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PRELIMINARY GEOTECHNICAL INVESTIGATION & LANDSLIDE RISK ASSESSMENT

For

121 PACIFIC ROAD, PALM BEACH NSW 2108

PREPARED FOR:	Karen, Colin & John Bowers C/- Daniel Boddam Architecture and Interior Design
REFERENCE:	REF-19-8048-A
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CONTROLLED DOCUMENT

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1. INTRODUCTION

Envirotech Pty Ltd was commissioned by Mr. Daniel Boddam from Architecture & Interior Design to undertake a Preliminary Geotechnical Investigation and Landslide Risk Assessment for the proposed development at 121 Pacific Road, Palm beach NSW 2108.

1.1 Overview

The objectives of the Geotechnical Investigation were to provide information on the surface and subsurface soil conditions within the excavated areas of the subject site, and to deliver a factual engineering assessment, comments and design recommendations relating to the effects of the excavation works within the building envelope.

The Landslide Risk assessment was conducted to evaluate the effect of the proposed development on the stability of the site, including risk to property and life.

1.1 Proposed Development

The proposed will entail the construction of a new residential dwelling including the following;

- Lower ground floor;
- Ground floor;
- First floor; and
- Swimming Pool.

1.2 Scope of Works

The scope of works comprised the following;

- A desktop study and review of available reports and geological maps held within our files;
- A review of available drawings and survey plans;
- Application for “Dial Before You Dig” plans;
- Walkover observations of the site;
- Assessment of the existing site conditions and local geology;
- Auger drilling of two (2) boreholes up to 4.00 m or refusal in the vicinity of the proposed excavation envelope;
- Insitu Dynamic Cone Penetrometer (DCP) testing at all borehole locations;
- Site Classification
- Geotechnical slope risk assessment;
- Engineering logs; and
- Geotechnical engineering assessment and recommendations.

1.3 Legislative Requirements

This assessment has been prepared in general accordance with the following guidelines and standards;

- Australian Standard 1726 (2017) - *'Geotechnical site investigations'*;
- Australian Standard 2159 (2009) - *'Piling –Design and installation'*;
- Australian Standard 2870 (2011) - *'Residential slabs and footings'*;
- Australian Standard 3798 (2007) - 'Guidelines on earthworks for commercial and residential developments';
- Australian Standard 4678 (2002) - *'Earth-retaining structures'*;
- Australian Standard 1170.4 (2007) - *'Structural design actions. Part 4: Earthquake actions in Australia'*; and
- Landslide Risk Management (Australian Geomechanics Society, 2007).

1.4 Context of Report

This report is to be read in its entirety and individual sections should not be reviewed to provide any level of information independently. Each section of the report relates to the rest of the document and as such is to be read in conjunction, including its appendices and attachments. Particular attention is drawn to the limitations of inherent site investigation and the importance of verifying the subsurface conditions inferred herein.

2. DESKTOP STUDY

A range of online resources in conjunction with Envirotech desktop files were accessed for the desktop study. Appendix B displays the soil landscape notes for the location. Appendix C displays the maps for the desktop study.

2.1 Primary Soil Landscapes

Landscape - undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 m, slopes 10-25%. Rock outcrop <25%. Broad convex crests, moderately inclined sideslopes with wide benches, localised rock outcrop on low broken scarps. Extensively cleared open-forest (dry sclerophyll forest) and eucalypt woodland.

2.2 Dominant Soil Materials

Gymea (Erosional)

Loose, coarse sandy loam. This is loamy sand to sandy loam with loose, apedal single-grained structure and porous sandy fabric. It generally occurs as topsoil. The colour often becomes lighter with depth and ranges from brownish-black, when organic matter is present, to bleached dull yellow-orange. It

is often water repellent under native vegetation. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.0). Small sandstone and platy ironstone fragments, charcoal fragments and roots are common.

Earthy, yellowish-brown clayey sand. This is commonly yellowish-brown clayey sand with apedal massive structure and porous earthy fabric. It commonly occurs as subsoil over sandstone bedrock (B horizon). Where it is exposed at the surface it forms hardsetting topsoil. Texture may increase gradually to a light sandy clay loam with depth. Colour is commonly yellowish-brown and orange mottles are occasionally present with depth. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.5). Sandstone and ironstone fragments are common and are often concentrated in stone lines in the upper parts of this material. Charcoal fragments are common whilst roots are rare.

Earthy to weakly pedal, yellowish-brown sandy clay loam. This is commonly a yellowish brown sandy clay loam to sandy clay with an apedal massive structure and an earthy porous fabric. It usually occurs as subsoil on coarse sandstone. Texture is commonly sandy clay loam but may increase gradually with depth to sandy clay. Occasionally a weakly pedal structure of sub-angular blocky shaped peds are present. Peds are commonly rough-faced and porous and range in size from 5-20 mm. Colour is commonly yellowish brown. Orange mottles may occur with depth. The pH ranges from strongly acid (pH 4.5) to slightly acid (pH 6.0). Strongly weathered sandstone fragments are common. Roots and charcoal fragments are rare.

Moderately to strongly pedal, yellowish-brown clay. This is commonly a yellowish-brown sandy clay or light clay with a moderately to strongly pedal structure and either a smooth or rough faced ped fabric. This material occurs as subsoil on shale bedrock. Peds ranging in size from 5mm to 50 mm, are either smooth or rough-faced and are polyhedral to sub-angular blocky. Colour is commonly yellow-brown but can vary from dark reddish-brown to light grey. Red, orange and grey mottles are occasionally present at depth. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.0). Shale and ironstone fragments are often present, but charcoal fragments are absent, and roots are rare.

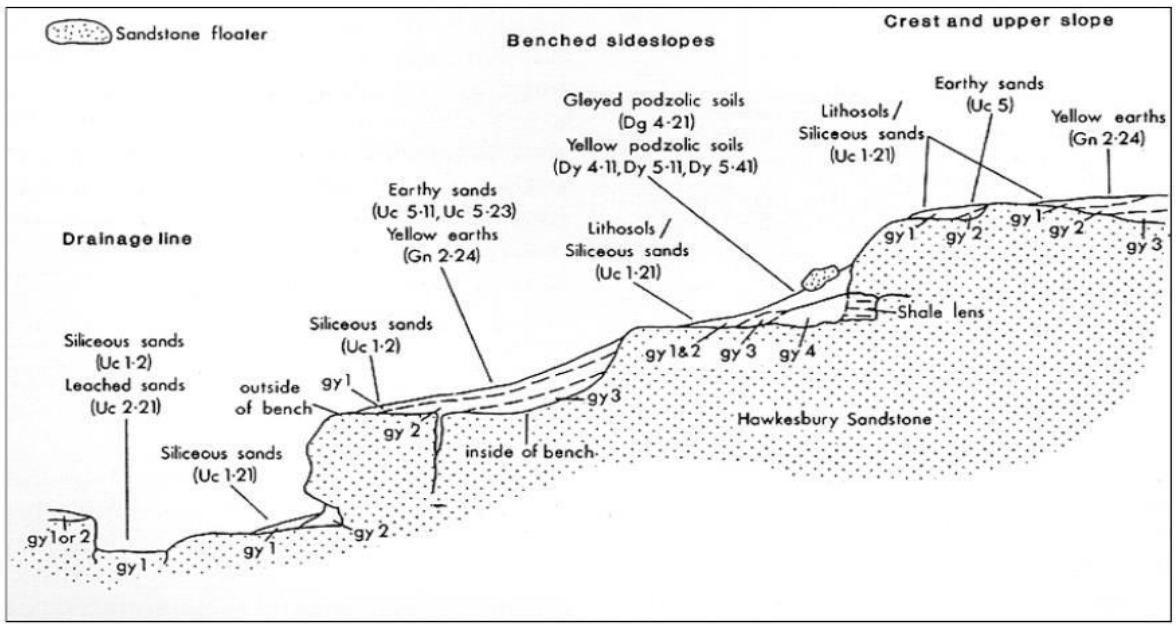


Figure 1 Schematic Cross Section of Gymea Soil Landscape

2.3 Land Zoning

With reference to the Pittwater Local Environmental Plan 2014 the site is classified as **E4 – Environmental Living**. The attached plan is shown in Appendix C.

2.4 Heritage

With reference to the Pittwater Local Environmental Plan 2014 the subject site is **not** classified as being heritage listed. The attached plan is shown in Appendix C.

2.5 Acid Sulfate Soils

With reference to the Pittwater Local Environmental Plan 2014 the subject site is classified as **Class 5** Acid Sulfate Soils. The attached plan is shown in Appendix C.

2.6 Landslide Risk Land

The site is considered to be at risk of slope instability. With reference to the Pittwater Local Environmental Plan 2014 the site is considered to be mapped **Geotechnical Hazard H1**. The attached plan is shown in Appendix C.

3. METHODOLOGY

1.1 Fieldwork

A site visit was made on Thursday 1st August 2019 by a geotechnical engineer from Envirotech. A preliminary walkover of the site was conducted during the site visit. The fieldwork consisted of a visual assessment and drilling of two (2) boreholes by a 4wd Ute Mounted Auger Drill (BH03) and Mechanical Hand Auger (BH02) to depths up to 1.10 m (met with refusal) at locations nominated by Envirotech.

Dynamic Cone Penetrometer (DCP) testing was undertaken at three (3) locations including the borehole positions. Pocket penetrometer testing was undertaken where possible on non-disturbed material.

Appendix A displays location of boreholes and Insitu testing undertaken.

1.2 Laboratory

No sampling was undertaken during the site visit.

2. SITE DESCRIPTION

The site was located at Lot 17, DP 8595 No. 121 Pacific Road, Palm Beach NSW 2108 (Figure 1). The area of the site was approximately 2453 m^2. The subject site is accessed by Pacific Road to the west. At the time of the inspection the subject site consisted of an existing dilapidated residential dwelling. The subject site was accessed via Pacific Road by a concrete driveway on the western side of the site.

Large eucalypt trees were present at the front of the property (Pacific Road) with managed lawns as an understory. Several retained areas and garden beds were present leading downslope to the east of the site. The rear of the site was heavily vegetated and mostly uninhabitable.

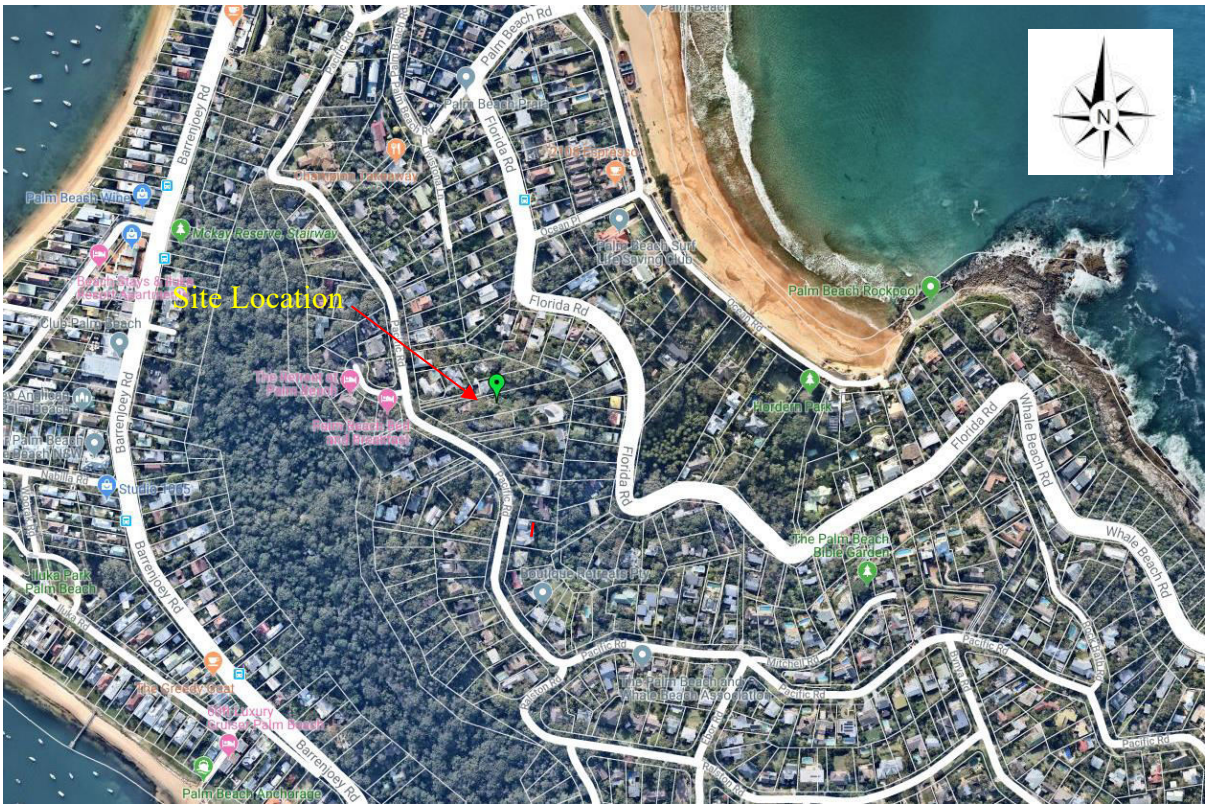


Figure 2 Site Location

2.1 Geology

In reference to the Sydney 1:100,000 Geological Sheet Series 9130 (Edition 1) 1983 the site consists of;

- Hawkesbury Sandstone - medium to coarse -grained quartz sandstone, very minor shale and laminite lenses.
- Newport and Garie Formation - Interbedded laminite, shale and quartz to lithic-quartz sandstone.

2.2 Subsurface Conditions

A summary of the subsurface strata is presented in the following table. Figure 3 displays typical recovered subsoils from the borehole investigation.

Table 1 A Descriptive Summary of Geological Units

UNIT	SOIL TYPE
UNIT A	TOPSOIL; Admix silt and sand with clay, grey brown, organics (roots/bark), moist
UNIT B	RESIDUAL: Silty CLAY w/ sand; brown mottled orange red, fine to medium sands
UNIT E	BEDROCK: Clayey SANDSTONE; EW - DW, red orange to pale grey and white, fine to medium sands, ELS to VLS, moist to slightly moist

Figure 3 Typical display of recovered borehole material

A summary of the subsurface strata depths is presented in the following table;

Table 2 Depth of Geological Units

BOREHOLE	GEOLOGICAL UNIT		
	UNIT A	UNIT B	UNIT C
BH01	0.00 - 0.05 m	-	0.20 - 1.00 m
BH02	-	0.00 - 0.15m	0.15 - 0.85m

Appendix E displays results of detailed logs. Appendix F details the Insitu DCP results.

3. LABORATORY RESULTS

No laboratory testing was undertaken for the purpose of this report.

4. GROUNDWATER

No groundwater was observed within the drilled boreholes. Furthermore, no surface water was observed during the site visit.

With reference to WaterNSW Groundwater Map there are thirty-four (34) bores located within 500m of the subject site. Table 3 below presents recorded groundwater levels (WaterNSW) at the bores which may provide a guide for approximate standing water levels (S.W.L) expected on the subject site;

Table 3 Water Bearing Zones (Source: WaterNSW)

Borehole	Depth From (m)	Depth To (m)	Strata	Thickness (m)	S.W.L (m)	Yield (L/s)
GW107355	5.10	5.70	SAND	0.60	-	1.00
GW110419	3.50	6.00	Lithic SAND	2.50	3.50	-
GW106874	2.13	5.18	SAND	3.05	2.37	0.30
GW108019	3.00	6.00	SAND	3.00	3.00	0.50
GW105677	2.00	4.00	SAND	2.00	2.00	0.50
GW106055	2.00	4.50	SAND	2.50	2.00	0.50
GW106385	2.00	4.00	SAND	2.00	2.00	0.50
GW108656	3.00	6.00	SAND	3.00	3.00	0.50
GW110788	3.40	4.20	SAND	0.80	-	1.00
GW106709	3.00	6.00	SAND	3.00	3.00	0.50
GW108817	3.00	6.00	SAND	3.00	3.00	0.50
GW105824	2.00	6.00	SAND	4.00	2.00	0.50
GW107894	4.00	6.00	SAND	2.00	4.00	0.50
GW106383	2.00	4.00	SAND	2.00	2.00	0.50
GW108567	1.80	6.00	SAND	4.20	1.80	1.00
GW105595	2.50	5.00	SAND	2.50	2.50	0.50
GW105596	3.00	5.40	SAND	2.40	3.00	-
GW112524	1.73	4.30	SAND	2.57	1.75	1.00
GW105986	2.00	4.00	SAND	2.00	2.00	0.50
GW105987	2.00	4.00	SAND	2.00	2.00	0.50
GW110789	2.60	3.60	SAND	1.00	-	1.00
GW105823	2.00	4.00	SAND	2.00	2.00	0.50
GW106559	3.00	5.00	SAND	2.00	3.00	0.50
GW106097	2.00	4.00	SAND	2.00	2.00	0.50
GW106119	2.00	4.00	SAND	2.00	2.00	1.50
GW107175	3.20	4.70	SAND	1.50	-	1.00
GW105726	2.13	4.88	SAND	2.75	2.13	1.00
GW115794	3.00	6.00	SAND	3.00	3.00	0.50

Note: Groundwater bores GW108858, GW105794, GW101648, 110407 & GW108959 did not display any information and therefore not included in the above table.

Although it is not anticipated groundwater will be encountered during excavation, if water is met, excavations during construction should be manageable by using conventional sump and pump methods. Suitable sediment control for all discharges should be included. Diverted flows from run-off should be directed (where possible) to Council, or other approved, stormwater systems to prevent water accumulating in areas surrounding retaining structures or footings.

5. RECOMMENDATIONS

1.1 Site Classification

The classification of a site involves several geotechnical factors such as depth of bedrock, the nature and extent of subsurface soils and any specific problems (slope stability, soft soils, filling, reactivity, etc.).

During the site investigation subsurface conditions presented Sandy CLAY to depths up to 0.90 m overlying SANDSTONE bedrock. In accordance with AS2870-2011 the subject site can be classified as **Class M** and having a characteristic surface movement (y_s) of **20-25 mm**. Notwithstanding, we recommend the proposed excavated works should enter minimum Class V Sandstone strata and that all footings for the structures will be founded into the consolidated sandstone bedrock.

If recommendations are adopted, we anticipate little to no ground movement from moisture changes within the natural sandy profile and therefore, adopting sound engineering principles, the site reactivity shall be classified **Class A**. It should be noted that if controlled fill is used as foundation material the site may be re-classified (if applicable) if assessed in accordance with engineering principles.

1.2 Site Preparation

Local geology and site conditions generally feature shallow rock however the extent of investigation displayed unsuitable soft soils (topsoil) up to 0.25 m depth. DCP and borehole drill results displayed the natural ground profile at depths greater than 0.25 m. Furthermore, auger refusal was encountered between 0.90 m – 1.10 m and interpreted as hard clayey sandstone bedrock. Considering this, the site should be stripped of all surface vegetation, organic topsoil, uncontrolled fill and other deleterious materials.

Removal of soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in the council stormwater system, open waters and on neighboring land. All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods should be adopted in accordance with local council requirements. Erosion and sediment control may be aided by minimizing the disturbance footprint.

Material removed from the site will need to be managed in accordance with the provision of current legislation and may include material type classification in accordance with NSW EPA (2014) Waste Classification Guideline and disposal at facilities appropriately licensed to receive the materials.

1.3 Excavation and Vibration

We understand that most excavation works will encounter weathered sandstone bedrock. In light of this;

- Overlying admixed sandy soils and vegetation including small trees may be removed by conventional earthmoving equipment such as an excavator with bucket.
- Excavation of loose (sandstone floaters) or rippable sandstone may be removed by an excavator with a tooth bucket or single ripper attachment.
- Consolidated sandstone (i.e. medium strength or stronger) to be removed may require vibratory rock breaking equipment or similar. We recommend demolition methods not involving impact be implemented where possible. This may include the use of hydraulic rock splitters rather than rock breakers.
- If vibratory rock breaking equipment is required, we recommend that, prior to the use of vibratory equipment, the excavation perimeter is saw cut with the aid of an excavator mounted rock saw or by drill and split techniques to minimise transmission of vibrations to adjoining structures.
- Following sawing of the perimeter of the excavation, sandstone bedrock may be broken up using a vibratory hammer suited to an excavator. Induced vibrations in structures adjacent to the excavation are to be examined to ensure that they do not exceed a peak particle velocity (PPV) of 6mm/sec.

Excavation works should be carried out by an experienced operator who is aware of factors affecting vibration and transmission of vibration such as orientation of the hammer, duration of hammering and speed of the vibration of the hammer. At the completion of excavation, inspection shall be made by an experienced geotechnical engineer to determine the necessity and extent of the permanent support measures based on the encountered soil, or in the case of rock strength, bedding, and possible joint sets/crushed zone and defect distance on excavation face, if there is any.

Prior to all excavation works, it is recommended that dilapidation surveys be undertaken out on the surrounding properties as a means of protecting all parties involved in or affected by the proposed works.

1.4 Retaining Structures

Adopted geotechnical strength and stiffness parameters for design of excavation support are provided in the following table;

Table 4 Adopted Design Excavation Material Parameters

Material	Unit Weight (kN/m³)	Undrained Shear Strength C_u(kPa)	Effective Strength Parameters		Elastic Parameters	
			Cohesion c′ (kPa)	Friction Angle φ′	Elastic Modulus E′ (MPa)	Poisson Ratio ν
Engineered Fill	20	50	10	27	5-10	0.25
Natural Soft Clay	18	25	0	25	1-3	0.25
Residual Firm Clay	18	75	10	27	5-10	0.25
Class V Sandstone	20	-	10	28	300	0.30
Class IV Sandstone	22	-	20	30	1000	0.30
Class III Sandstone or better	24	-	50	35	5000	0.35

1.4.1 Temporary Supports

Where space permits, temporary batter slopes within the natural sandy clay soils and Class V bedrock are recommended. Excavations may be battered back to slopes 2V:1H for temporary batters provided that no surcharge loads, including construction and existing footing loads, are placed within 2 m of the top of the slope. Suitable erosion, sediment and disturbance prevention plans should be designed and implemented for all unsupported slopes.

Temporary shoring may be required where;

- Space limitations do not allow for batters
- Surcharge loads are applied near the edge of excavations
- Soft/wet ground conditions are encountered
- Significant seepage or water inflow occurs

Any temporary excavations into soil and weathered rock exceeding 1.0 m depth should be supported by a suitably designed and installed shoring system in accordance with AS4678 Earth Retaining Structures. The soil pressure can be calculated by;

- A qualified and suitably experienced engineer using finite Rankine formula for SAND and Terzaghi formula for CLAY. If groundwater is to be retained an external dewatering system must be adopted or water pressures be included in the calculations by the engineer.
- Adopting 10H where H is the effective vertical height in meters I.e. an excavation with an effective vertical height of 4.0m would require a shoring system with a capacity rated to 10*4.0 = 40KPa.

If temporary shoring is utilised, it is typically adequate to select a shoring system which won't retain water and to monitor the ground water in and beside the excavation to ensure compliance.

1.4.2 Permanent Supports

All permanent retaining structures must be designed by a qualified and suitably experienced engineer in accordance with all applicable standards, legislation and guidelines. Full hydrostatic pressure should be assumed from surface level to account for events such as flooding. The pressure distribution on cantilever retaining structures, due to earth pressures and surcharges behind the wall, may be assumed to be triangular and calculated as follows;

ph = gkH + qk
Where,
ph = Horizontal pressure (kN/m2)
g = Wet density (kN/m3)
k = Coefficient of earth pressure (ka or ko)
H = Retained height (m)
q = Surcharge pressure behind retaining wall (kN/m2)

In the case that excavations encroach sandstone bedrock, supports can generally maintain grades between vertical and 8(V):1(H). Sandstone may contain adversely orientated jointing and crossbedding defects, along with susceptibility to accelerated weathering when, interbedded with mudstones, exposed to water and air. To manage potential risks associated with the rock material, we recommend that a geotechnical inspection of the exposed rock faces be inspected regularly at depths no greater than 1.5 m intervals. A recommended environmental and risk analysis should be performed to ensure the risks from erosion, run off and slope failure are managed and within acceptable limits.

1.4.3 Retaining Wall Design Parameters

The following table presents the recommended design parameters for retaining structures. For the design of flexible retaining structures, where some lateral movement is acceptable, an active earth pressure coefficient is recommended. Should it be critical to limit lateral deformation of a retaining structure, adopted at rest earth pressure coefficient should be considered.

Table 5 Retaining Wall Design Parameters

Material	Unit Weight (kN/m3)	Active Earth pressure Coefficient (K_a)	At Rest Earth pressure Coefficient (K_o)
Engineered Fill	20	0.35	0.50
Soft to Firm Silty Clays	18	0.35	0.50
VL Strength Sandstone	20	0.40	0.50
M Strength Sandstone	24	0.40	0.50
MH Strength Sandstone	24	0.30	0.40

Note: VL – Very low, M – Medium, MH – Medium to High
The earth pressure coefficients provided have been calculated assuming zero friction between the wall and soil, that the wall is perfectly vertical (90°), the surrounding surface level is perfectly horizontal (0°) and an over consolidation ratio (OCR) equal to 1. The retaining wall designer should make an independent assessment of the parameters appropriate to the conditions and methodology used.

1.5 General

It is recommended that any excavated rock faces be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete or changes to batter angles are required. Support options may include a reinforced shotcrete wall and/or rock bolting subject to inspection and approval by an experienced geotechnical engineer. Minimum 10cm thick shotcrete retaining wall with 10×10 mesh may be adopted.

Anchors could be inclined up to a maximum of 30° below horizontal (60° base angle), if required to intercept bedrock /higher strength bedrock. In the absence of shear strength data or 'pull-out' tests, typical rock bolt values for ultimate bond stress of 800 kPa for distinctly weathered sandstone and 1.9 MPa for medium strength or better sandstone may be adopted. Required length of anchors needs to be determined after inspection of excavation face based on the defect distance although a minimum fixed anchor length of 3 m is recommended to guard against variable rock quality and constructional imperfections.

The following should be noted during anchor design and construction:

- The contractor should adopt design values including an appropriate factor of safety relevant to the installation methodology and anchor type adopted,
- Anchor holes must be clean prior to grouting, and
- Steel anchors should be check stressed to 125% of the nominal working load and then locked off at 60% to 65% of the working load. For manufacture of polymers, the designer should select appropriate values.

Requirements of rock bolting (if required) will need to be detailed and approved after inspection in completion of excavation by a suitably experienced and qualified geotechnical engineer. Appropriate drainage should be provided between excavation face and retaining walls (e.g. strip drains and ag-line in free draining gravel).

At the completion of rock excavation/cut, if topsoil/vegetative overburden is encountered along the top line of the excavation (up to depth of 0.5m), a sandstone block retaining wall is suggested to retain the overburden material. If depth of the overburden soil is more than 0.5m, it shall be battered by 1(V):2(H). The retaining wall designer should consider the additional surcharge loading from existing structures, construction equipment, backfill compaction and ground water.

Backfill should comprise of select fill meeting the requirements of controlled fill (Class 1) and compacted to provide a uniform density over the full width of the wall. The following requirements should be met in accordance with AS 4678;

- The select fill should be frictional, free of organic material, contaminants and deleterious substances.
- Particle size of material should be defined as in Table D5 of AS 4678.

- Backfill should be placed and compacted in maximum 100 mm thick layers.
- The Plasticity Index should be less than 12.
- Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls therefore the use of hand-held compaction equipment would be appropriate.
- Appropriate drainage should be provided between backfill/soil exposure and retaining walls (e.g. strip drains and ag-line in free draining gravel) such that it is capable of relieving the hydrostatic head behind the structure or reinforced soil mass.
- Non-woven geotextile fabric is recommended to be utilised between the compacted soil and fee-draining back filled material to prevent clogging.

Use of heavy machinery should be avoided, where possible, within 2 m of the crest of any open soil excavation to prevent excessive local surcharge loads, vibrations and undue settlement within exposed soils.

Careful consideration of nearby structures (e.g. footings, services, utilities, etc) must be given when they are within the excavation zone of influence. The excavation zone of influence extends as a triangle from the base of the excavation to ground level at 1V:2H (Figure 2). If a service falls within this zone a qualified and suitably experienced engineer should design a shoring system and develop an installation methodology which limits the settlement and horizontal movement, so the structure will not be affected.

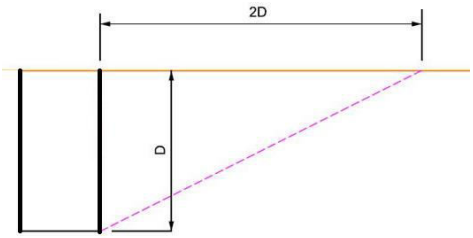


Figure 4 Excavation Zone of Influence

1.6 Foundations

On completion of excavation works, we estimate low strength sandstone (minimum Class V) is expected to be present at founding depths. We therefore recommend the structure be uniformly supported on footings founded within the Class V sandstone. Pad and strip footings and piles founded within the consolidated bedrock may be designed based on the allowable end bearing pressures outlined in Table 6.

For piles, we recommend a minimum socket of 0.3 m into the appropriate stratum to achieve the allowable end bearing pressures. For rock sockets longer than 0.3 m we recommend adopting assigned allowable shaft adhesion values set out in the table provided the socket is satisfactorily cleaned and roughened (Class R2 or better).

For all footings, both shallow and piles, the lowest quality bedrock within 1.5 times the width/diameter of the footing/pile will give the allowable bearing pressure for the design of the footings. The allowable bearing pressures and adhesion values set out in the following table are based on serviceability criteria and should result in settlements of less than 1% of the footing diameter/width.

Table 6 Footing Design Parameters

Pells (1998) et al Rock Class	Allowable Bearing Pressure (kPa)	Allowable Shaft Adhesion (compression) (kPa)	Allowable Shaft Adhesion (tension/uplift) (kPa)
Stiff CLAY	100	10	5
Class V Sandstone	1000	100	50
Class IV Sandstone	1500	150	75
Class III Sandstone	3000	300	150

1.7 Earthquake

AS 1170.4 'Structural design actions, Part4: Earthquake actions in Australia' provides advice regarding structural design against potential seismic events.

In accordance with Table 4.1 of AS 1170.4, the following parameters can be adopted:

- Site subsoil can be classified as 'Class C_e – Shallow soil site';
- A Hazard Design Factor (Z) of 0.09 can be given; and a
- Probability Factor (k_p) of 1.0 can be adopted.

6. LANDSLIDE RISK ASSESSMENT

6.1 Topography

Undulating to rolling low hills with local relief 20-80 m and slopes of 10-25%. Sideslopes with narrow to wide outcropping sandstone rock benches (10-100 m), often forming broken scarps of <5 m.

6.2 Encountered Site Conditions

The site was located at Lot 17, DP 8595 No. 121 Pacific Road, Palm Beach NSW 2108 (Figure 1). The area of the site was approximately 2453 m^2. At the time of the site inspection the site displayed an existing dilapidated residential dwelling with concrete driveway leading from the access point of the site (Pacific Road) to the west. Small open grassed areas existed within the front portions of the subject site. Along with several scattered mature trees and shrubs.

The rear of the property consisted of cleared open sloped areas leading to dense largely uninhabited bushland (Figure 5). Outcropping of massively bedded sandstone bedrock was present at the rear of the existing dwelling (Figure 6). The property consisted of numerous small man-made sandstone

retaining walls (Figure 7) and one large (approximately 2 m high) sandstone block retaining wall along the northern side of the dwelling (Figure 8).

Figure 5 Dense bushland looking east

Figure 6 Typical display of sandstone outcrop

Figure 7 Small man-made sandstone block retaining wall

Figure 8 Large man-made sandstone block retaining wall

6.3 Slope Instability

Assessing the instability of a slope (i.e. Landslide Risk Assessment) requires careful consideration of a wide range of inputs by an experienced and suitably qualified professional. The primary outcome of a Landslide Risk Assessment is to identify signs of stress in the landscape, the potential and mechanisms (**Error! Reference source not found.**) for distress to form, the likelihood of distress causing a landslide and the risk to life and property a landslide will cause.

The most common considerations are:

- The slope of the land
- Local and broad topography
- Cut and fill
- Existing vegetation (type, density, and existing slip evidence)
- Cleared vegetation
- Soil moisture changes (rain, flow paths and non-natural sources)
- Foundation type

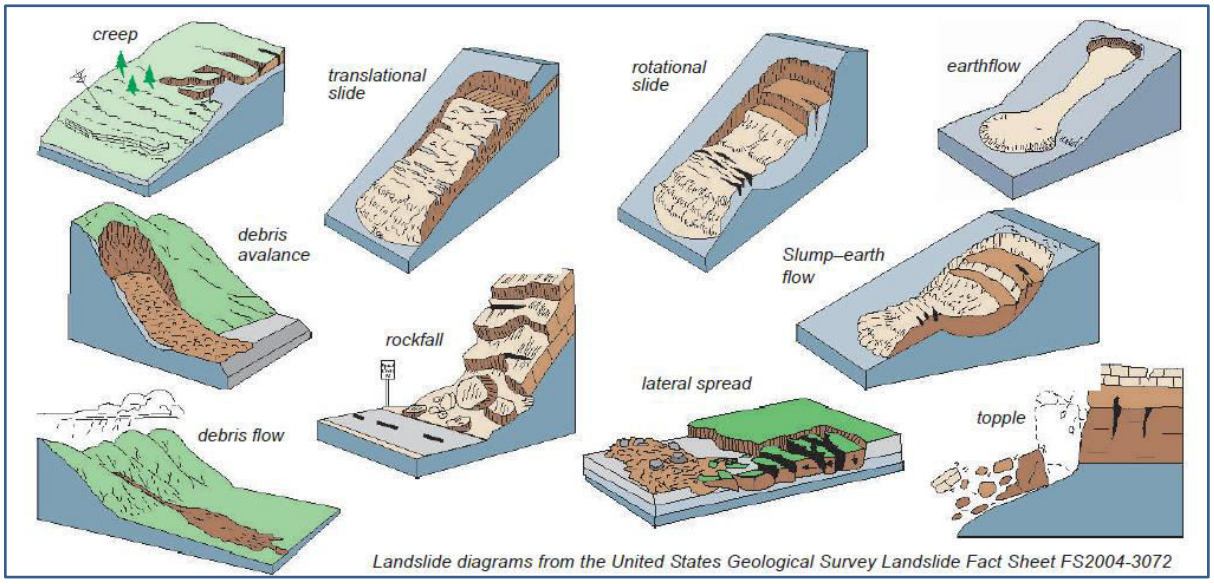


Figure 9 Landslide mechanisms

The Australian Geomechanics Society published quantitative measures for performing a Risk Analysis (Australian Geomechanics Vol 42 No 1, 2007). This approach has been adopted for assessing the risk of a landslide to property and life.

NOTE: This assessment only investigates the risk associated with the proposed construction of a new dwelling. It does not consider the current risk state of the site and its surrounds, nor any structures or infrastructure**.**

6.4 Slope Stability Assessment

The site and desktop inspection suggest the subject site is built upon relatively shallow residual Sandy Clays overlying low to medium strength SANDSTONE. Commonly, natural outcropping of friable sandstone, massive boulders and floaters are typical of the area as can be seen in Figure 6. Insitu testing of the soil profile suggests underlying bedrock to be at an approximate depth of 1.00 m although we anticipate the depth to rock to vary within the investigation area, in particular the area directly at the rear of the existing dwelling which consists of up to an approximate 1 - 1.50 m of fill.

The slope gradients and classification for the subject site are as follows;

- Overall site east-west - 11.9% Moderate slope
- Rear of site south-north - 30% Steep slope
- Front of site south-north - 4.6% Gentle slope

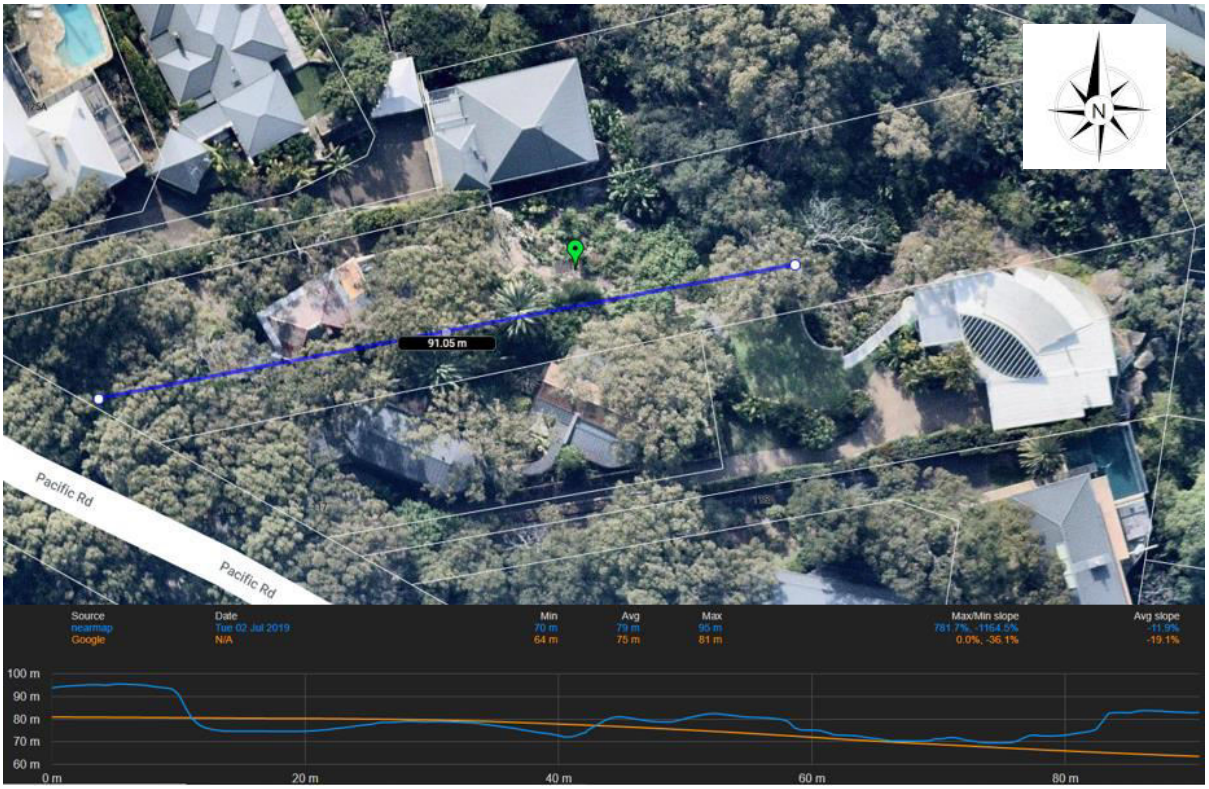


Figure 10 Overall site slope gradient looking east-west

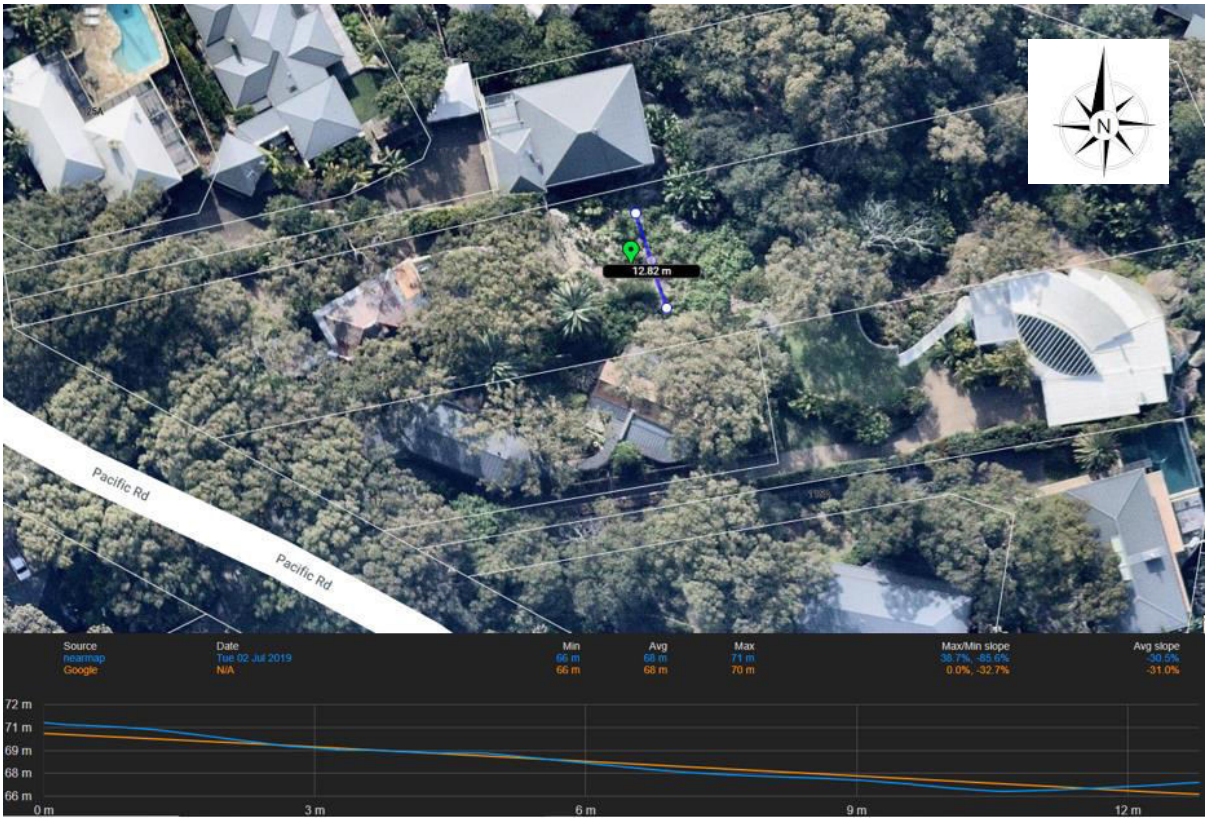


Figure 11 Rear of site gradient looking south to north

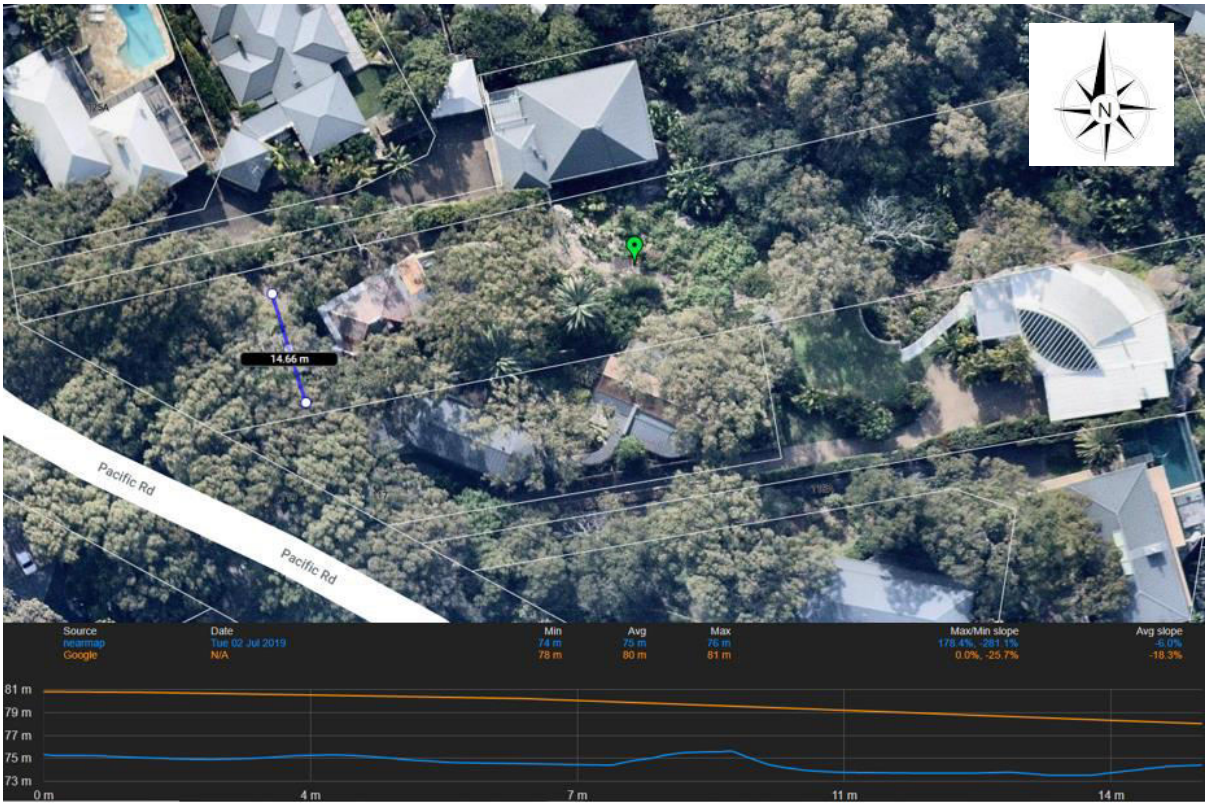


Figure 12 Front of site gradient looking south to north

The assessment assumes that the proposed new residential dwelling will be founded onto shallow sandstone bedrock. This slope assessment only investigates the effect the proposed will likely have on the site and the respective risk to property and life. The risk to property includes the total value of the entire dwelling.

The primary failure modes considered in this assessment are 'rock fall and 'debris flow'. The risk matrix adopted is displayed below. Specific values for the consequence and likelihood are shown in Appendix G.

Table 7 Matrix Summary

LIKELIHOOD	CONSEQUENCE				
	1	**2**	**3**	**4**	**5**
A	VH	VH	VH	H	M/L
B	VH	VH	H	M	L
C	VH	H	M	M	VL
D	H	M	L	L	VL
E	M	L	L	VL	VL
F	L	VL	VL	VL	VL

VERY HIGH (VH)
HIGH (H)
MEDIUM (M)
LOW (L)
VERY LOW (VL)

6.5 Discussion/Recommendations

The landslide risk assessment (Appendix D) shows an **acceptable** risk for loss of life for the person(s) - risk level **suitable** for new developments. Risk to property is considered to be **low**. No immediate mitigation measures are required for this site however it is advised that the slopes are monitored for erosion and movement (irrespective of the whether the proposed is constructed).

Particular attention should be made to any loose unconsolidated surface material and loose sandstone boulders or floaters within the proposed footprint, particularly during the construction period. If warning signs of slope failure are noticed, such as creep or debris flow during and after heavy rain periods or movement in the rock masses, the relevant authorities should be notified and action to stabilise the affected area using a retaining wall, sediment fencing, or other suitable means should be implemented.

The following recommendations must be adhered to and are explicitly provided for the existing conditions currently observed at the time the site inspection was made;

- The proposed must be founded into the existing consolidated sandstone bedrock. Loose scree and floaters or boulders, sand sediment and other soil materials (colluvium) should be removed in order to expose the founding bedrock.
- If practical, remove or stabilise boulders which may have unacceptable risk and support rock faces where necessary.

- Cut and fill should be avoided where possible to minimise slope disturbance.
- All retaining walls over 1.0m must be designed by a suitably qualified and experienced engineer. Reference to AS 4678 (2002) - *'Earth-retaining structures'* should be adopted for detailed construction requirements.
- All retaining walls must have gravel, geotextile material and drainage installed professionally.
- Drainage within retained areas must be constructed in order to mitigate periods of high intensity rainfall and/or rainfall events characteristic of local climate behaviour.
- Exposed excavated cuts in slopes should not be left exposed and should be supported as soon as practically possible post excavation.
- All retained areas must be constructed as soon as possible after cut/fill operation.
- Ground cover should be maintained whenever possible. If erosion is identified, a sediment and erosion control plan should be determined and actioned.
- Tree removal should be kept to a minimum as the underlying root system provides structure and stability to the underlying soils. The removal of mature trees may also have an effect on soil suction and shrink-swell properties of the soils – Refer to AS 2870 'Residential Slabs and Footings' Appendix H – Guide to Design of Footings for Trees.
- The practice notes in Appendix F should be followed at all times.

This assessment is based solely on the effect construction within the subject site may have on the proposed new residential dwelling;

- Being designed and constructed by suitably experienced and qualified professionals,
- The footings being founded into consolidate sandstone bedrock or engineered material in accordance with AS 2870 'Residential Slabs and Footings'
- Having a design life equivalent to the design life of the development

Based on the assessment and assumptions presented, the site is suitable for the proposed development without the requirement for mediation measures.

7. LIMITATIONS

EnviroTech Pty. Ltd. Pty. Ltd. has undertaken the following report in accordance with the scope of works set out between EnviroTech Pty. Ltd. and the client. EnviroTech Pty. Ltd. derived the data in this report primarily from the site and soil assessment conducted on the date of site inspection. The impacts of future events may require future investigation of the site and subsequent data analysis, together with a re-evaluation of the conclusions and recommendations of this report.

In preparing this report, EnviroTech Pty. Ltd has relied upon, and assumed accurate, certain site information provided by the client and other persons. Except as otherwise stated in the report, we have not attempted to verify the accuracy or completeness of any such information. EnviroTech Pty. Ltd. accepts no liability or responsibility whatsoever for or in respect to any use or reliance upon this report by any third party.

The information contained within this report have been prepared exclusively for the client. Envirotech have prepared the report to address the risk associated with scale of the works. The report has been prepared with a degree of care and skill ordinarily exercised in similar investigations by reputable members of the environmental industry in Australia. No other warranty, expressed or implied, is made or intended. This report is to be read in its entirety including attachments and appendices and should not read in individual sections.

A third party should not rely upon the information prior to making an assessment that the scope of work conducted meets their specific needs. Envirotech cannot be held liable for third party reliance on this document.

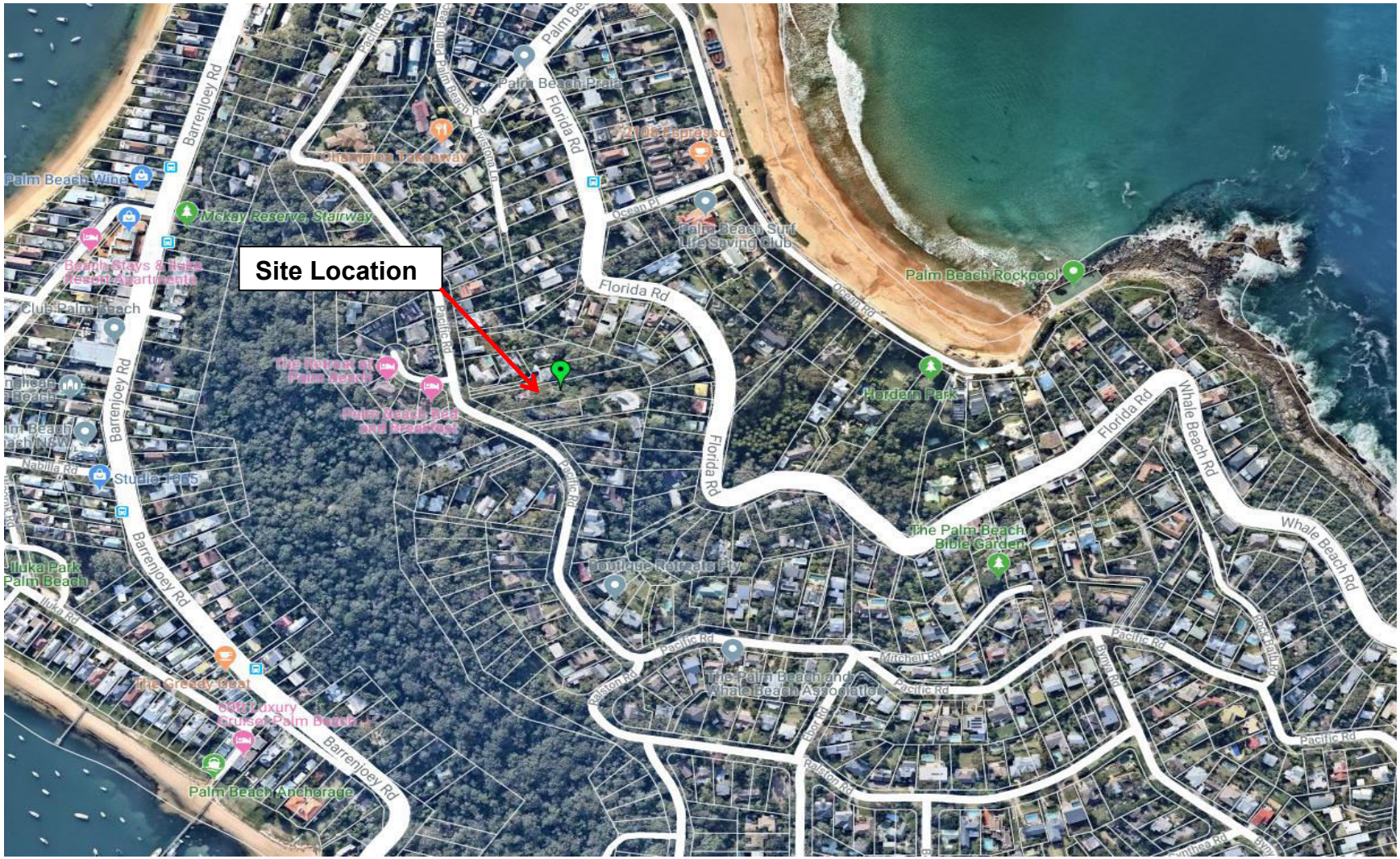
Envirotech's professional opinions are based upon its professional judgment, experience, training and results from analytical data. In some cases, further testing and analysis may be required, thus producing different results and/or opinions. Envirotech Pty Ltd has limited its investigation to the scope agreed upon with its client.

8. REFERENCES

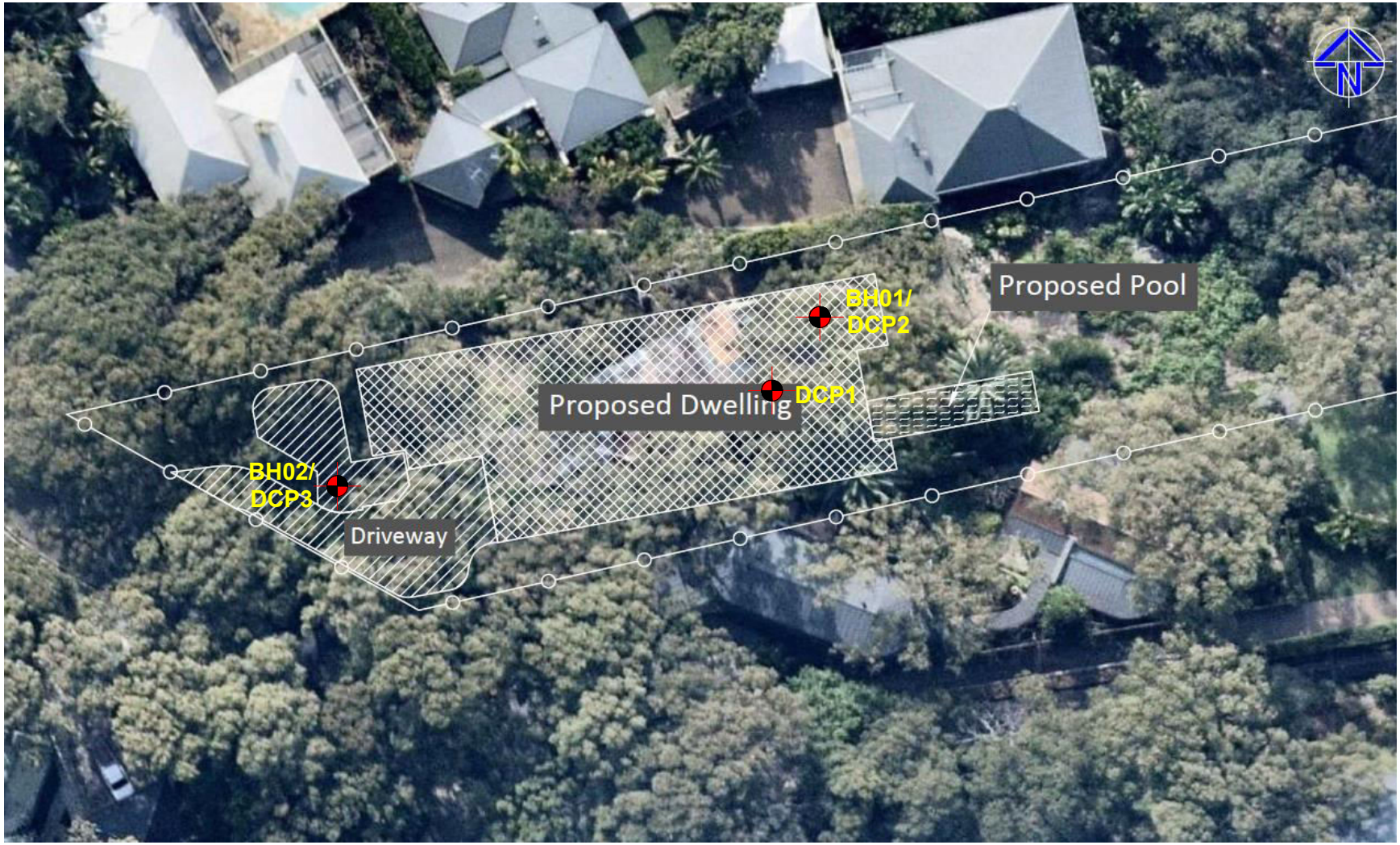
- Australian Standard 4678-2002 *'Earth-retaining structures'*
- Australian Standard 3798-2007 *'Guidelines on Earthworks for Commercial and Residential Developments'*
- Australian Standard 2159-2009 *'Piling –Design and installation'*
- Australian Standard 2870-2011 *'Residential Slabs and Footings'*
- Australian Standard 1170.4-2007 *'Structural design actions. Part 4: Earthquake actions in Australia'*
- Australian Standard 1726-2017 *'Geotechnical site investigations'*
- Northern Beaches Council policies, guidelines and requirements
- Pells et al 'Foundations on Sandstone and Shale in the Sydney Region' (1998)
- NSW Resources and Geoscience: Sydney 1:100,000 Geological Sheet Series 9130 (Edition 1) 1983 (https://resourcesandgeoscience.nsw.gov.au/_data/assets/image/0006/343527/Sydney100K_Geological_Sheet_9130_1st_edition_1983.jpg)
- NSW Spatial Information Exchange (http://maps.six.nsw.gov.au/)
- NSW Espade (http://www.environment.nsw.gov.au/eSpadeWebapp/)
- Pittwater Local Environmental Plan 2014
- Landslide Risk Management (Australian Geomechanics Society, 2007)

Appendix A – Site and Borehole Locations

Site Location



Borehole and DCP Test locations



Note: Borehole not to size. Borehole/test location approximate. DCP undertaken in all borehole locations.

Appendix B – Soil Landscape

gy	GYMEA	Erosional

Source: Soil and Land Resources of the Hawkesbury-Nepean Catchment *interactive DVD*

Landscape— undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 m, slopes 10-25%. Rock outcrop <25%. Broad convex crests, moderately inclined sideslopes with wide benches, localised rock outcrop on low broken scarps. Extensively cleared open-forest (dry sclerophyll forest) and eucalypt woodland.

Soils— shallow to moderately deep (30-100 cm) *Yellow Earths (Gn2.24)* and *Earthy Sands (Uc5.11, Uc5.23)* on crests and inside of benches; shallow (<20 cm) *Siliceous Sands (Uc1.21)* on leading edges of benches; localised *Gleyed Podzolic Soils (Dg4.21)* and *Yellow Podzolic Soils (Dy4.11, Dy5.11, Dy5.41)* on shale lenses; shallow to moderately deep (<100 cm) *Siliceous Sands (Uc1.21)* and *Leached Sands (Uc2.21)* along drainage lines.

Limitations— localised steep slopes, high soil erosion hazard, rock outcrop, shallow highly permeable soil, very low soil fertility.

LOCATION

Occurs extensively throughout the Hornsby Plateau and along the foreshores of Sydney Harbour and the Parramatta and Georges Rivers. Examples include areas of Northbridge, Forestville, Drummoyne, Balmain, Arcadia and Berrilee.

LANDSCAPE

Geology

Hawkesbury Sandstone, which is a medium to coarse-grained quartz sandstone with minor shale and laminite lenses.

Topography

Undulating to rolling low hills with local relief 20-80 m and slopes of 10-25%. Sideslopes with narrow to wide outcropping sandstone rock benches (10-100 m), often forming broken scarps of <5 m.

Vegetation

The original dry sclerophyll woodland and open-forest have been extensively cleared. Low, dry sclerophyll open-woodland dominates ridges and upper slopes. Common species include red bloodwood *Eucalyptus gummifera*, yellow bloodwood *E. eximia*, scribbly gum *E. haemastoma*, brown stringybark *E. capitellata* and old man banksia *Banksia serrata*. On the more sheltered slopes, black ash *E. sieberi*, Sydney peppermint *E. piperita* and smooth-barked apple *Angophora costata* are common tree species. The dry sclerophyll understorey consists of shrubs from the families Epacridaceae, Myrtaceae, Fabaceae and Proteaceae.

Land use

Land use is mostly urban residential. Developed suburbs include Forestville, Northbridge and Drummoyne. Steeper sections are used for recreational purposes and often remain covered with native vegetation. Grazing occurs at Berrilee and there are small hobby farms in the north-west.

Existing Erosion

Severe sheet erosion occurs following bushfires, which destroy or damage stabilising vegetative cover. Minor gully erosion occurs along unpaved or poorly maintained roads and fire trails especially those frequented by four-wheel-drive vehicles and trail bikes.

Associated Soil Landscapes

Small areas (<40 ha) of Hawkesbury (**ha**) and Lambert (**la**) soil landscapes have been included within the Gymea soil landscape. In many respects these landscape have qualities in common with the Gymea soil landscape.

SOILS

Dominant Soil Materials

gy1— Loose, coarse sandy loam. This is loamy sand to sandy loam with loose, apedal single-grained structure and porous sandy fabric. It generally occurs as topsoil (A1 horizon).

The colour often becomes lighter with depth and ranges from brownish-black (10YR 2/2), when organic matter is present, to bleached dull yellow-orange (10YR 7/2). It is often water repellent under native vegetation. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.0). Small sandstone and platy ironstone fragments, charcoal fragments and roots are common.

gy2— Earthy, yellowish-brown clayey sand. This is commonly yellowish-brown clayey sand with apedal massive structure and porous earthy fabric. It commonly occurs as subsoil over sandstone bedrock (B horizon). Where it is exposed at the surface it forms hardsetting topsoil.

Texture may increase gradually to a light sandy clay loam with depth. Colour is commonly yellowish-brown (10YR 6/8) and orange mottles are occasionally present with depth. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.5). Sandstone and ironstone fragments are common and are often concentrated in stone lines in the upper parts of this material. Charcoal fragments are common whilst roots are rare.

gy3— Earthy to weakly pedal, yellowish-brown sandy clay loam. This is commonly a yellowish-brown sandy clay loam to sandy clay with an apedal massive structure and an earthy porous fabric. It usually occurs as subsoil (B or C horizon) on coarse sandstone.

Texture is commonly sandy clay loam, but may increase gradually with depth to sandy clay. Occasionally a weakly pedal structure of sub-angular blocky shaped peds are present. Peds are

commonly rough-faced and porous and range in size from 5-20 mm. Colour is commonly yellowish brown (10YR 5/8, 6/6, 6/8; 2.5Y 5/6, 5/4). Orange mottles may occur with depth. The pH ranges from strongly acid (pH 4.5) to slightly acid (pH 6.0). Strongly weathered sandstone fragments are common. Roots and charcoal fragments are rare.

gy4— Moderately to strongly pedal, yellowish-brown clay. This is commonly a yellowish-brown sandy clay or light clay with a moderately to strongly pedal structure and either a smooth or rough-faced ped fabric. This material occurs as subsoil on shale bedrock (B and C horizons).

Peds ranging in size from 5 mm to 50 mm, are either smooth or rough-faced and are polyhedral to sub-angular blocky. Colour is commonly yellow-brown (10YR 6/6),, but can vary from dark reddish-brown (2.5YR 3/6) to light grey (7.5YR 8/1). Red, orange and grey mottles are occasionally present at depth. The pH ranges from strongly acid (pH 4.0) to slightly acid (pH 6.0). Shale and ironstone fragments are often present, but charcoal fragments are absent and roots are rare.

Associated Soil Materials

Litter and decomposing organic debris. In areas of natural bushland, litter and organic debris occur on the soil surface. The litter layer can be developed to depths of up to 10 cm. Charcoal fragments are common. This material is often found in debris dams in association with white, loose quartz sand.

White, loose quartz sand. A surface wash of quartz sand grains. It occurs in depositional areas such as small debris dams and fans on breaks of slope. It is often mixed with the litter layer and is usually water repellent.

Occurrence and Relationships

Crests. Generally up to 30 cm of loose, quartz sandy loam (**gy1**) overlies bedrock (*Siliceous Sands* and *Lithosols* (*Uc 1.21*)) or <30 cm of earthy, yellowish-brown clayey sand (**gy2**) (*Earthy Sands* (*Uc5.11*)). Occasionally (**gy2**) overlies up to 30 cm of yellow earthy/weakly pedal sandy clay loam (**gy3**) (*Yellow Earths* (*Gn2.24*)). Boundaries between soil materials are gradual. Total soil depth is <50 cm.

Where severe erosion has occurred, **gy2** or **gy3** is often exposed as a hardsetting layer at the surface. Bedrock is exposed in some areas, particularly where bushfires are frequent.

Sideslopes. The soils on the sideslopes are discontinuous and rock outcrop may cover up to 25% of the ground surface. On the outside of benches and areas close to rock outcrop, up to 20 cm of **gy1** overlies bedrock (*Siliceous Sands*/*Lithosols* (*Uc1.21*)). On the inside of benches, up to 30 cm of **gy1** overlies 10-30 cm of **gy2**. Occasionally **gy2** overlies up to 30 cm of **gy3**. The boundaries between soil materials are gradual. Total soil depth is 30-70 cm (*Yellow Earths* (*Gn2.24*), *Earthy Sands* (*Uc5.11*)).

Shale lenses. Where shale lenses occur on the inside of benches, up to 30 cm of **gy1** overlies up to 100 cm of strongly pedal yellowish-brown clay (**gy4**). The boundary between soil materials is sharp to clear. Total soil depth is <100 cm (*Gleyed Podzolic Soils* (*Dg 4.21*), *Yellow Podzolic Soils* (*Dy 5.41*)).

Drainage lines. Up to 100 cm of **gy1** overlies bedrock (*Siliceous Sands* (*Uc1.2*) and *Leached Sands* (*Uc 2.21*)).

LIMITATIONS TO DEVELOPMENT

Urban Capability

Generally, low to moderate capability for urban development.

Rural Capability

Land not capable of being grazed or cultivated.

Landscape Limitations

Erosion hazard
Rock outcrop
Rockfall hazard (localised)
Steep slopes (localised)
Shallow soil

Soil Limitations

gy1 High permeability
Low available water capacity
Stoniness
Low fertility

gy2 Low available water capacity
Stoniness
Very low fertility
Very strongly acid
Very high aluminium toxicity

gy3 Low available water capacity
Low wet strength (localised)
Low permeability (localised)
Stoniness (localised)
Very low fertility
Very strongly acid
High aluminium toxicity

gy4 Low wet strength
High erodibility
Low permeability
Low available water capacity
Stoniness (localised)
Very low fertility
Very strongly acid
Very high aluminium toxicity

Fertility

Very poor. The soils of this unit are generally shallow, stony, moderately acid and highly permeable with low available water capacities. They also have a low to very low nutrient status with very low phosphorus and nitrogen levels and very low CEC.

Erodibility

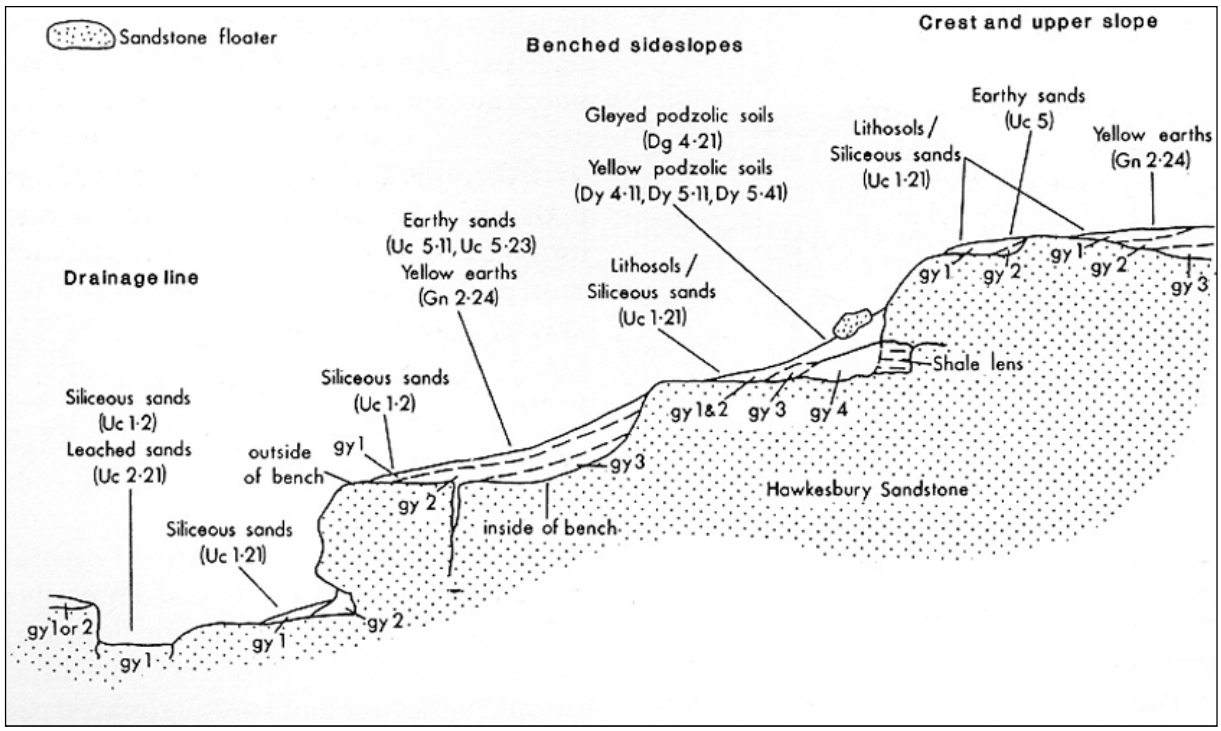
gy1 and **gy2** are composed of coarse sand grains and have very low erodibilities as they are freely drained and are held together by high organic matter contents (**gy1**) and/or non-dispersive clays (**gy2**). However, (**gy3**) is moderately erodible as it has a weakly coherent earthy fabric with low organic matter content. **gy4** is highly erodible as it is very low in organic matter and consists dominantly of fine sands in a clay matrix.

Erosion Hazard

The erosion hazard for non-concentrated flows is generally high to very high, but can range from moderate to extreme. Calculated soil loss for the first twelve months of development range up to 19 t/ha for topsoil and 464 t/ha for subsoil. Soil erosion hazard for concentrated flows is high to extreme.

Surface Movement Potential

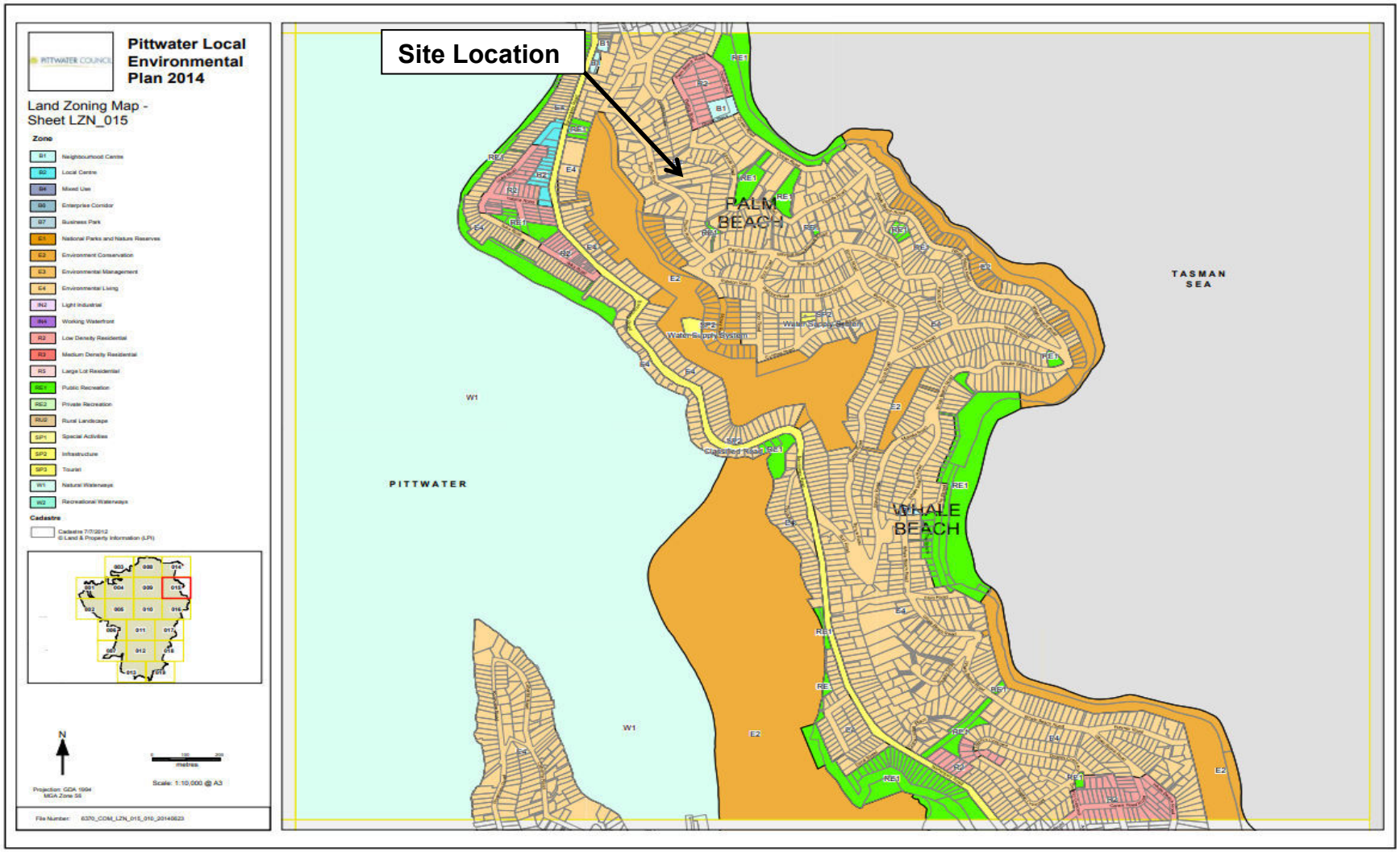
The shallow sandy soils are stable to slightly reactive. In isolated instances where gy4 is >100 cm thick soils may be moderately reactive.



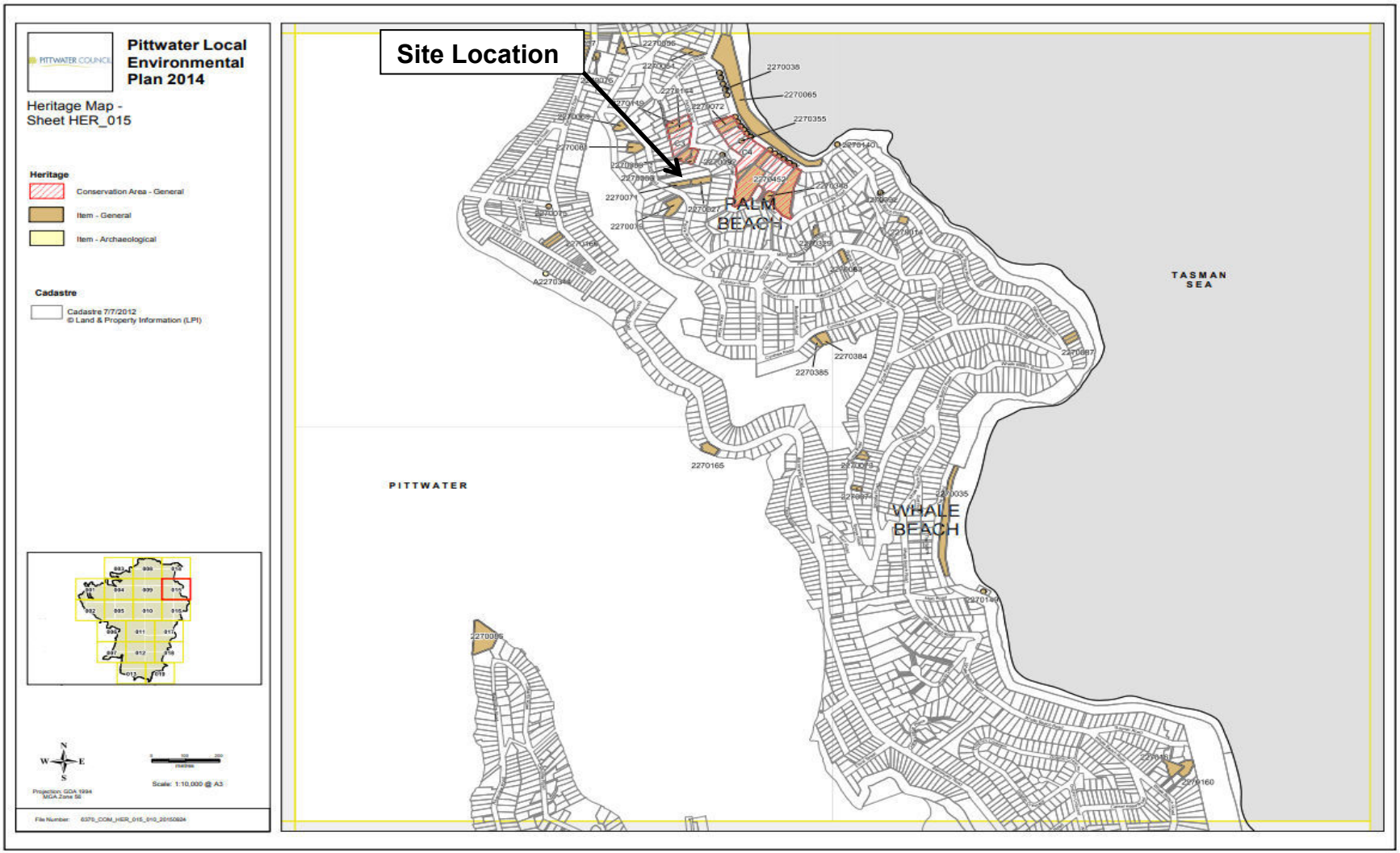
Schematic cross-section of Gymea soil landscape illustrating the occurrence and relationship of the dominant soil materials.

Appendix C – Desktop Study

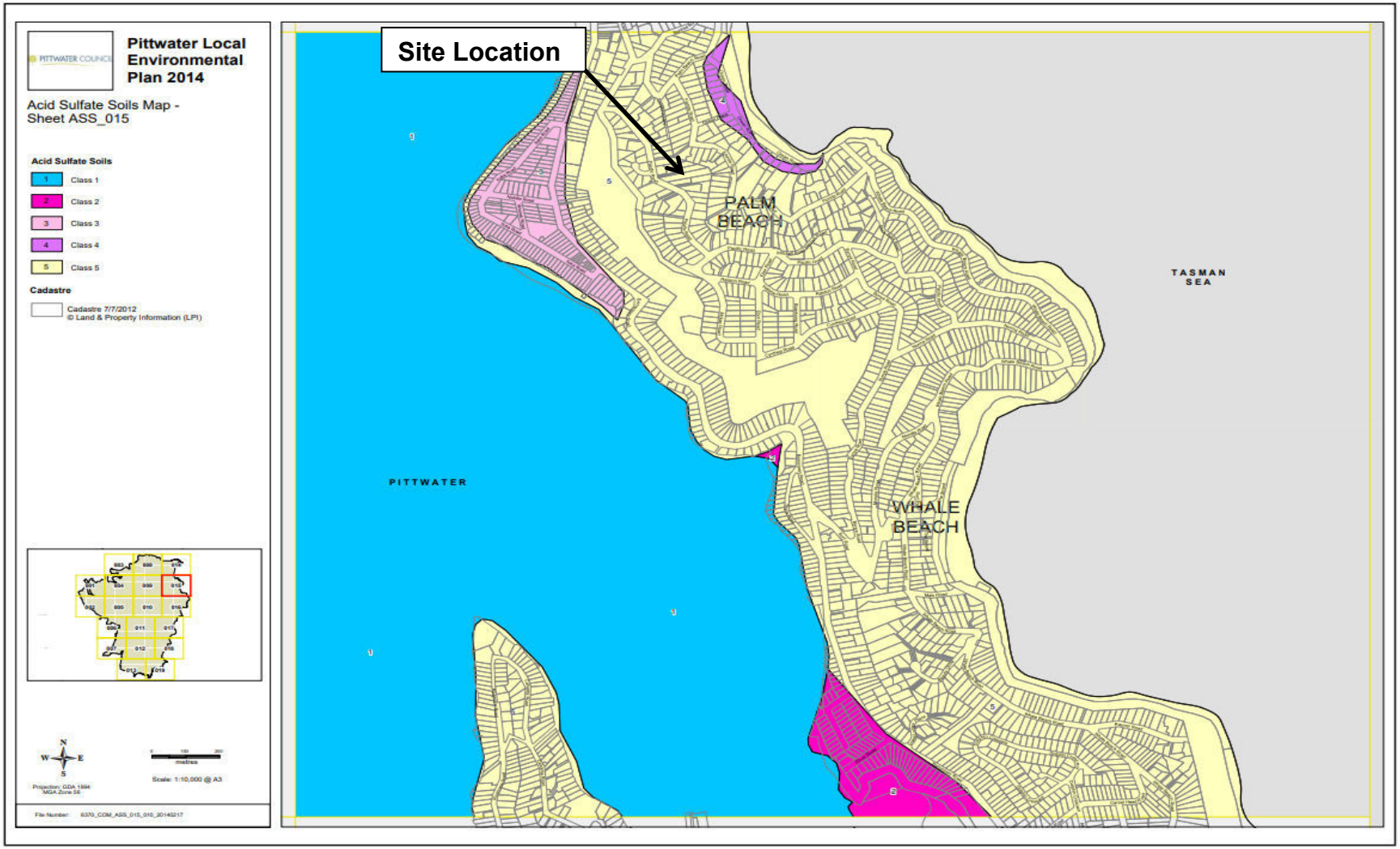
Land Zoning Map



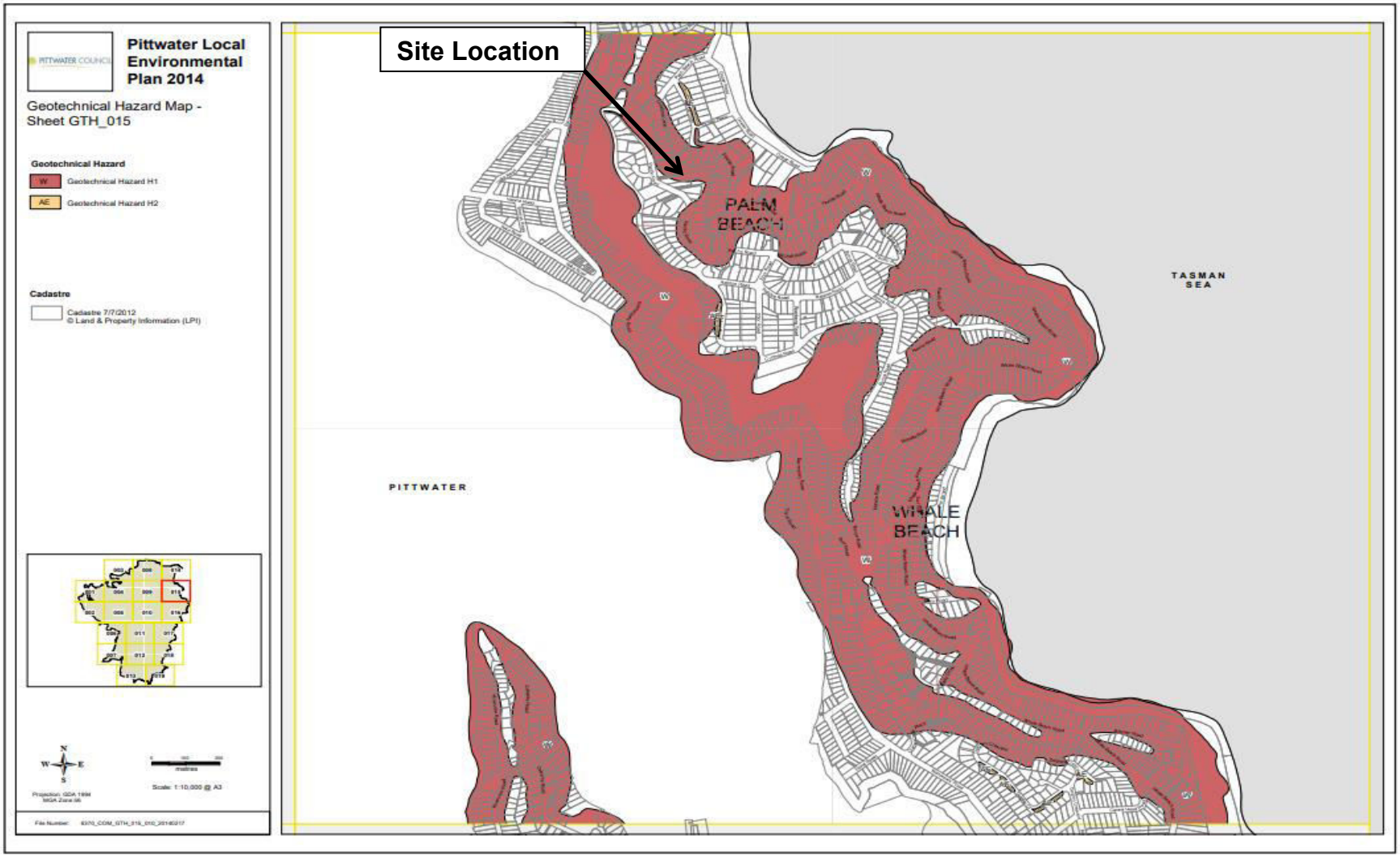
Heritage Map



Acid Sulfate Soils Map



Geotechncial Hazard Map



Appendix D – Geotechnical Explanatory Notes

Explanatory Notes

Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer as follows:

UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

MOISTURE CONDITION

Dry - Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist - Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet - Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL Moisture Content greater than the Plastic Limit.
MC~PL Moisture Content near the Plastic Limit.
MC<PL Moisture Content less than the Plastic Limit.

PLASTICITY

The potential for soil to undergo change in volume with moisture change is assessed from its degree of plasticity. The classification of the degree of plasticity in terms of the Liquid Limit (LL) is as follows:

Description of Plasticity	LL (%)
Low	<35
Medium	35 to 50
High	>50

COHESIVE SOILS - CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

Strength	Symbol	Pocket Penetrometer Reading (kPa)
Very Soft	VS	< 25
Soft	S	20 to 50
Firm	F	50 to 100
Stiff	St	100 to 200
Very Stiff	VSt	200 to 400
Hard	H	> 400

COHESIONLESS SOILS - RELATIVE DENSITY

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Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm are recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

Term	Symbol	Density Index	N Value (blows/0.3 m)
Very Loose	VL	0 to 15	0 to 4
Loose	L	15 to 35	4 to 10
Medium Dense	MD	35 to 65	10 to 30
Dense	D	65 to 85	30 to 50
Very Dense	VD	>85	>50

COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

Name	Subdivision	Size
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 μm to 2.36 mm
	medium	200 μm to 600 μm
	fine	75 μm to 200 μm

.

Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$\text{RQD (\%)} = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{total length considered}}$$

$$\text{TCR (\%)} = \frac{\text{length of core recovered}}{\text{length of core run}}$$

ROCK STRENGTH

Rock strength is described using AS1726 and ISRM – Commission on Standardisation of Laboratory and Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials and the Point Load Index", as follows:

Term	Symbol	Point Load Index $Is_{(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

ROCK MATERIAL WEATHERING

Rock weathering is described using the following abbreviation and definitions used in AS1726:

Abbreviation	Term
RS	Residual soil
XW	Extremely weathered
DW	Distinctly weathered
SW	Slightly weathered
FR	Fresh

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DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm	Thinly Laminated
	6 to 20 mm	Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION

Type:	Description
B	Bedding
F	Fault
C	Cleavage
J	Joint
S	Shear Zone
D	Drill break

Planarity/Roughness:

Class	Description
I	rough or irregular, stepped
II	smooth, stepped
III	slickensided, stepped
IV	rough or irregular, undulating
V	smooth, undulating
VI	slickensided, undulating
VII	rough or irregular, planar
VIII	smooth, planar
IX	slickensided, planar

The inclination if defects are measured from perpendicular to the core axis.

WATER


Water level at date shown


Partial water loss


Water inflow


Complete water loss

Groundwater not observed: The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

Groundwater not encountered: The borehole/test pit was dry soon after excavation; however groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

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Graphic Symbols for Soils and Rocks

Typical symbols for soils and rocks are as follows. Combinations of these symbols may be used to indicated mixed materials such as clayey sand.

Soil Symbols

Main components

 CLAY

 SILT

 SAND

 GRAVEL

 BOULDERS / COBBLES

 TOPSOIL

 PEAT

Minor Components

 Clayey

 Silty

 Sandy

 Gravelly

Other

 FILL

 BITUMEN

 CONCRETE

Rock Symbols

Sedimentary Rocks

 SANDSTONE

 SILTSTONE

 CLAYSTONE, MUDSTONE

 SHALE

 LAMINITE

 COAL

 LIMESTONE

 CONGLOMERATE

Igneous Rocks

 GRANITE

 BASALT

 UNDIFFERENTIATED IGNEOUS

Metamorphic Rocks

 SLATE, PHYLLITE, SCHIST

 GNEISS

QUARTZITE

Engineering Classification of Shales and Sandstones in the Sydney Region – A Summary Guide

The Sydney Rock Class classification system is based on rock strength, defect spacing and allowable seams as set out below. All three factors must be satisfied.

CLASSIFICATION FOR SANDSTONE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>24	>600	<1.5
II	>12	>600	<3
III	>7	>200	<5
IV	>2	>60	<10
V	>1	N.A.	N.A.

CLASSIFICATION FOR SHALE

Class	Uniaxial Compressive Strength (MPa)	Defect Spacing (mm)	Allowable Seams (%)
I	>16	>600	<2
II	>7	>200	<4
III	>2	>60	<8
IV	>1	>20	<25
V	>1	N.A.	N.A.

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UNIAXIAL COMPRESSIVE STRENGTH (UCS)

For expedience in field/construction situations the uniaxial (unconfined) compressive strength of the rock is often inferred, or assessed using the point load strength index (Is_{50}) test (AS 4133.4.1 – 1993). For Sydney Basin sedimentary rocks the uniaxial compressive strength is typically about 20 x (Is_{50}) but the multiplier may range from about 10 to 30 depending on the rock type and characteristics. In the absence of UCS tests, the assigned Sydney Rock Class classification may therefore include rock strengths outside the nominated UCS range.

DEFECT SPACING

The terms relate to spacing of natural fractures in NMLC, NQ and HQ diamond drill cores and have the following definitions:

Defect Spacing (mm)	Terms Used to Describe Defect Spacing[1]
>2000	Very widely spaced
600 – 2000	Widely spaced
200 – 600	Moderately spaced
60 – 200	Closely spaced
20 – 60	Very closely spaced
<20	Extremely closely spaced

[1]After ISO/CD14689 and ISRM.

ALLOWABLE SEAMS

Seams include clay, fragmented, highly weathered or similar zones, usually sub-parallel to the loaded surface. The limits suggested in the tables relate to a defined zone of influence. For pad footings, the zone of influence is defined as 1.5 times the least footing dimension. For socketed footings, the zone includes the length of the socket plus a further depth equal to the width of the footing. For tunnel or excavation assessment purposes the defects are assessed over a length of core of similar characteristics.

Source: Based on Pells et al (1978), as revised by Pells et al (1998).
Pells, P.J.N, Mostyn, G. and Walker, B.F. – Foundations on Sandstone and Shale in the Sydney Region. Australian Geomechanics Journal, No 33 Part 3, December 1998.

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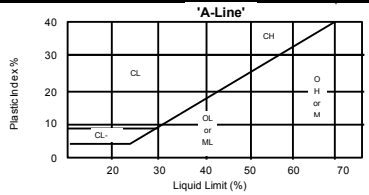
Summary of Soil Logging Procedures

Coarse Material: grain size - colour - particle shape - secondary components - minor constituents - moisture condition - relative density - origin - additional observations.

Fine Material: plasticity - colour - secondary components - minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Guide to the Description, Identification and Classification of Soils

Major Divisions				SYMBOL	Typical Names
> 200mm		BOULDERS			
60 to 200mm		COBBLES			
COARSE GRAINED SOILS	More than 50% by dry mass less than 60mm is greater that 0.076mr	GRAVEL	More than 50% of coarse fraction > 2.36mm	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
				GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels.
		Gravelly Soils		GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures
		SANDS	More than 50% of coarse fraction < 2.36mm	SW	Well-graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
		Sandy Soils		SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	More than 50% by dry mass less than 60mm is less than 0.076mm	Liquid Limit < 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
				OL	Organic silts and organic silty clays of low plasticity.
		Liquid Limit > 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorgnic clays of high plasticity, fat clays.
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				Pt	Peat and other highly organic soils.



Grain sizes			
Gravel		Sand	
Coarse -	63 to 20mm	Coarse -	2.36 to 0.6mm
Medium -	20 to 6 mm	Medium -	0.6 to 0.2mm
Fine -	6 to 2.36mm	Fine -	0.2 to 0.075mm

GEOLOGICAL ORIGIN:-

Fill - artificial soils / deposits
Alluvial - soils deposited by the action of water
Aeolian - soils deposited by the action of wind
Topsoil - soils supporting plant life containing significant organic content
Residual - soils derived from insitu weathering of parent rock.
Colluvial - transported debris usually unsorted, loose and deposited

Field Identification of Fine Grained Soils - Silt or Clay?

Dry Strength - Allow the soil to dry completely and then test its strength by breaking and crumbling between the fingers.
High dry strength - Clays; Very slight dry strength - Silts.

Toughness Test - the soil is rolled by hand into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly until it has dried sufficiently to break into lumps. In this condition inorganic clays are fairly stiff and tough while inorganic silts produce a weak and often soft thread which may be difficult to form and readily breaks and crumbles.

Dilatancy Test - Add sufficient water to the soil, held in the palm of the hand, to make it soft but not sticky. Shake horizontally, striking vigorously against the other hand several times. Dilatancy is indicated by the appearance of a shiny film on the surface of the soil. If the soil is then squeezed or pressed with the fingers, the surface becomes dull as the soil stiffens and eventually crumbles. These reactions are pronounced only for predominantly silt size material. Plastic clays give no reaction.

Descriptive Terms for Material Portions

COARSE GRAINED SOILS		FINE GRAINED SOILS	
% Fines	*Term/Modifier*	*% Coarse*	*Term/Modifier*
< 5	Omit, or use "trace"	< 15	Omit, or use "trace"
> 5, < 12	"with clay/silt" as applicable	> 15, < 30	"with sand/gravel" as applicable
> 12	Prefix soil as "silty/clayey"	> 30	Prefix as "sandy/gravelly"

Moisture Condition

for non-cohesive soils:

Dry -	runs freely through fingers.
Moist -	does not run freely but no free water visible on soil surface.
Wet -	free water visible on soil surface.

for cohesive soils:

MC > PL	Moisture content estimated to be greater than the plastic limit.
MC ~ PL	Moisture content estimated to be approximately equal to the plastic limit. The soil can be moulded
MC < PL	Moisture content estimated to be less than the plastic limit. The soil is hard and friable, or powdery.

The plastic limit (PL) is defined as the moisture content (percentage) at which the soil crumbles when rolled into threads of 3mm dia.

Consistency - For Clays & Silts

Description	*UCS(kPa)*	*Field guide to consistency*
Very soft	< 25	Exudes between the fingers when squeezed in hand
Soft	25 - 50	Can be moulded by light finger pressure
Firm	50 - 100	Can be moulded by strong finger pressure
Stiff	100 - 200	Cannot be moulded by fingers. Can be indented by thumb.
Very stiff	200 - 400	Can be indented by thumb nail
Hard	> 400	Can be indented with difficulty by thumb nail
Friable	-	Crumbles or powders when scraped by thumbnail

Relative Density for Gravels and Sands

Description	*SPT "N" Value*	*Density Index (ID) Range %*
Very loose	0 - 4	< 15
Loose	4 - 10	15 - 35
Medium dense	10 - 30	35 - 65
Dense	30 - 50	65 - 85
Very dense	> 50	> 85

Summary of Rock Logging Procedures

Description order: constituents - rock name - grain size - colour - weathering - strength - minor constituents - additional observations.
- minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

Definition - Sedimentary Rock	
Conglomerate	more than 50% of the rock consists of gravel (> 2mm) sized fragments
Sandstone	more than 50% of the rock consists of sand (0.06 to 2mm) sized grains
Siltstone	more than 50% of the rock consists of silt sized granular particles and the rock is not laminated
Claystone	more than 50% of the rock consists of clay or mica material and the rock is not laminated
Shale	more than 50% of the rock consists of clay or silt sized particles and the rock is laminated

Weathering		
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a change in volume but the soil has not significantly transported.
Extremely Weathered	EW	Rock is weathered to such an extent that it has 'soil' properties; ie. it either disintegrates or can be remoulded, in water
Distinctly Weathered	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 deposition of weathering products in pores.
Slightly Weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition or staining.

Stratification			
thinly laminated	< 6mm	medium bedded	0.2 - 0.6m
laminated	6 - 20mm	thickly bedded	0.6 - 2m
very thinly bedded	20 - 60mm	very thickly bedded	> 2m
thinly bedded	60mm - 0.2m		

Discontinuities

order of description: depth - type - orientation - spacing - roughness / planarity - thickness - coating

	Type	Class	Roughness/Planarity	Class	Roughness/Planarity
B	Bedding	I	rough or irregular, stepped	VI	slickensided, undulating
F	Fault	II	smooth, stepped	VII	rough or irregular, planar
C	Cleavage	III	slickensided, stepped	VIII	smooth, planar
J	Joint	IV	rough or irregular, undulating	IX	slickensided, planar
S	Shear Zone	V	smooth, undulating		
D	Drill break				

Rock Strength

Term		Is(50)	Field Guide
Extremely Low	EL		Easily remoulded by hand to a material with soil properties.
		0.03	
Very low	VL		May be crumbled in the hand. Sandstone is "sugary" and friable
		0.1	
Low	L		A piece of core 150 mm long x 50 mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
		0.3	
Medium	M		A piece of core 150 mm long x 50 mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.
		1	
High	H		A piece of core 150 mm long x 50 mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife.
		3	
Very High	VH		A piece of core 150 mm long x 50 mm dia. May be broken readily with hand held hammer. Cannot be scratched with pen knife.
		10	
Extremely High	EH		A piece of core 150 mm long x 50 mm dia. Is difficult to break with hand held hammer. Rings when struck with a hammer.

* - rock strength defined by point load strength (Is 50) in direction normal to bedding

Degree of fracturing	
fragmented	The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter
highly fractured	Core lengths are generally less than 20mm - 40mm with occasional fragments.
fractured	Core lengths are mainly 30mm - 100mm with occasional shorter and longer lengths
slightly fractured	Core lengths are generally 300mm - 1000mm with occasional longer sections and shorter sections of 100mm – 300mm.
unbroken	The core does not contain any fracture.

- spacing of all types of natural fractures, but not artificial breaks, in cored bores.

The fracture spacing is shown where applicable and the Rock Quality Designation is given by:

$$RQD\ (\%) = \frac{\text{sum of unbroken core pieces 100 mm or longer}}{\text{total length considered}}$$

Appendix E – Borehole Logs

ENVIRONMENTAL BOREHOLE / TESTPIT BH01

PROJECT NUMBER 19-8048	**DRILLING DATE** 01-08/2019	**COORDINATES** Refer to site plan
PROJECT NAME Geotechnical Investigation	**DRILLING COMPANY** Emvirotech Pty Ltd	**COORD SYS** N/A
CLIENT Architecture & Interior Design	**DRILLER** BH	**SURFACE ELEVATION** ~72 m
ADDRESS 121 Pacific Rd Palm Beach NSW 2108	**DRILLING METHOD** Hand Auger	**LOGGED BY** BH
	TOTAL DEPTH 1.10 m	**CHECKED BY** CB

COMMENTS

Depth (m)	Penetrometer (kPa)	Penetration Resistance (Blows per 100mm) 0–20	Graphic Log	USCS	Material Description	Moisture	Consistency	Additional Observations
				SM-MH	TOPSOIL: Admix sand with some clay, grey brown, organics (grass and roots), fine to medium sands	Moist	Loose to very loose	
				CL	RESIDUAL: Silty CLAY with sand; low plasticity, brown with orange red mottles, fine to medium sands, trace coarse sandstone rock fragments, moisture content < plastic limit	Moist	Soft	
0.5	220					Moist		
						Moist	Firm	
				S.S	BEDROCK: Clayey SANDSTONE: EW-DW, red orange to pale grey and white, fine to medium sands, ELS to VLS	Moist to slightly moist	Hard	
1								Minimum Class V strength
					Termination Depth at:1.10 m			

Notes: EW/DW-Extremely/Distinctly Weathered, VLS-Very low strength, ELS-Extremely low strength

produced by ESlog.ESdat.net on 06 Aug 2019

ENVIRONMENTAL BOREHOLE / TESTPIT BH02

PROJECT NUMBER 19-8048
PROJECT NAME Geotechnical Investigation
CLIENT Architecture & Interior Design
ADDRESS 121 Pacific Rd Palm Beach NSW 2108

DRILLING DATE 01-08/2019
DRILLING COMPANY Emvirotech Pty Ltd
DRILLER BH
DRILLING METHOD Hand Auger
TOTAL DEPTH 0.90 m

COORDINATES Refer to site plan
COORD SYS N/A
SURFACE ELEVATION ~80 m
LOGGED BY BH
CHECKED BY CB

COMMENTS

Depth (m)	Penetrometer (kPa)	Penetration Resistance (Blows per 100mm) 0 20	Graphic Log	USCS	Material Description	Moisture	Consistency	Additional Observations
				SM-MH	TOPSOIL: Admix sand with some clay, grey brown, organics (grass and roots), fine to medium sands	Moist	Loose to very loose	
				CL	RESIDUAL: Silty CLAY with sand; low plasticity, brown with orange red mottles, fine to medium sands, trace coarse sandstone rock fragments, moisture content < plastic limit		Soft	
						Moist		
0.5	190					Moist		
						Moist	Firm	
				S.S	BEDROCK: Clayey SANDSTONE: EW-DW, red orange to pale grey and white, fine to medium sands, ELS to VLS	Moist to slightly moist	Hard	Minimum Class V strength
					Termination Depth at:0.90 m			
1								

Notes: EW/DW-Extremely/Distinctly Weathered, VLS-Very low strength, ELS-Extremely low strength

produced by ESlog.ESdat.net on 06 Aug 2019

Appendix F – Dynamic Cone Penetrometer (DCP) Results

envirotech
Consulting Group

1, 23 Rowood Road, Prospect NSW 2148
P: 1300 888 324 F: 02 8834 0760
W: www.envirotech.com.au
E: info@envirotech.com.au

Dynamic Cone Penetrometer Report – AS 1289 6.3.2

Test No:	BH01		BH02		BH01		
Location:	Refer to Plan		Refer to Plan		Refer to Plan		
Start Level:	~ 70 - 80 m AHD – Surface Ground Level						
Depth (m)	Number of blows per 100mm						
0 – 0.1	1		2		3		
0.1 – 0.2	1		2		3		
0.2 – 0.3	2		4		4		
0.3 – 0.4	2		2		6		
0.4 – 0.5	2		1		7		
0.5 – 0.6	7		3		8		
0.6 – 0.7	9		2		6		
0.7 – 0.8	1		4		9		
0.8 – 0.9	1		6		11 - R		
0.9 – 1.0	5		6				
1.0 – 1.1	11		5 - R				
1.1 – 1.2	21						
1.2 – 1.3	17						
1.3 – 1.4	16						
1.4 – 1.5	6 - R						
1.5 – 1.6							
1.6 – 1.7							
1.7 – 1.8							
1.8 – 1.9							
1.9 – 2.0							

NOTE: R – Refusal on ROCK

Appendix G – Landslide Risk Assessment

Risk to Life Assessment

Method based on AGS 2007 Guildlines

PROJECT DETAILS **Risk assessment is based on the recommendations in Section 5 (of report) being implimented and maintained.**

Project	121 PACIFIC ROAD, PALM BEACH NSW 2108			Job. No.	19-8048
Author	BH	Reviewed	DM	Created	27/08/2019

STEP 1 : ENTER SITE AND DESIGN DATA

Hazard Type	**Debris Flow & Rock Fall**

$P_{(H)}$	Annual probability of landslide	**0.0001**

INDICATIVE VALUE	RECURRENCE INTERVAL	DESCRIPTION	DESCRIPTOR	LEVEL
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 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

$P_{(S:H)}$	Probablity of spatial impact impacting building location taking into account travel distance and travel direction	**0.72**

	FACTOR	DESCRIPTION	UNITS	VALUE
	W_1	Likely slide/fall width	m	**5**
	W_2	Width of allotment / investigation area	m	**20**
	W_3	Width of dwelling / investigation element	m	**15**
	L_{1Min}	Minimum run-out length	m	**1**
	L_{1Max}	Maximum run-out length	m	**20**
	L_2	Length of allotment / investigation area	m	**60**
	L_3	Length of dwelling / investigation element	m	**43**
	L_{PMin}	Probability of runout being 0 - 1 m long	(0 - 1)	**1.00**
	L_{PMax}	Probability of runout being 1 - 20 m long	(0 - 1)	0.70
LOW (L)	W_F	Likelihood of across slope strike on risk element	(0 - 1)	**0.50**
	$L_{F\,Min}$	Likelihood of downslope strike on risk element for minimum run-out distance	(0 - 1)	0.73
	$L_{F\,Max}$	Likelihood of downslope strike on risk element for maximum run-out distance	(0 - 1)	1.00
	$L_{F\,Design}$	Likelihood of downslope strike (integrated) on risk element run-out distance	(0 - 1)	**1.43**

$P_{(T:S)}$	Temporal spatial probability given the spatial impact	**0.16**

FACTOR	DESCRIPTION	UNITS	VALUE
T_1	Percentage of time person(s) are on-site	%	65%
T_2	Percentage of dwelling / element that person(s) occupy	%	25%

$V_{(D:T)}$	Vulnerability of the individual (ie. probability of loss of life given the impact)	**0.05**

CASE	DESCRIPTION	RANGE IN DATA	RECOMMENDED VALUE	COMMENTS
Person in open space	If struck by a rockfall	0.1 - 0.7	0.50	May be injured but unlikely to cause death
	If buried by debris	0.8 - 1.0	1.00	Death by asphyxia almost certain
	If not buried	0.1 - 0.5	0.10	High chance of survival
Person in a vehicle	If vehicle is buried / crushed	0.9 - 1.0	1.00	Death is almost certain
	If the vehicle is damaged only	0.0 - 0.3	0.30	High chance of survival
Persons in building	If the building collapses	0.9 - 1.0	1.00	Dealth is almost certain
	If the building is inundated with debris and the person is buried	0.8 - 1.0	1.00	Death is highly likely
	If the debris strikes the building only	0.0 - 0.1	0.05	Very high chance of survival

STEP 2 : RISK EVALUATION

$R_{(LoL)}$	Risk (annual probability of loss of life of an individual)	**5.82E-07**
Risk Assessment	**Acceptable risk for loss of life for the person(s). Risk level suitable for new developments.**	

Risk to Property Assessment

Method based on Australian Geomechanics Vol. 42 No 1, March 2007

PROJECT DETAILS

Project	121 PACIFIC ROAD, PALM BEACH NSW 2108			Job. No.	19-8048
Author	BH	Reviewed	DM	Created	27/08/2019

STEP 1 : LIKELIHOOD

LEVEL	D			
INDICATIVE VALUE	**RECURRENCE INTERVAL**	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
10^{-1}	10 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	100 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	1000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	10,000 years	The enent might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	100,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	0.0001	The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

STEP 2 : CONSEQUENCE

LEVEL	3		
INDICATIVE VALUE	**DESCRIPTION**	**DESCRIPTOR**	**LEVEL**
200%	Structure completely destroyed or large scale damage requiring major engineering works for stabilisation.	CATASTOPHIC	1
60%	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works	MAJOR	2
20%	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.	MEDIUM	3
5%	Limited damage to part of structure, or part of site requiring some reinstatement/stabilisation works.	MINOR	4
1%	Little damage.	INSIGNIFICANT	5

STEP 3 : Risk Matrix

LIKELYHOOD	CONSEQUENCE				
	1	**2**	**3**	**4**	**5**
A	VH	VH	VH	H	M/L
B	VH	VH	H	M	L
C	VH	H	M	M	VL
D	H	M	L	L	VL
E	M	L	L	VL	VL
F	L	VL	VL	VL	VL

LOW (L)	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required. The recommendations in Section 5 (of report) must be followed for this risk level to apply.

Appendix H – Site Photographs

Site Photographs

Access driveway

Neighbouring property - Southern side boundary retaining wall

Natural sandstone retainng wall

Managed lawns - Open woodland canopy at front of site (Pacific drive)

Sandstone floater

Existing dwelling looking east

View looking from rear of site toward existing dwelling

Natural downward slope toward the east and north-east

Appendix I – Practice Notes Guidelines

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

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}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-3}$	1000 years	200 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-4}$	10,000 years	2000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-5}$	100,000 years	20,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}	$5x10^{-6}$	1,000,000 years	200,000 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

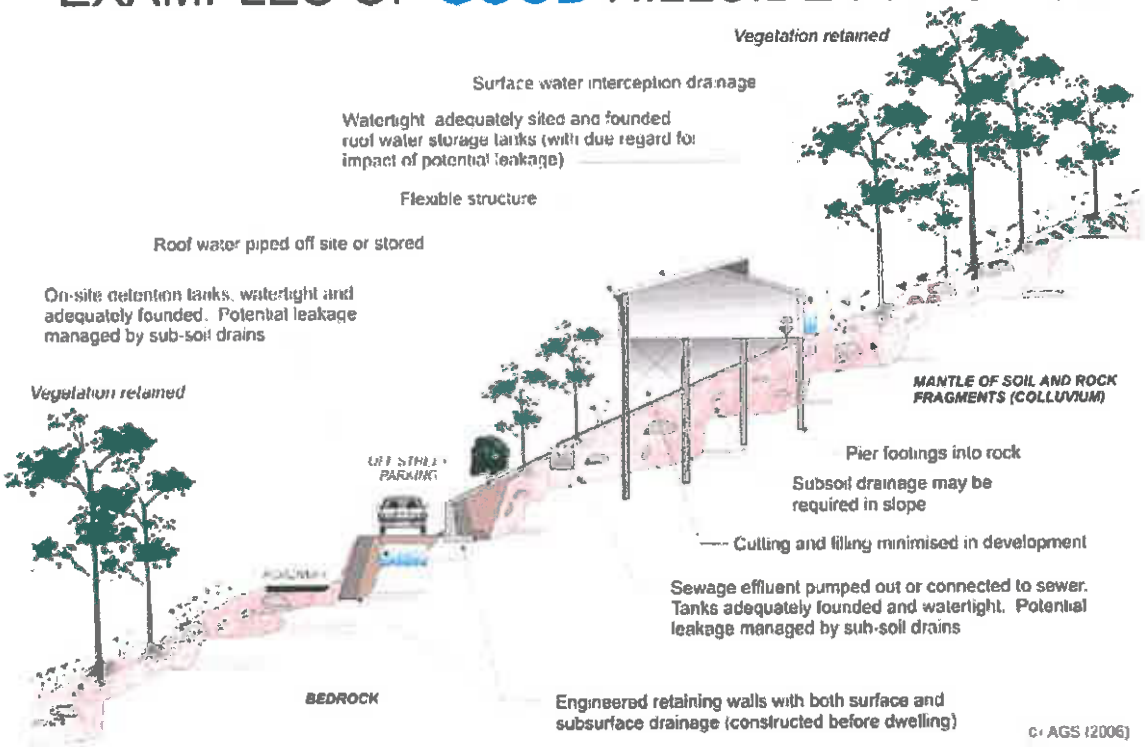
Risk Level		Example Implications (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
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.

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



EXAMPLES OF POOR HILLSIDE PRACTICE