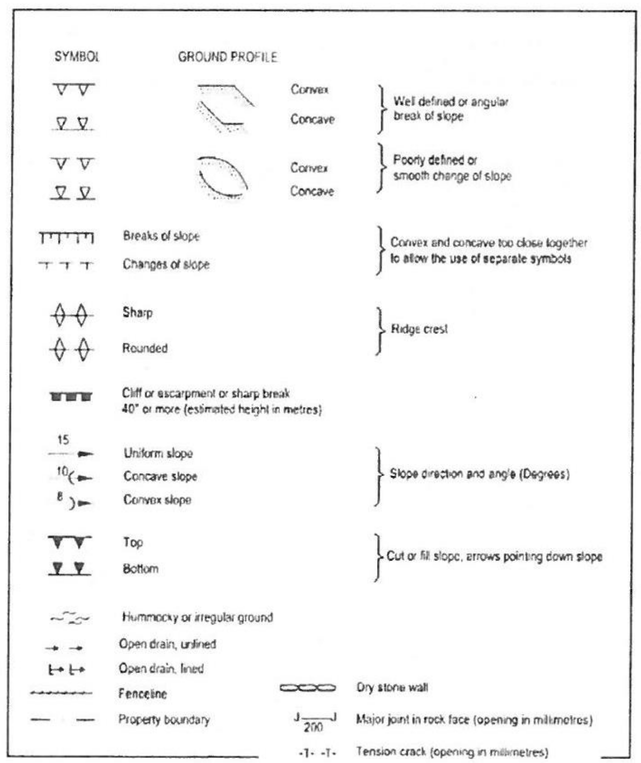
Reproduction of Information for Contractual Purposes

Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institution of Engineers Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a special ally edited document. The Company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

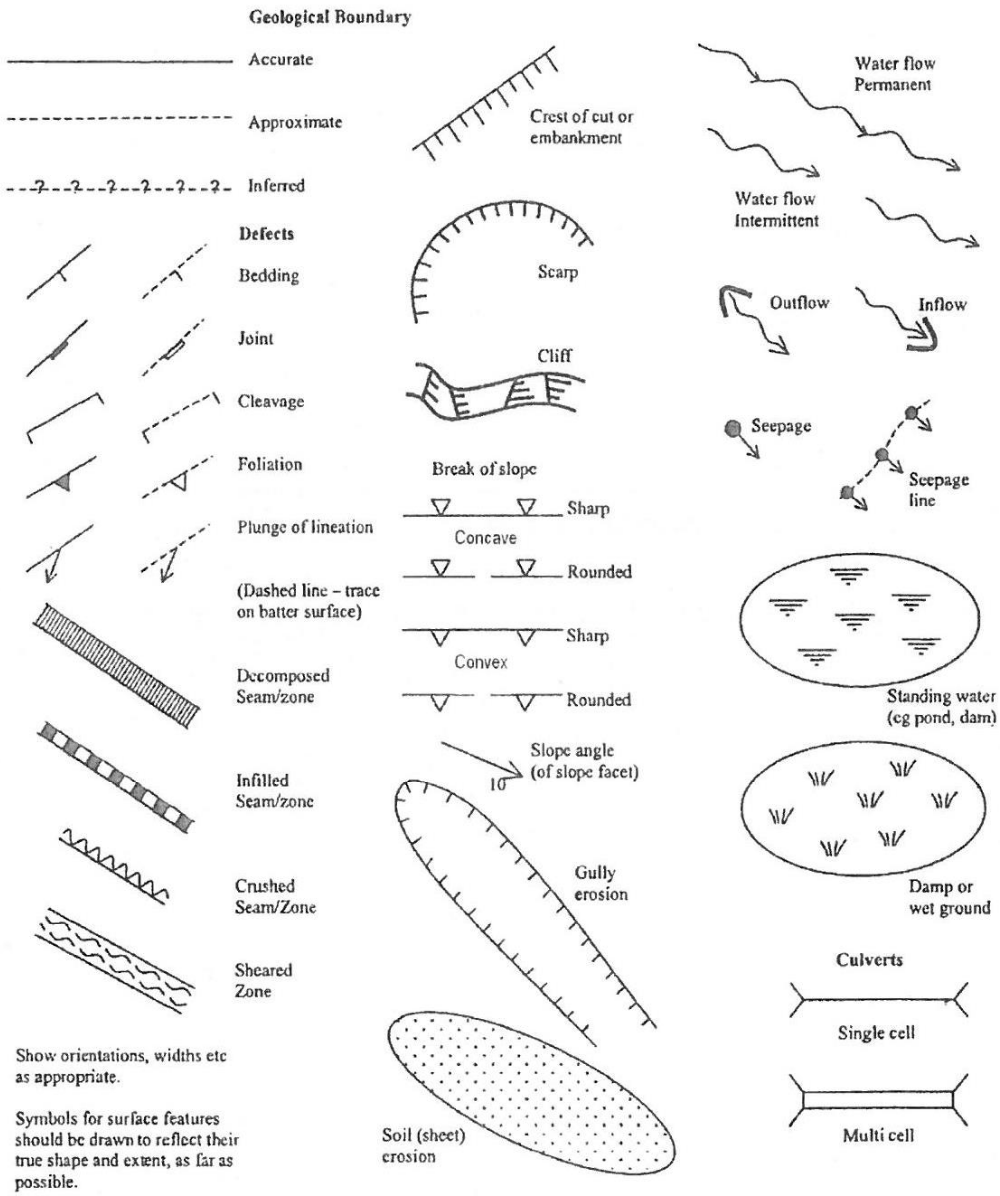
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.





Example of Mapping Symbols
(after V Gardiner & R V Dackombe (1983).Geomorphological Field Manual. George Allen & Unwin).

APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS AND TERMINOLOGY



Examples of Mapping Symbols (after Guide to Slope Risk Analysis Version 3.1 November 2001, Roads and Traffic Authority of New South Wales).

Appendix 2

N

VL - Very Loose	VS - Very Soft	ELS - Extremely Low Strength	EW - Extremely Weathered	fg - Fine Grained
L - Loose	S - Soft	VLS - Very Low Strength	HW - Highly Weathered	mg - Medium Grained
MD - Medium Dense	F - Firm	LS - Low Strength	DW - Distinctly Weathered	cg - Coarse Grained
D - Dense	St - Stiff	MS - Medium Strength	MW - Moderately Weathered	MAS - Massive
VD - Very Dense	VSt - Very Stiff	HS - High Strength	SW - Slightly Weathered	BD - Bedded
	H - Hard	VHS - Very High Strength	FR - Fresh	OC - Outcrop

SITE PLAN & TEST LOCATIONS FIGURE 1.

CROZIER
GEOTECHNICAL CONSULTANTS

Crozier Geotechnical ABN: 96 113 453 624
Unit 12, 42-46 Wattle Road Phone: (02) 9939 1882
Brookvale NSW 2100 Fax: (02) 9939 1883
Crozier Geotechnical is a division of PJC Geo-Engineering Pty Ltd

LEGEND

AUGER LOCATIONS

SCALE: NOT TO SCALE
DRAWING: FIGURE 1
DATE: 18/10/2019

APPROVED BY: TMC
DRAWN BY: JY
PROJECT: 2019-120

PREPARED FOR:
The Pittwater House School

ADDRESS:
70 South Creek Road, Collaroy, NSW

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 1

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 13.88

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	In Situ Testing Results	
0.00						
0.05	TOPSOIL: Brown, silty sand with roots					
0.30	FILL: Brown and grey, coarse grained, moist, sandy gravel and probable cobbles with some concrete pieces (<5cm)		0.30			
	SILTY SAND(SM): Very loose, dark grey, fine grained, dry-moist, silty sand	D	0.40			
			0.50			
0.60	é loose, pale brown grey	S			1,0,1 N=1	
			0.95			
			1.00			
		D				
			1.50			
		S			2,2,2 N=4	
1.80	é trace/with clay below 1.80m depth					
			1.95			
2.00	é brown/yellow brown		2.00			
		D				
2.50			2.50			
	SANDY CLAY(CI): Stiff, brown, moist, sandy clay, fine to medium grained sand	S			4,4,7 N=11	
2.80	é fine to medium subangular gravels at 2.8m depth					
			2.95			
	é orange brown mottled grey, moist		3.00			
3.30	é red mottled grey					
		D				
3.70	é grey mottled orange red					
			4.00			
4.00	... Very stiff	S			5,8,7 N=15	
			4.45			
4.80	...red mottled grey		4.80			
5.00		D	5.00			

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: GW seepage at 6.0m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 1

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 2 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 13.88

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
5.00						
		S	5.50 5.95		11,10,10 N=20	
6.00	é seepage at 6.0m depth					
7.00		S	7.00 7.45		5,12,12 N=24	
	é orange brown mottled grey, moist					
		S	8.50 8.95		6,7,11 N=18	
9.00						
10.45		S	10.00 10.45		7,9,12 N=21	
	End of borehole at 10.45m depth					

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: Saw seepage at 6.0m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 2

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 13.21

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
0.00						
0.10	ASPHALT (100mm)					
	FILL: Brown pink grey, clayey sandy gravel					
0.40			0.40			
	SILTY SAND(SM): Medium dense grading, dark grey, fine to medium grained, dry-moist, silty sand	D	0.50			
0.60	é pale grey	S	0.95		4,5,5 N= 10	
1.30	é orange brown, moist		1.30			
		D	1.50			
1.80	é with clay	S	1.95		1,3,6 N=9	
2.00			2.00			
2.10	SANDY CLAY (CI): Stiff, orange brown mottled grey and red sandy clay fine grained sand	D	2.50			
2.80	é grey	S	2.95		3,6,7 N=13	
2.95	é orange brown mottled grey, moist					
3.50	é red and grey mottled					
4.00			4.00			
		(S)	4.45		4,6,7 N=13	
			4.50			
4.80	é grading to clayey sand	S	4.95		3,5,8 N=13	

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: GW seepage at 5.2m CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 2

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 2 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 13.21

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results
5.00					
			5.50		
		S			4,5,8 N= 13
			5.95		
6.50	é zones of clayey sand				
7.00	é very stiff		7.00		
		S			3,7,11 N=18
7.45			7.45		
	é orange brown mottled grey, moist				
			8.50		
		S			6,13,17 N=30
8.90	é hard with tabular gravel, fine to coarse sub angular of sandstone		8.95		
9.00					
			10.00		
	é very stiff	S			6,11,12 N=23
10.45			10.45		
	End of borehole at 10.45m				

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: Saw seepage at 5.2m CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 3

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.15

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results
0.00					
0.10	TOPSOIL: Brown, silty sand with rootlets				
0.30	FILL: Brown mottled pale grey, fine to medium grained, moist, silty sandy gravel with some angular pieces of concrete and sandstone gravels		0.30		
		D			
0.50			0.50		
	SILTY SAND: Medium dense, pale grey, fine to medium grained , moist	S			3,4,7 N=11
0.95			0.95		
		D			
1.10	é red brown and pale grey, with clay		1.10		
		D			
1.50			1.50		
1.60					3,3,2 N=5
	SANDY CLAY(CI): Firm, brown mottled orange, medium plasticity, moist/wet, sandy clay with zones of clayey sand	S			
1.95	é wet		1.95		
2.00		D	2.00		
2.50	é stiff		2.50		
		S			4,8,9 N=14
			2.95		
3.00	é orange brown mottled grey, moist		3.00		
		D	3.20		
4.00	é red mottled grey		4.00		
		S			4,6,7 N=13
4.45			4.45		

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: GW layer of seepage at 1.80m to 2.50m and then GW seepage from 5.5m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 3

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 2 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.15

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
5.00						
			5.50		4,5,8 N=13	
		S				
			5.95			
7.00	é very stiff		7.00		4,6,10 N=16	
		S				
			7.45			
	é orange brown mottled grey, moist					
			8.50			
8.60	é layer pale grey				5,6,9 N=15	
		S				
			8.95			
9.00						
10.00			10.00		7,10,12 N=22	
		S				
10.45			10.45			
	End of borehole at 10.45m depth					

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: Saw layer of seepage at 1.80m to 2.50m and then saw seepage from 5.5m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 4

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.76

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	In Situ Testing Results
0.00					
0.10	CONCRETE				
	SILTY SAND(SM): Very loose, dark grey, fine grained, moist, silty sand		0.30		
0.40	é pale grey	D	0.40		
			0.50		
0.70	é brown grey	S			2,2,2 N=4
			0.95		
			1.20		
1.40	é trace cray	D	1.50		
1.55	SANDY CLAY(CI): Stiff, grey mottled orange and yellow, sandy clay, fine to medium grained sand, moist, zones of clayey sand	S			2,4,6 N=10
			1.95		
2.00					
			2.50		
		S			4,5,8 N=13
			2.95		
	é orange brown mottled grey, moist				
4.00	é red orange mottled pale grey		4.00		
		(S) Disturbed			4,6,8 N=14
			4.45		

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: GW seepage @ 5.5m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 3/10/2019 **BH No.:** 4

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 2 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.76

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	In Situ Testing Results
5.00					
			5.50		
		S			3,5,10 N=15
			5.95		
6.80	é bands of grey sand at 6.80m depth				
7.00	é very stiff, red orange with pale grey		7.00		
		S			5,7,10 N=17
			7.45		
	é orange brown mottled grey, moist		8.00		
		D	8.20		
			8.50		
		S			5,8,10 N=18
			8.95		
9.00					
			10.00		
		S			7,7,11 N=18
10.45			10.45		
	End of borehole at 10.45m depth				

RIG: Multi-purpose CE180 DRILLER: BG DRILLING LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS:

REMARKS: Saw seepage @ 5.5m depth CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 5

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 13.3m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
	FILL: Pale brown grey, sandy, medium to coarse gravel.				
0.30	SAND (SP) Medium dense, dark grey, fine grained, dry-moist. (Alluvium)	B	0.30		
0.60	é fine to medium grained, pale grey.	D/B	0.60 0.70		
1.10	CLAYEY SILT (SC) Very stiff to hard, dark grey, mottled orange clayey silt, moist (Alluvium)	D	1.20 1.30		
1.60	SILTY/CLAYEY SAND (SM/SC) Medium dense, orange brown, fine grained, moist. (Alluvium)	D	1.60 1.80		
	End of borehole 2.00m depth				

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tungsten carbide bit.

GROUND WATER OBSERVATIONS: None observed during drilling

REMARKS: CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 6

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.2m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results
0.00					
	FILL: Pale brown grey, sandy, medium to coarse gravel.		0.20		
0.30		D			
	SAND (SP) Medium dense, dark grey, fine grained sand, dry-moist. (Alluvial Soils)		0.40		
0.60	é fine to medium grained, pale grey.				
0.70	GRAVELLY SAND (SP): Dense, orange brown, and dark brown, fine to medium grained sand, moist (Alluvial Soils)	B			
1.50	CLAYEY SAND (SC): Medium dense, yellow orange fine grained sand, moist . (Alluvial Soils)				
	End of borehole 2.0m depth				
2.00					

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS: CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 7

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 14.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
	FILL: Pale brown silty sand with rootlets. (TOPSOIL to 0.10m)				
0.30	...pale brown gravelly sand,fine to medium grained, moist				
0.50			0.50		
	SAND (SP) Dense, pale grey, fine to medium grained sand, moist (Alluvium)	D	0.70		
1.00			1.00		
	GRAVELLY SAND (SP): Dense, orange brown, grading yellow brown gravelly sand with clay/silt, moist (Alluvium)	B			
1.60			1.60		
	SANDY CLAY (CL) Stiff, yellow brown sandy clay, fine grained sand, moist, locally grading to a clayey sand. (Alluvium)	D	1.80		
	End of borehole 2.0m depth.				
2.00					

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS: CHECKED:

Crozier Geotechnical Consultants

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 8

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 15.8m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	Results	
0.00						
	FILL: Pale brown silty sand with rootlets. (TOPSOIL to 0.10m)	D	0.00 0.10			
0.30	SAND (SP) Medium dense, pale grey, fine to medium grained sand, moist (Alluvium)					
0.50	GRAVELLY SAND (SP): Dense, orange brown, grading yellow brown gravelly sand with clay/silt, moist. (Alluvium)	B	0.50			
1.70	CLAYEY SAND (SC) Medium dense, brown fine to medium grained clayey sand, locally grading to a sandy clay, moist. (Alluvium)		1.70			
2.00	End of borehole 2.0m depth					
2.00						

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS: CHECKED:

Crozier Geotechnical Consultants

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 9

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 16.4m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
0.20	FILL: Pale brown silty sand with rootlets. (TOPSOIL to 0.20m)	D	0.10		
0.40	SILTY SAND (SM) Medium demse, orange brown, with fine to medium gravel. (Alluvium)		0.40		
	CLAYEY SAND (SC) Medium dense, orange brown fine to medium grained clayey sand, locally grading to a sandy clay, moist. (Alluvium)	B			
1.40	é orange yellow		1.40		
2.00	End of borehole 2.0m depth.				

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS: CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools **DATE:** 24/09/2019 **BH No.:** 10

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 18.50m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing	
		Type	Depth (m)	Type	Results
0.00					
0.15	Pavers over pale brown sand.				
	SILTY SAND (SM): Very loose, dark grey/black silty sand, moist. (Alluvium)				
0.80	SAND (SP) Medium dense, pale grey, fine grained sand, trace gravel, moist (Alluvium)				
1.60	GRAVELLY SAND (SW) Medium dense to dense, orange brown, fine to medium grained sand, mediun grained subrounded gravel, moist. (Alliuvium)				
2.00					
2.40	SANDY CLAY (CI) Stiff to very stiff, orange, fine grained sand, locally with zones of clayey sand, moist. (Residual Deposits)		2.60		
		D			
			2.80		
3.00	é mottled grey				
4.00					
4.80	é grey motled orange				

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: None observed during drilling

REMARKS: CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd | **DATE:** 24/09/2019 | **BH No.:** 10

PROJECT: Alterations to existing and construction of new structures. | **PROJECT No.:** 2019-120 | **SHEET:** 2 of 2

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. | **SURFACE LEVEL:** RL å 18.5m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
6.00	é orange mottled grey and white.					
	End of Borehole 7.0m depth					
1.00						
2.00						

RIG: Dingo restricted access | DRILLER: AC | LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS:

CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.:** 11

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 23.2m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling Type	Sampling Depth (m)	In Situ Testing Type	In Situ Testing Results	
0.00						
	ASPHALT PAVING (50mm) over brown grey medium to coarse sandy gravel					
0.30	SANDY CLAY (CI/CH) Very stiff grading hard orange brown and grey mottled sandy clay, fine grained (Residual Soils)		0.50			
		D	0.60			
		B				
1.50	é red		1.50			
		D	1.70			
1.80	é grey, orange and red mottled.					
	End of borehole 2.0m depth					
2.00						

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS:

CHECKED:

TEST BORE REPORT

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019 **BH No.** 12

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120 **SHEET:** 1 of 1

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SURFACE LEVEL:** RL å 22.4m

Depth (m)	Description of Strata PRIMARY SOIL - strength/density, colour, grainsize/plasticity, moisture, soil type incl. secondary constituents, other remarks	Sampling		In Situ Testing		
		Type	Depth (m)	Type	Results	
0.00						
0.20	ASPHALT PAVING (50mm) over brown grey medium to coarse sandy gravel					
	FILL: Grey fine grained sand, dry.					
0.50	é brown grey gravelly sand, clods of clay					
2.00						
	End of borehole 2.0m depth.					
2.00						

RIG: Dingo restricted access DRILLER: AC LOGGED: KN

METHOD: Spiral flight auger with tunnsten carbide bit.

GROUND WATER OBSERVATIONS: Nonoe observed during drilling

REMARKS: CHECKED:

DYNAMIC PENETROMETER TEST SHEET

CLIENT: The Pittwater House Schools Ltd **DATE:** 24/09/2019

PROJECT: Alterations to existing and construction of new structures. **PROJECT No.:** 2019-120

LOCATION: The Pittwater House School, 70 South Creek Road, Collaroy. **SHEET:** **1 of 1**

	Test Location							
Depth (m)	DCP5	DCP6	DCP7	DCP8	DCP9	DCP10	DCP11	DCP12
0.00 - 0.15	20	--	2	1	1	33	--	--
0.15 - 0.30	33	--	7	7	13	27	--	--
0.30 - 0.45	8	4	11	5	14	1	6	16
0.45 - 0.60	5	4	10	5	6	0	5	4
0.60 - 0.75	4	5	9	4	5	1	7	6
0.75 - 0.90	5	6	8	3	3	11	10	32
0.90 - 1.05	5	10	6	18	4	20	16	End
1.05 - 1.20	9	23	10	10	2	15	17	
1.20 - 1.35	13	16	13	13	3	13	End	
1.35 - 1.50	9	7	11	11	3	11		
1.50 - 1.65	8	7	13	13	4	6		
1.65 - 1.80	4	7	15	15	7	10		
1.80 - 1.95	3	9	19	19	6	11		
1.95 - 2.10	5	17	19	19	6	14		
2.10 - 2.25	End	End	End	End	End	12		
2.25 - 2.40						13		
						Pre-drill to 3.15m		
3.15 - 3.30						7		
3.30 - 3.45						10		
3.45 - 3.60						9		
3.60 - 3.75						14		
3.75 - 3.90						16		
3.90 - 4.05						17		
						End		

TEST METHOD: AS 1289. F3.2, CONE PENETROMETER

REMARKS:

(B) Test hammer bouncing upon refusal on solid object

-- No test undertaken at this level due to prior excavation of soils

Appendix 3

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

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