GEOTECHNICAL INVESTIGATION

FOR

WILLIAM WANG

11 SEAFORTH CRESCENT, SEAFORTH

REPORT GG12016.001A

26 JUNE 2024

Geotechnical Investigation for a proposed new residential dwelling at 11 Seaforth Crescent, Seaforth

Prepared for

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1. INTRODUCTION

This report presents the results of a geotechnical investigation undertaken by Green Geotechnics for a proposed new residential dwelling to be constructed at 11 Seaforth Crescent, Seaforth, NSW. The investigation was commissioned by William Wang by return acceptance of Proposal PROP-2025-204A, dated 2 May 2025

We understand from the supplied preliminary architectural drawings that the development will comprise the demolition of existing structures on the site followed by the construction of a two and three level stepped residential dwelling. The dwelling will be constructed on sloping ground with Level 9 (driveway) set at Reduced Level (RL) 47 metres Australian Height Datum (AHD), and Level 3 (bach pad) having a finished floor level of RL 27.8 metres AHD, giving an overall elevation change of around 20 metres across the main dwelling.

Due to the slope of the site construction of the main dwelling will require the formation of levelled benches. The maximum excavation depth for any single bench is in the order of 6 metres.

The site is located on sloping ground and includes sandstone outcrops and cliffs, therefore Northern Beaches Council require a Landslip Risk Assessment for the site in accordance with AGS 2007 Guidelines. Further, we understand that a geotechnical assessment of the site will be required to progress the structural design.

The purpose of the investigation was to:

- assess the surface and subsurface conditions over the site,
- undertake a slope risk assessment in accordance with AGS2007 Guidelines, assigning both the risk to life and to property,
- classify the site in accordance with AS2870,
- provide recommendations regarding the appropriate foundation system for the site, including design parameters,
- provide parameters for the design of retaining walls,
- provide recommendations regarding vibration control during rock excavations and trimming, and
- provide recommendations to address the outcomes of the slope risk assessment.

2. FIELDWORK DETAILS

The fieldwork was carried out on 28 May 2025 and comprised a detailed site walkover together with the drilling of eight (8) boreholes numbered BH1 to BH8. Due to restricted site access the boreholes were drilled using hand auger equipment.

The site location is shown in the attached Figure A. The borehole locations, as shown on Figure B, were determined by taped measurements from existing surface features overlain on available survey drawings of the site. Photographs of the site are shown on Figure C.

The strength of the soils encountered in the boreholes was assessed by undertaking Dynamic Cone Penetrometer (DCP) tests adjacent to each borehole. The strength of the weathered bedrock was assessed based on a tactile assessment of observed rock outcrops and cuttings.

Groundwater observations were made in all boreholes during the fieldwork. No longer term monitoring of groundwater was carried out.

The fieldwork was completed in the full-time presence of our senior field geologist who set out the boreholes, nominated the sampling and testing, and prepared the field logs. The logs are attached to this report, together with a glossary of the terms and symbols used in the logs.

For further details of the investigation techniques adopted, reference should be made to the attached explanation notes.

Environmental and contamination testing of the soils was beyond the agreed scope of the works.

3. RESULTS OF INVESTIGATION

3.1 Site Description

The site is identified as Lot 16 in DP 4889, and is roughly rectangular in shape with an area of approximately 1,846m^2. At the time of the fieldwork the site was occupied by a one and two storey brick residential dwelling with a tile roof and suspended concrete patio at the rear.

The dwelling is located on the northwestern portion of the site, set back around 9 metres from Seaforth Crescent. The upper floor of the dwelling is around RL 40.1 metres AHD and the lower level is around RL37 metres AHD.

The dwelling is accessed via a set of steps which descend a sandstone outcrop. At the rear of the dwelling is a meandering pathway which descends a steep slope down to a mid terrace area. The mid terrace is near level and covered by dense vegetation. To the southeast of the mid terrace is a prominent sandstone monolith. To the southeast of the monolith is a further vegetated slope which leads down to the bay area.

Due to the slope of the site there are numerous sandstone outcrops, sandstone boulders and retaining walls. These are further discussed below and are indicated on the attached plan:

- Upper rock shelf – A rock shelf was observed traversing the site around 1-3 metres inside the front boundary. The rock face has a height of around 2 metres and is near vertical. The face is covered by dense vegetation. The top of the rock face is slightly lower than the nature strip of Seaforth Crescent.

- Boulder 1 – Boulder 1 is positioned on top of the upper rock shelf and is located to the southwest of the access pathway. The rock shelf below the boulder is dipping downslope. The boulder is around 3 to 4 metres long.

- Mid rock shelf – A rock shelf was observed outcropping below the suspended concrete deck at the rear of the dwelling. The rock face has a height of less than 1 metre and appears horizontal.

- Lower Rock Shelf – The lower rock face is exposed on the back side of the mid terrace area. The rock face has a steep dip. A low height sandstone block wall has been constructed on top of the dipping rock face to provide an access pathway down to the mid terrace area. The lower rock shelf extends into the adjoining property to the northeast.

- Boulder 2, 3 and Sandstone Monolith – A series of sandstone outcrops are present on the southeastern side of the mid terrace area. The sandstone exposures rise around 2-3 metres above the mid terrace area. When viewed from the low side the larger central monolith appears to be resting on a level in-situ rock shelf. The monolith is intersected by jointed blocks at its northeastern and southwestern extents which have formed Bolder 2 and Boulder 3. Boulder 2 and Boulder 3 are several metres high. A wedge of sandstone bedrock appears to be held between the monolith and Boulder 2.

- Boulder 4 – Boulder 4 is located down slope of the monolith and is approximately 12 metres long and 3 to 4 metres high. The boulder appears partially buried, however is covered by dense vegetation at its base.

- Retaining walls – There are several retaining walls on the slope. The majority of the walls have been constructed for landscaping purposes and to facilitate access to the lower portion of the site.

The lower and mid portion of the slope is covered by dense vegetation with mature trees grasses and plants.

To the northwest of the site is Seaforth Crescent and to the southeast is The Spit. To the northeast of the site are the dwellings of No.9 and No.9A Seaforth Crecent. The dwelling on No.9 comprises a three storey structure set back around 2.5 metres from the site boundary. The dwelling on No.9 has been constructed on-top of the lower rock shelf. The dwelling on No.9A comprises a two storey brick structure set back around 2.5 metres from the boundary with the subject site. The dwelling of No.9A is accessed via an inclinator which runs between the site boundary and dwellings.

To the southwest of the site is a three storey garage/studio belonging to No.13 The Crescent. The garage has been constructed to the boundary with the subject site. The dwelling of No.13 is located towards the base of the slope fronting the spit and has also been constructed close to the site boundary. The dwelling of No.13 is also accessed via an inclinator.

3.2 Regional Geology & Subsurface Conditions

The 1:100,000 series geological map of Sydney (Geological Survey of NSW, Geological Series Sheet 9130) indicates that the site is underlain by Triassic Age bedrock belonging to the Hawkesbury Sandstone Formation. Bedrock within this formation comprises fine to medium grained quartz sandstone. There are outcrops of bedrock on the site which are consistent with this geological setting.

Based on the results of the intrusive investigations and our site observations we expect the subsurface conditions to comprise localised filling overlying inter dispersed lenses of colluvial clays overlying sandstone bedrock. Fill materials were encountered in the boreholes to depths of up to 1.2 metres, however maybe locally deeper in the mid terrace area. The fill comprises a combination of gravelly clayey sands and gravelly sandy clays with some sandstone cobbles and boulders.

Colluvial silty sandy clays were encountered below the topsoil and fill materials in boreholes 4 and 7, extending to depths of around 0.6 metres at which depth hand auger refusal occurred on either in situ bedrock or detached sandstone boulders.

Based on our site observations we have identified 3 in-situ rock shelves, identified as the upper, mid and lower rock shelf, the sandstone monolith located downslope of the lower rock shelf maybe in situ, however given that the rock is several metres higher than the mid terrace area it is possible that this monolith is a large detached boulder of bedrock which is resting on the rock shelf below.

The exposed sandstone in-situ bedrock was assessed to be mostly medium strength and massive. The lower rock shelf is extensively exposed below the dwelling of No.9. The exposed bedrock below No.9 appears free of any significant seams or defects.

4. LANDSLIDE RISK ASSESSMENT

4.1 Introduction

A landslide risk assessment has been undertaken for 11 Seaforth Crescent, Seaforth. It is not technically feasible to assess the stability of a particular site in absolute terms such as stable or unstable, and it must be recognised by the reader that all sites have a risk of land sliding, however small. However, a risk assessment can be undertaken by the recognition of surface features supplemented by limited information on the regional and local subsurface profile, and with the benefit of experience gained in similar geological environments.

Natural hill slopes are formed by processes that reflect the site geology, environment and climate. These processes include down slope movement of the near surface soil and rock. In geological time all slopes are 'unstable'. The area of influence of these down slope movements may range from local to regional and are rarely related to property boundaries. The natural processes may be affected by human intervention in the form of construction, drainage, fill placement and other activities.

4.2 Purpose of the Assessment

The purpose of this assessment is to enable the owner, potential owner or other parties interested in the site in question, to be aware of the level of risk associated with potential slope movements within the property, and within the area immediately surrounding the property. The risk is assessed considering the existing development of the property and proposed developments of which we have been informed of and which are summarised in this report. The onus is on the owner, potential owner or other party to decide whether the level of risk presented in this report is acceptable in the light of the possible economic consequence of such risk.

4.3 Risk Assessment Methodology

The risk assessment in this report is based on the guidelines on Landslide Risk Management (LRM) as presented in the Australian Geomechanics publication, Volume 42, Number 1, dated March 2007. This issue presents a series of LRM guidelines and further understanding on the application of the risk assessments for the recommended use by all practitioners nationwide.

Definition of the terms used in this report with respect to the slope risk assessment and management are given in Appendix B.

It must be accepted that the risks associated with hillside construction are greater than construction on level ground in the same geological environment. The impact of development may be adverse, and imprudent construction techniques can increase the potential for movement. Areas of instability rarely respect property boundaries and poor practices on one property can trigger instability in the surrounding area.

4.4 Hazard Identification

A landslide is defined as "the movement of a mass of rock, debris or earth down a slope". Apart from ground subsidence and collapse, this definition is open to the movement of material types including rock, earth and debris down slope. The causes of landslides can be complex. However, two common factors include the occurrence of a failure of part of the soil or rock material on a slope and the resulting movement is driven by gravity. The actual motion of a landslide is subdivided into the five kinematically distinctive types of material movement including fall, topple, slide, spread, and flow. For further information regarding types of landslides please refer to Appendix C – Landslide Terminology from Australian Geomechanics Practice Note Guidelines For Landslide Risk Management 2007.

The frequency of landslides are difficult to quantify and typically dependant on the inter-relationship between the factors influencing the stability of the slope. Some of the common factors affecting the stability of slopes include the weather (prolonged rainfall with water percolating into rock mass defects can cause washout of fines and reduction of rock mass strength), land development, vegetation removal, changes in drainage and earthquakes. One or a combination of these conditions could result in a landslide failure event.

For the site of 11 Seaforth Crescent, Seaforth, the following landslide hazards have been considered in the risk assessment.

TABLE 4.1 – Landslide Hazard Identification

Hazard Description	Estimated Volume (m^3)	Justification
1. Failure of an in-situ rock face	20-30	The site has at least three in-situ rock faces. The exposed in-situ rock appears massive and relatively unfractured, however the presence of sandstone boulders on the site suggests that past toppling and rock falls have occurred.
2. Failure of a Cut face During Bulk Excavation	5-10	Construction of the dwelling will require excavating to depths of up to 6 metres. The proposed excavation works have the potential to expose or destabilise fractured or jointed bedrock which could collapse into the excavation. The excavation works also have potential to cause localised slumping in the overlying fill materials and colluvial soils.
3. Movement / toppling of Boulder 1	10-15	Boulder 1 is located immediately upslope of the dwelling. The proposed earthworks have the potential to destabilise the boulder which could result in its down slope movement.
4. Movement / toppling of Boulder 2	6-10	The proposed new dwelling is located up-slope of Boulder 2
5. Movement / toppling of Boulder 3	6-10	The proposed new dwelling is located up-slope of Boulder 3.
6. Movement / toppling of Monolith	80-100	The proposed new dwelling is located up-slope of the monolith.

7. Movement / toppling of Boulder 4	60-80	The proposed new dwelling is located up-slope of Boulder 4.
8. Retaining wall failure	1-3	There are numerous low height walls on the site which vary in their construction type and condition. it is however expected that most if not all of the walls will be removed during construction of the dwelling and associated landscaping.

4.5 Risk Assessment to Property

The Risk to property has been estimated by assessing the likelihood of an event and the consequences if such an event takes place. The relationship between likelihood, consequence and risk is determined by a risk matrix. The risk categories and implications are shown in Attachment 3 of Appendix C (taken from Practice Note Guidelines for Landslide Risk Management 2007, Appendix C).

The assessment process involved the following:

- Risk estimation (comparative analysis of likelihood of a slope failure versus consequence of the failure).
- Evaluation of the estimated (assessed) risk by comparing against acceptance criteria.

The following factors observed during the site walkover were taken into consideration when undertaking the slope risk assessment:

- Topography: The site is situated on moderately to steeply sloping ground with outcrops of sandstone bedrock, large detached sandstone boulders and low height retaining walls.
- Geology: The surface soils comprise fill overlying intersdispersed colluvial clays and sandstone bedrock. The bedrock includes some in-situ outcrops together with large, detached boulders.
- Drainage: The site in general is reasonably drained. No groundwater seepage was observed during the site walkover inspection however surface run-off is expected during and following heavy rainfall. The site drains to The Spit.
- Slope stability: There were no signs of active slope instability noted during the site walkover. There was no evidence of soil creep and there is no historical evidence of deep-seated movements within the sandstone bedrock within the local area. There is no evidence that any of the large boulders have mobilised recently.

Based on the above factors and site observations, an assessment of risk to property have been carried out as shown in Tables4.2 below for the principal dwelling.

TABLE 4.2 – Risk to Property – Main Dwelling

Hazard		1	2	3	4
Likelihood	Descriptor	Rare	Possible	Possible	Unlikely
	Approximate Annual Probability	1 x 10^{-5}	1 x 10^{-3}	1 x 10^{-3}	1 x 10^{-4}
Consequence		Major	Minor	Minor	Minor
Risk Category		Low	Moderate	Moderate	Low

TABLE 4.2 Continued – Risk to Property – Main Dwelling

Hazard		5	6	7	8
Likelihood	Descriptor	Unlikely	Unlikely	Unlikely	Possible
	Approximate Annual Probability	1 x 10^{-4}	1 x 10^{-4}	1 x 10^{-4}	1 x 10^{-3}
Consequence		Minor	Minor	Minor	Insignificant
Risk Category		Low	Low	Low	Very Low

The assessed risk to property for the main dwelling is low to moderate risk. Based on the information provided by the AGS and presented in Attachment 1, Appendix C, the implications for a risk level of low is it is usually acceptable to regulators. Moderate risks 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.

For the subject site the implementation and treatment options to address the moderate risks are as follows:

- Hazard 2 (Cut face failure) – Excavations are to be carried out under the supervision of a geotechnical engineer as per the recommendations given in Section 5.3.
- Hazard 3 – It is recommended that Boulder 1 be broken up and removed from site during the bulk excavation works.

4.6 Risk Assessment to Loss of Life

A risk assessment for the loss of life was undertaken for the identified geotechnical hazards for the site. The risk assessment and management process adopted for this study was carried out in general accordance with AGS (2007a).

In accordance with the AGS 2007c Landslide Risk Management Guidelines for loss of life, the individual risk for loss of life can be calculated from:

$$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$$

Where

- $R_{(LoL)}$ is the risk - annual probability of loss of life (death) - of an individual.
- $P_{(H)}$ is the annual probability of the landslide.
- $P_{(S:H)}$ is the probability of spatial impact of the landslide impacting on a location potentially occupied by a person.
- $P_{(T:S)}$ is the temporal spatial probability (e.g. of the location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.
- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

In accordance with AGS 2007, the regulator should set risk acceptance criteria. In this case, Northern Beaches Council is the regulator, and requires the risk to life post development to be 'Tolerable' for existing areas of residential subdivision, provided risk control measures are put in place to control the risk.

The risk acceptance criteria consider the occurrence of the potential geotechnical hazards identified for the site and evaluate the risk against a Tolerable Risk Criteria for loss of life. In this instance, the individual risk is accepted due to being tolerable or risk mitigation measures are undertaken to reduce the risk to more tolerable levels.

The AGS 2007 guidelines indicate that the regulator, with assistance from the practitioner where required, is the appropriate authority to set the standards for risk relating to perceived safety in relation to other risks and government policy. The importance of the implementation of levels of the tolerable risk should not be understated due to the wide ranging implications, both in terms of the relative risks or safety to the community and the potential economic impact to the community. The AGS provide recommendations in relation to tolerable risk for loss of life as shown below in Table 4.3.

TABLE 4.3 – AGS Recommendations – Risk to Life

Situation	Suggested Tolerable Loss of Life Risk for Person Most at Risk
Existing Slope(1) / Existing Development(2)	10^{-4}/annum
New Constructed Slope(3) / New Development(4) / Existing Landslide	10^{-5}/annum

Notes:

1. "Existing Slopes" in this context are slopes that are not part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

2. "Existing Development" includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognisable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.

3. "New Constructed Slope" includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).

4. "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope/Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.

5. "Existing Landslides" have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of "public safety".

Given the extent of proposed earthworks, the proposed development at 11 Seaforth Crescent must be considered a New Development. The AGS risk threshold provided in Table 3.3 for new developments suggests the 'Tolerable Loss of Life for the person most at risk' is 10^{-5} per annum.

The risk assessment has been based on observations made during the site visit by an experienced engineering geologist, and by reviewing available geotechnical data and the future geotechnical requirements for development as outlined elsewhere in this report. Departures from the recommendations in this report may change the quantification of the hazard risk. A risk assessment has been carried out for the identified geotechnical hazards and is presented in Section 4.4 of this report.

The annual probability of a failure occurring has been calculated based on engineering judgement and observations made during the site visit. The probability of spatial impact is calculated by dividing the size of the estimated landslide by the size of the building area. For the main dwelling this has been taken as $300m^2$. Hazards 4, 5, 6 and 7 have not been considered for the main dwelling as they are located downslope of the structure.

The temporal spatial probability for Hazards 1, 3 and 8 for the main dwelling have been calculated based on the assumption that someone will be present in the house for 16 hours a day. This is then divided by the number of hours in a day. For Hazard 2 this has been decreased to 10 hours a day as this is primarily a construction risk. The vulnerability of an individual is based on values from Australian Geomechanics Vol. 42. If visitor numbers to the site were to increase, then this would change the risk to loss of life. This could affect whether the risk is considered tolerable or otherwise.

Any changes to the site will affect the risk assessment outcome, making it necessary to carry out the risk assessment again.

From our quantitative risk to life assessment, we have estimated the annual probability of risk to life to be as follows:

TABLE 4.4 – Risk to Life – Main Dwelling

Hazard	1	2	3	8
$R_{(LoL)}$	3.9×10^{-6}	2.6×10^{-5}	1.8×10^{-4}	5.9×10^{-6}

Based on Table 4.4, the risk to life for the main dwelling is considered tolerable, provided Boulder 1 is removed.

5. GEOTECHNICAL RECOMMENDATIONS

5.1 Primary Geotechnical Considerations

Based on the results of the assessment, we consider the following to be the primary geotechnical considerations for the development:

- Rock excavation for the main dwelling, and the generation of ground borne vibrations,
- Temporary excavation batter stability, and
- Foundation design for structural loads.

5.2 Site Classification to AS2870

The classification has been prepared in accordance with the guidelines set out in the "Residential Slabs and Footings" Code, AS2870 – 2011.

Based on the subsurface conditions observed, in particular the presence of fill and the site slope, the site is classified as a **Problem Site (P)**. However, provided the recommendations given below in Section 4.5 are adopted and footings are founded in the underlying sandstone bedrock, the site may be reclassified as a **Stable Site (A)**.

Foundation design and construction consistent with this classification shall be adopted as specified in the above referenced standard and in accordance with the following design details.

5.3 Excavation Conditions and Vibration Control

All excavation recommendations should be complemented with reference to the NSW Government Code of Practice for Excavation work, dated January 2020.

It would be appropriate before commencing excavation to undertake a dilapidation survey of any adjacent structures that may potentially be damaged. This will provide a reasonable basis for assessing any future claims of damage.

Based on the subsurface conditions observed in boreholes and our site observations, bulk excavation works on the subject site are expected to encounter localised fill materials, intersdispersed colluvial deposits and sandstone bedrock. The bedrock may include bands of medium and high strength rock.

Typically, the Hawkesbury Sandstone is horizontally bedded with sub-vertical joints. This type of profile can be observed in many places in Sydney where Hawkesbury Sandstone is exposed.

Excavation of the overlying soils is expected to be achievable using conventional earthmoving equipment such as medium to large tracked excavators fitted with bucket attachments. However, excavation of the underling bedrock is expected to require the extensive use of hydraulic rock jammers or rock breakers. Rock hammers will also be required to break up any large boulders that need to be removed from the site.

During the use of hydraulic impact hammers, precautions must be made to reduce the risk of vibrational damage to adjoining structures. Prior to the commencement of rock hammering, we recommend that the boundary lines of the excavation first be cut with a rock saw. At the commencement of the use of hydraulic impact hammers we recommend that full time quantitative vibration monitoring be carried out on the adjoining structures, or at the boundaries by an experienced vibration consultant or geotechnical engineer to check that vibrations are within acceptable limits.

Australian Standard AS 2187: Part 2-2006 recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 "Evaluation and measurement for vibration in buildings Part 2" as they "are applicable to Australian conditions". The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where the minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (e.g. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

For residential structures, BS 7385 recommends vibration criteria of 7.5 mm/s to 10 mm/s for frequencies between 4 Hz and 15 Hz, and 10 mm/s to 25 mm/s for frequencies between 15 Hz to 40 Hz and above. These values would normally be applicable for new residential structures or residential structures in good condition. Higher values would normally apply to commercial structures, and more conservative criteria would normally apply to heritage structures. However, structures can withstand vibration levels significantly higher than those required to maintain comfort for their occupants. Human comfort is therefore likely to be the critical factor in vibration management.

Excavation methods should be adopted which limit ground vibrations at the adjoining structures to not more than 5mm/sec. Vibration monitoring is recommended to verify that this is achieved.

Table 5.1 – Recommendations for rock breaking equipment

Distance from adjoining structure (m)	Maximum Peak Particle Velocity 5mm/sec	
	Equipment	Operating Limit (% of maximum capacity)
1.5 to 2.5	Hand operated hack hammer only	100
2.5 to 5.0	300 kg rock hammer	50
5.0 to 10.0	300 kg rock hammer	100
	600 kg rock hammer	50

At all times, the excavation equipment must be operated by experienced personnel, per the manufacturer's instructions, and in a manner, consistent with minimising vibration effects.

If during excavation with the hydraulic impact hammers, vibrations are found to be excessive or there is concern, then alternative lower vibration emitting equipment, such as rock saws, rock grinders or smaller hammers may need to be used. The use of a rotary grinder or rock sawing in conjunction with ripping presents an alternative low vibration excavation technique, however, productivity is likely to be slower. When using a rock saw or rotary grinder, the resulting dust must be suppressed by spraying with water.

It should be noted that vibrations that are below threshold levels for building damage may be experienced at adjoining developments. Rock excavation methodology should also consider acceptable noise limits as per the "Interim Construction Noise Guideline" (NSW EPA).

5.4 Excavation Methodology & Retaining Wall Design

From the outcomes of the site inspection, bulk excavations of the dwelling are expected to encounter localised fill overlying in-situ sandstone bedrock, and possibly colluvial clayey soils with large detached sandstone boulders.

Until the excavation is commenced and the actual conditions are exposed it is not practical to be more definitive. We recommend that the excavation be initially commenced from the centre of the site and then extend out towards the excavation perimeters.

Excavations in the overlying fill materials and any colluvial soils must be temporarily battered at no steeper than 1H:1V. Excavations in the underlying competent sandstone should remain stable unsupported, at least in the short term. In some areas, support using rock bolts, shotcrete and/or underpinning using brick piers or infill concrete may be necessary. The latter would only normally be required if blocks fall out near to the boundary lines.

The site observations suggest there could be detached boulders and some included joints. If joints are continuous, they could form wedges which may need to be supported with bolts. If boulders extend beyond excavation boundaries, then they will need to be trimmed and supported. As noted above particular care will be required when excavating close to boundaries. This work should be carried out in small sections so that the subsurface conditions can be identified and any appropriate shoring or support can be installed before too large an area is exposed.

It is recommended that an experienced engineering geologist or geotechnical engineer observes the excavation as it progresses. At that time, they will be able to recommend any support that is required for either temporary or permanent conditions and help to finalise the design of the final cut slopes and any retaining walls that may be required.

All loosened rocks should either be stabilised or removed from the sides of the excavation as it proceeds. If floaters are encountered care will be required as they can often be sizeable in this geological environment, appearing to be part of the "solid" rock profile.

As noted above, experience has demonstrated that near vertical cuts in the competent in-situ sandstone found in this area will normally remain stable for long lengths of time. If you are considering permanent unsupported vertical cuts, it is essential that the excavation boundary lines are first cut using a rock saw to create a clean face. The use of hydraulic rock hammers to create final permanent cut faces is not recommended as the hammers may induce fractures in the rock that may require long term support.

An alternative to leaving the rock face exposed is to design perimeter walls to support the excavation in the long term. Long term support will also be required for any cut slopes in soils/filling.

When considering the design of any retaining structures, it will be necessary to allow for the loading from any adjoining structures, the ground surface slope and the water table present. The presence of any existing boulders which are to be retained should also be considered when assessing surcharge loads.

The lateral earth pressure for a cantilevered wall should be determined as a proportion of the vertical stress, as given in the following formula:

$\sigma z = K z \gamma$, where σz = Horizontal pressure at depth z (kPa)

K = Earth pressure coefficient

z = Depth (m)

γ = Unit weight of soil or rock (kN/m^3)

Retaining walls may be designed using the parameters provided below in Table 5.2.

TABLE 5.2 – Retaining Wall Design Parameters

Material	Dry Unit Weight (kN/m^3)	Earth Pressure Coefficient		
		Active (K_a)	At Rest (K_O)	Passive (K_p)
Topsoil / Fill	18	0.4	0.6	-
Colluvial Clays	19	0.38	0.58	2.5
In-situ Sandstone Bedrock	22	10 kPa		4.5

The embedment of retaining walls can be used to achieve passive support. A triangular passive earth pressure distribution (increasing linearly with depth) may be assumed, starting from 0.5 m below excavation toe/base level.

Adequate drainage will need to be provided for any subsurface structures and behind retaining walls to prevent the build-up of hydrostatic forces. The drainage should comprise a geotextile encapsulated free draining backfill (such as 10 mm or 20 mm single size aggregate) with a slotted drainage pipe at the base of the wall for the relief of hydrostatic pressures.

Water collected by the drainage system should be discharged to a formal stormwater drainage system downslope of the proposed building. If drainage is not provided behind retaining walls, then the walls should be designed to withstand hydrostatic pressures over the full height of the respective walls.

5.5 Foundation Design

The existing topsoil and fill materials should not be relied upon for foundation support. Further, due to their varying composition and distribution across the site, we do not recommend relying on any natural clayey soils for foundation support. We recommend that the structures be uniformly founded on the underlying sandstone bedrock.

The bedrock was assessed to be at least Class IV. Footings or piles founded on Class IV sandstone bedrock may be proportioned using an allowable end bearing pressure of 1,000 kPa. For piled foundations socketed into the bedrock, an allowable adhesion of 100 kPa may be adopted for the pile shaft socketed into rock.

Care should be undertaken during foundation construction to ensure that the footings are founded on in-situ sandstone bedrock, and not detached cobbles or boulders.

Settlements for footings on rock are anticipated to be about 1% of the minimum footing dimension, based on serviceability parameters provided above. All footings should be poured with minimal delay (i.e. preferably on the same day of excavation) or the base of the footing should be protected by a concrete blinding layer after cleaning of loose spoil and inspection.

Conventional open hole bored cast in-situ piles are considered suitable for the site conditions, however Drilling of rock sockets into the sandstone bedrock will require the use of large excavators equipped with rock augers.

The initial stages of footing excavation/drilling, particularly if bored piles are adopted, should be inspected by a geotechnical engineer/engineering geologist to ascertain that the recommended foundation material has been reached and to check initial assumptions about foundation conditions and possible variations that may occur between borehole locations. The need for further inspections can be assessed following the initial visit.

6. FURTHER GEOTECHNICAL INPUT

The following summarises the scope of further geotechnical work recommended within this report. For specific details reference should be made to the relevant sections of this report.

- Complete dilapidation surveys of the adjoining buildings and structures.
- Inspection of the excavation cut faces as they progress.
- Inspection of footing excavations to ascertain that the recommended foundation has been reached and to check initial assumptions regarding foundation conditions and possible variations that may occur.
- We also recommend that Green Geotechnics view the proposed earthworks and structural drawings in order to confirm they are within the guidelines of this report.

Nevertheless, it will be essential during excavation and construction works that progressive geotechnical inspections be commissioned to check initial assumptions about excavation and foundation conditions and possible variations that may occur between inspected and tested locations and to provide further relevant geotechnical advice.

7. GENERAL RECOMMENDATIONS

Any development on the site should follow good hillside building practices (refer to Attachment 4 for some examples).

Based on the observations made during the site walkover and the risk assessment undertaken, it has been determined that the site has a low to moderate risk of slope instability. The site is suitable for residential development provided good hillside building practices are followed. There are no geotechnical constraints for the proposed development of the site; however, Section 5 of this report provides advice and recommendations that should be taken into consideration and applied to any future development.

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and Green Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, the subsurface conditions may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed.

REPORT INFORMATION

Introduction

These notes have been provided to amplify Green Geotechnics report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

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

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation.

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

Groundwater

Where groundwater levels are measured in boreholes there are several limitations, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. The borehole must be flushed, and any water must be extracted from the hole if further water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, Green Geotechnics will be pleased to review the report and the sufficiency of the investigation work.

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

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, Green Geotechnics will be pleased to assist with investigations or advice to resolve the matter.

Site Anomalies

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

Copyright

FIGURES

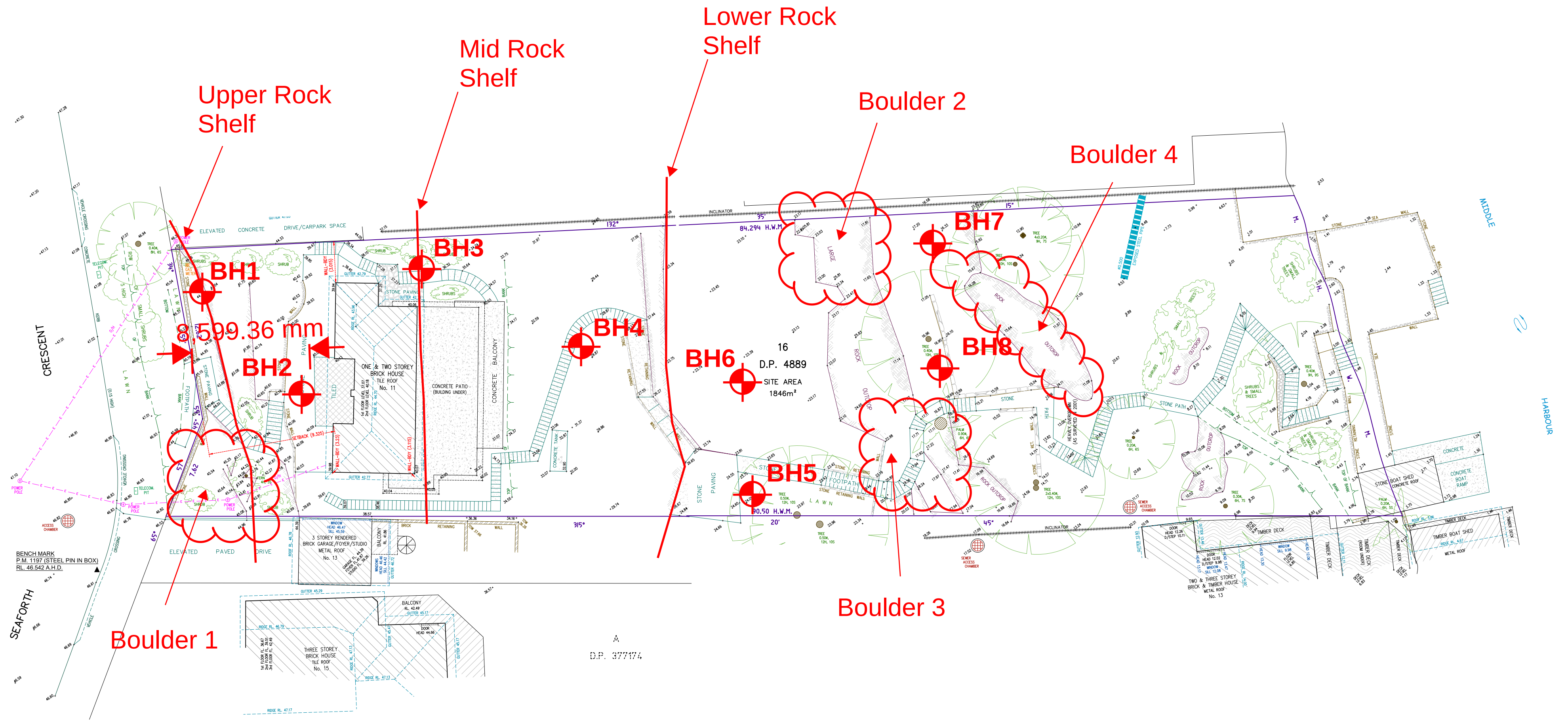
GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Figure No: GG12016.001A
	Client: William Wang		Drawn By: MG
	Date: 2 June 2025	**SITE LOCATION PLAN**	Scale: Unknown

Legend:

= Borehole

= DCP

= Test Pit



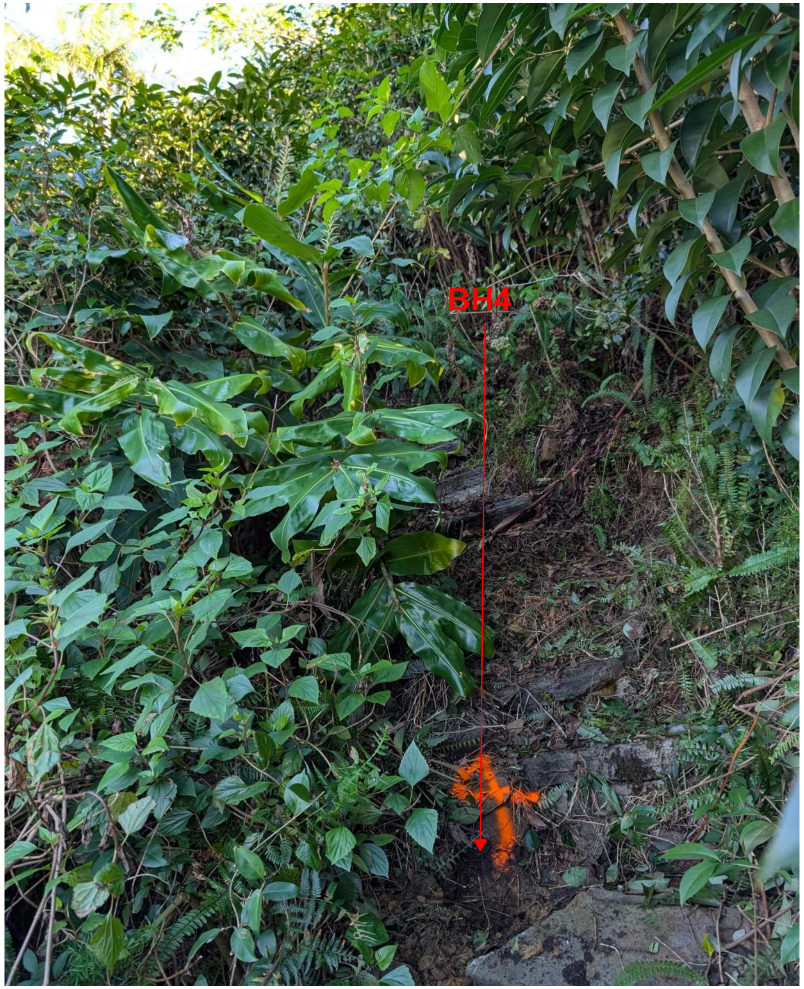
GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Figure No: GG12016.001B
	Client: William Wang		Drawn By: MG
	Date: 2 June 2025	**TEST LOCATION PLAN**	Scale: Unknown

Location of BH1

Location of BH2

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 1 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

Location of BH3



Location of BH4

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 2 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

Location of BH5

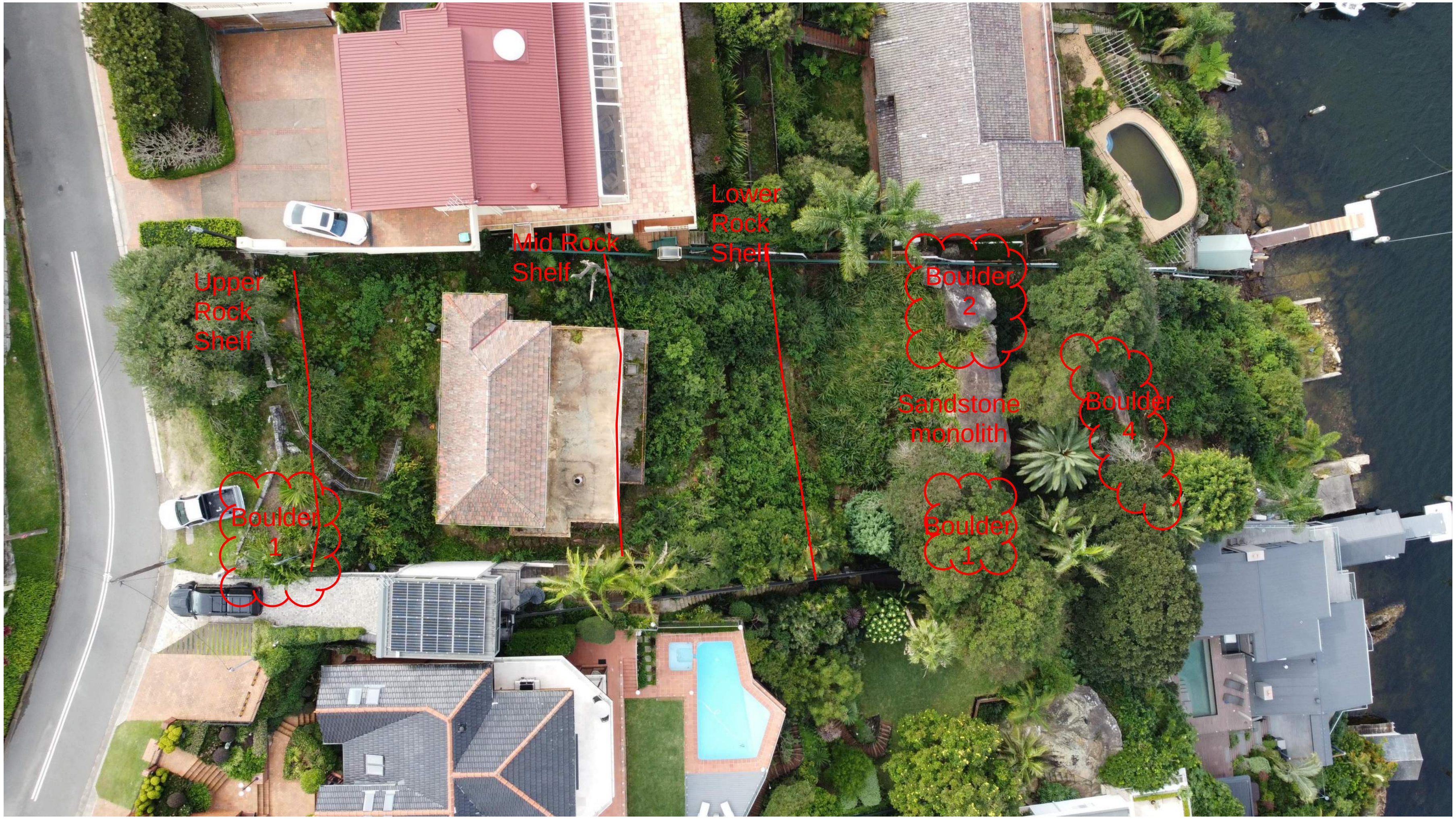
Location of BH6

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 3 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

Location of BH7

Location of BH8

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 4 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

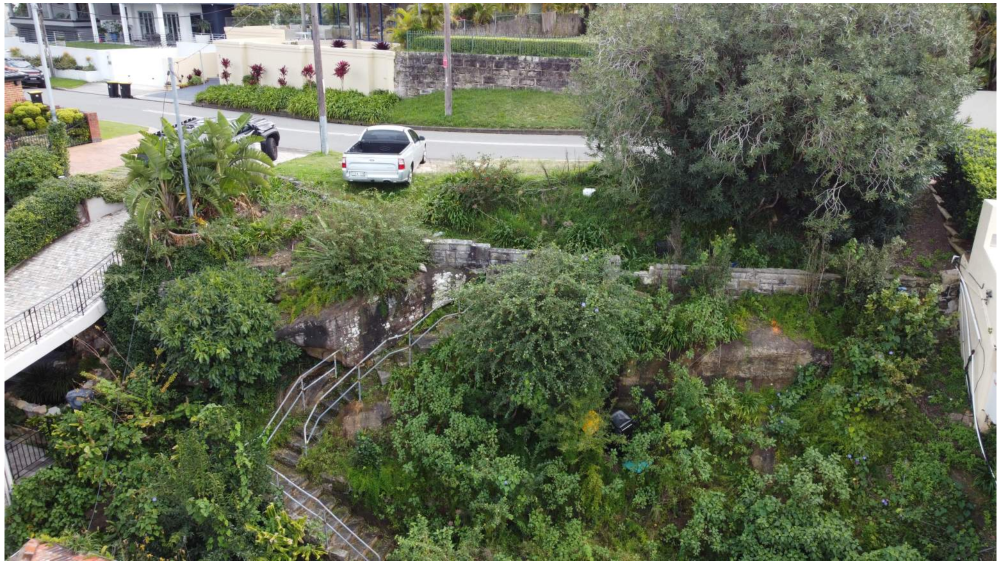


GREEN GEOTECHNICS

Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 5 of 10
Client: William Wang		
Date: 2 June 2025	**SITE PHOTOGRAPHS**	

Boulder 4

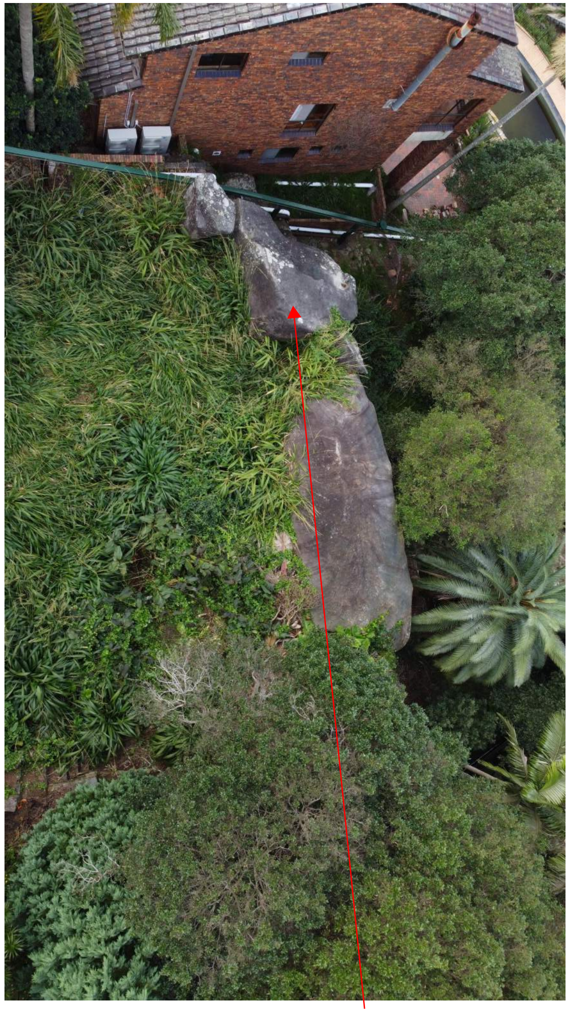
Lower rock shelf



Upper Rock Shelf

Boulder 1

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 7 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	



Sandstone monolith and Boulder 2

Mid rock shelf

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 8 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

Boulder 2 from mid terrace

Boulder 2 and wedged block from below monolith

Lower rock shelf

Boulder 3

GREEN GEOTECHNICS	Project No: GG12016.001	Geotechnical Investigation 11 Seaforth Crescent, Seaforth	Page: 10 of 10
	Client: William Wang		
	Date: 2 June 2025	**SITE PHOTOGRAPHS**	

APPENDIX A – BOREHOLE LOGS & DCP TEST RESULTS

GREEN GEOTECHNICS

Borehole No.
BH1
Page 1 of 1

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	44.40 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Drilling Information								*Soil Description*					*Observations*
Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA							0.10m			SANDSTONE: fine to medium grained, pale grey with orange brown.			ROCK
										Hole Terminated at 0.10 m Refusal on sandstone			
						43.9	0.5						
						43.4	1.0						
						42.9	1.5						
						42.4	2.0						
						41.9	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

GREEN GEOTECHNICS

Borehole No.
BH2
Page 1 of 1

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	40.00 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Drilling Information | **Soil Description** | **Observations**

Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA									SC	FILL Gravelly Clayey SAND: fine to medium grained, dark grey, with some ash/ gravel.	M		FILL
						39.5	0.5						
							0.80m		CL	FILL Gravelly Sandy CLAY: low plasticity, dark brown with orange brown, sand is fine to medium grained; with some sandstone cobbles/ gravel.	M		
						39.0	1.0 (1.00m)			Hole Terminated at 1.00 m Refusal in fill			
						38.5	1.5						
						38.0	2.0						
						37.5	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Borehole No.
BH3

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	36.70 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Drilling Information								Soil Description					Observations
Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA							0.40m		CL	FILL Gravelly Sandy CLAY: low plasticity, dark brown, sand is fine grained; with some wire/ brick/ cobbles/ gravel.	M		FILL
						36.2	0.5			Hole Terminated at 0.40 m Refusal in fill			
						35.7	1.0						
						35.2	1.5						
						34.7	2.0						
						34.2	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

GREEN GEOTECHNICS

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	29.90 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description (Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional)	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA							0.20m		CL	TOPSOIL Silty CLAY: low plasticity, dark brown, trace of fine grained sand.	M		TOPSOIL
						29.4	0.5 / 0.60m		CI	Silty Sandy CLAY: medium plasticity, orange brown with red brown, sand is fine grained; trace of cobbles/ sandstone gravel.	M	F / St	COLLUVIAL SOIL
							0.61m			SANDSTONE: fine to medium grained, orange brown.	D		ROCK
										Hole Terminated at 0.61 m Refusal on weathered sandstone (possible boulder/ cobble)			
						28.9	1.0						
						28.4	1.5						
						27.9	2.0						
						27.4	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

GREEN GEOTECHNICS

Borehole No.
BH5
Page 1 of 1

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	24.00 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA									CL	FILL Gravelly Sandy CLAY: low plasticity, orange brown with dark brown and dark grey, sand is fine to medium grained; with some cobbles/ gravel.	M		FILL
							0.30m			Hole Terminated at 0.30 m Refusal in fill			
						23.5	0.5						
						23.0	1.0						
						22.5	1.5						
						22.0	2.0						
						21.5	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

GREEN GEOTECHNICS

Borehole No.
BH6

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	23.40 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA							0.30m		CL	FILL Gravelly Silty CLAY: low plasticity, dark brown, with some gavel/ cobbles (sandstone/ brick/ terracotta pipe).	M		FILL
										Hole Terminated at 0.30 m Refusal in fill (possible old pool/ pond)			
						22.9	0.5						
						22.4	1.0						
						21.9	1.5						
						21.4	2.0						
						20.9	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

GREEN GEOTECHNICS

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	16.50 m
Hole Diameter:	65 mm	Bearing:		Datum:	AHD
				Operator:	JK

Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description: Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA							0.30m		CL	FILL Gravelly Sandy CLAY: low plasticity, dark brown, sand is fine to medium grained; with some cobbles/ sandstone gravel.	M		FILL
HA						16.0	0.5 / 0.60m		CI	Silty Sandy CLAY: medium plasticity, orange brown, sand is fine grained; trace of cobbles/ sandstone geotextile.	M	St	COLLUVIAL SOIL
										Hole Terminated at 0.60 m Refusal on sandstone cobbles/ boulder)			
						15.5	1.0						
						15.0	1.5						
						14.5	2.0						
						14.0	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Engineering Log - Borehole

Project No.: GG12016.001

Client:	William Wang	Commenced:	28/5/2025
Project Name:	Geotechnical Investigation: 11 Seaforth Crescent, Seaforth	Completed:	28/5/2025
Hole Location:	11 Seaforth Crescent, Seaforth	Logged By:	JK
Hole Position:	See Plan	Checked By:	MG

Drill Model and Mounting:	Hand Auger	Inclination:	-90°	RL Surface:	16.80 m		
Hole Diameter:	65 mm	Bearing:		Datum:	AHD	Operator:	JK

Drilling Information								Soil Description					Observations
Method	Support	Penetration	Groundwater Levels	Samples & Field Tests	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	Material Description Fraction, Colour, Structure, Bedding, Plasticity, Sensitivity, Additional	Moisture Condition	Consistency Relative Density	Structure and Additional Observations
HA									SC	FILL Gravelly Clayey SAND: fine to medium grained, dark brown, with some brick/ concrete/ tile gravel. (0.40m)	M		FILL
						16.3	0.5			Hole Terminated at 0.40 m Refusal in fill			
						15.8	1.0						
						15.3	1.5						
						14.8	2.0						
						14.3	2.5						

Method
AS - Auger Screwing
ADV - Auger V Bit
ADT - Auger Tungsten Carbide Bit
RR - Rock Roller
WB - Washbore

Support
C - Casing

Penetration
No resistance ranging to refusal

Water
Level (Date)
Inflow
Partial Loss
Complete Loss

Graphic Log/Core Loss
Core recovered (hatching indicates material)
Core loss

Samples and Tests
U - Undisturbed Sample
D - Disturbed Sample
SPT - Standard Penetration Test
PP - Pocket Penetrometer

Classification Symbols and Soil Descriptions
Based on Unified Soil Classification System

Moisture Condition
D - Dry
M - Moist
W - Wet
w - Moisture Content
PL - Plastic Limit
LL - Liquid Limit

Consistency/Relative Density
VS - Very Soft
S - Soft
F - Firm
VSt - Very Stiff
H - Hard
Fr - Friable
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

Dynamic Cone Penetrometer Test Report

GREEN GEOTECHNICS

Project Number: GG12016.001
Site Address: 11 Seaforth Crescent, Seaforth
Test Date: 28/05/2025

Test Method: **AS1289.6.3.2**

Technician: JK

Test No	BH1	BH2	BH3	BH4	BH5	BH6
Starting Level	Surface Level	Surface Level	Surface Level	Surface Level	Surface Level	Surfac Level
Depth (m)	Penetration Resistance (blows / 150mm)					
0.00 - 0.15	22	*	1	1	*	1
0.15 - 0.30	Refusal	1	1	2	4	1
0.30 - 0.45		2	12	2	6	4
0.45 - 0.60		1	22	8	22	22
0.60 - 0.75		2	Refusal	6	Refusal	Refusal
0.75 - 0.90		4		22		
0.90 - 1.05		12		Refusal		
1.05 - 1.20		22				
1.20 - 1.35		Refusal				
1.35 - 1.50						
1.50 - 1.65						
1.65 - 1.80						
1.80 - 1.95						
1.95 - 2.10						
2.10 - 2.25						
2.25 - 2.40						
2.40 - 2.55						
2.55 - 2.70						
2.70 - 2.85						
2.85 - 3.00						

Remarks: * Pre drilled prior to testing

Dynamic Cone Penetrometer Test Report

Project Number: GG12016.001
Site Address: 11 Seaforth Crescent, Seaforth
Test Date: 28/05/2025

Test Method: **AS1289.6.3.2**

Technician: JK

Test No	BH7	BH8				
Starting Level	Surface Level	Surface Level				
Depth (m)	Penetration Resistance (blows / 150mm)					
0.00 - 0.15	1	1				
0.15 - 0.30	22	6				
0.30 - 0.45	Refusal	1				
0.45 - 0.60		2				
0.60 - 0.75		4				
0.75 - 0.90		22				
0.90 - 1.05		Refusal				
1.05 - 1.20						
1.20 - 1.35						
1.35 - 1.50						
1.50 - 1.65						
1.65 - 1.80						
1.80 - 1.95						
1.95 - 2.10						
2.10 - 2.25						
2.25 - 2.40						
2.40 - 2.55						
2.55 - 2.70						
2.70 - 2.85						
2.85 - 3.00						

Remarks: * Pre drilled prior to testing

SAMPLING & IN-SITU TESTING

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock. Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure. Undisturbed samples are taken by pushing a thin walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength and are necessary for laboratory determination of shear strength and compressibility.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator.

Large Diameter Augers

Boreholes can be drilled using a large diameter auger, typically up to 300 mm or larger in diameter mounted on a standard drilling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration.

Diamond Core Rock Drilling

A continuous core sample of can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter (NMLC). The borehole is advanced using a water or mud flush to lubricate the bit and removed cuttings.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable, and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as: 15, 30/40 mm.

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.

- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

SOIL DESCRIPTIONS

Description and Classification Methods

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

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle Size (mm)
Boulder >200	Boulder >200
Cobble 63 - 200	Cobble 63 - 200
Gravel 2.36 - 63	Gravel 2.36 - 63
Sand 0.075 - 2.36	Sand 0.075 - 2.36
Silt 0.002 - 0.075	Silt 0.002 - 0.075
Clay <0.002	Clay <0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle Size (mm)
Coarse Gravel	20 – 63
Medium Gravel	6 – 20
Fine Sand	2.36 – 6
Coarse Sand	0.6 – 2.36
Medium Sand	0.2 – 0.6
Fine Sand	0.075 – 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion
And	Specify
Adjective	20 - 35%
Slightly	12 - 20%
With some	5 - 12%
With a trace of	0 - 5%

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained Shear Strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	ST	50 - 100
Very stiff	VST	100 - 200
Hard	H	200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (DCP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N Value	CPT qc value (MPa)
Very loose	VL	<4	<2
Loose	L	4 - 10	2 -5
Medium Dense	MD	10-30	5-15
Dense	D	30-50	15-25
Very Dense	VD	>50	>25

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Fill - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

ROCK DESCRIPTIONS

GREEN
GEOTECHNICS

Rock Strength

The Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $IS_{(50)}$ MPa	Approximate Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200

* Assumes a ration of 20:1 for UCS to $IS_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Residual Soil	RS	Soil developed on extremely weathered rock, the mass structure and substance fabric are no longer evident.
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable.
Distinctly Weathered	DW	Rock strength usually changed by weathering. The rock may be highly discoloured usually by iron staining.
Moderately weathered	MW	Staining and discolouration of rock substance has taken place.
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	No signs of decomposition or staining.

Degree of Fracturing

The following classification applies to the spacing of natural fractures in core samples (bedding plane partings, joints and other defects, excluding drilling breaks

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured Core	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Unbroken Core lengths mostly > 1000 mm

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	2 m

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$RQD\ \% = \frac{\text{cumulative length of 'sound' core sections} \geq 100\text{ mm long}}{\text{total drilled length of section being assessed}}$$

'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling/handling, then the broken pieces are fitted back together and are not included in the calculation of RQD.

ABBREVIATIONS

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
ADT	Auger Drill TC Bit
ADV	Auger Drill V Brit
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

Z	Water seep
V	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
S	Chemical sample
U50	Undisturbed tube sample (50mm)
W	Water sample
PP	Pocket Penetrometer (kPa)
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

C	Crushed Seam
DB	Drilling Break
DL	Drilling Lift
EW	Extremely Weathered Seam
HB	Handling Break
IS	Infilled Seam
J	Joint
MB	Mechanical Break
P	Parting
S	Sheared Surface
SS	Sheared Seam
SZ	Sheared Zone

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cn	clean
ct	coating
sn	stained
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pr	planar
st	stepped
un	undulating

Roughness

po	polished
rf	rough
sl	slickensided
sm	smooth
vr	very rough

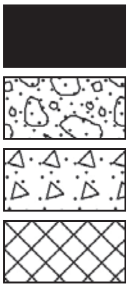
Other

fg	fragmented
bnd	band
qtz	quartz

SYMBOLS

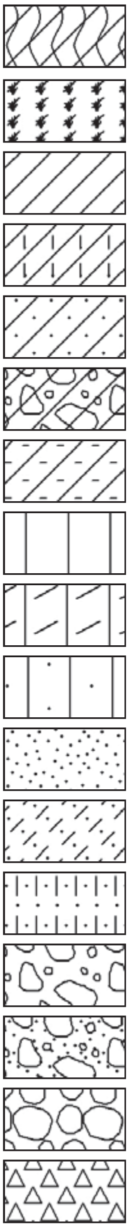
Graphic Symbols for Soil and Rock

General



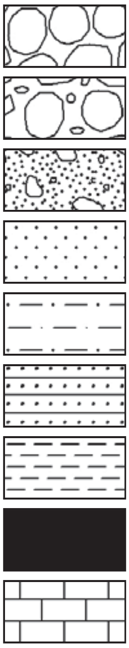
- Asphalt
- Road base
- Concrete
- Filling

Soils



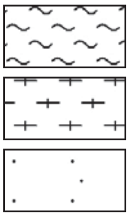
- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks



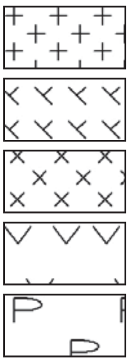
- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks



- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks



- Granite
- Dolerite, basalt, andesite
- Dacite, epidote
- Tuff, breccia
- Porphyry

UNIFIED SOIL CLASSIFICATION TABLE

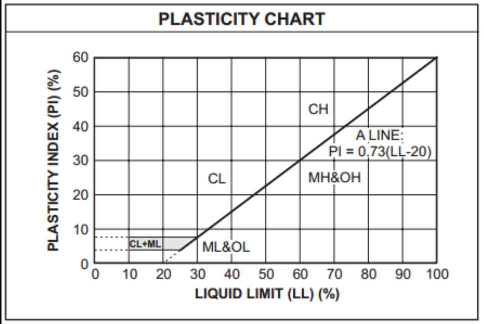
Field Identification Procedures (Excluding particles larger than 75um and basing fractions on estimated weights)				Group Symbols	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils More than half of the material is large that 75um sieve size[b]	Gravels More than half of the coarse fraction is larger than a 4mm sieve	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name: indicative approximate percentages of sand and gravel; maximum size; angularity; surface condition, and hardness of the coarse grains; local of geologic name and other pertinent descriptive information; and symbols in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics Example: *Silty Sand*, gravelly; about 20% hard, angular gravel particles 12mm maximum size; rounded and subangular sand grains, coarse to fine, about 15% non-plastic fines low dry strength; well compacted and moist in place; alluvial sand; *(SM)*	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, grave-sand mixtures, little or no fines		Not meeting all graduation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are borderline cases of requiring use of dual symbols
			Plastic fines (for identification procedures see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line with *PI* greater than 7
	Sands More than half of the coarse fraction is smaller than a 4mm sieve	Clean sands (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all graduation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are borderline cases of requiring use of dual symbols
			Plastic fines (for identification procedures see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits above "A" line with *PI* greater than 7

The 75um sieve size is about the particle visible to the naked eye

Use grain size curve in identifying the fractions as given under field identification

Determine percentages of gravel and sand from grain size curve
Depending on percentage of fines (fraction smaller than 75um sieve size) coarse grained soils are classified as follows
Less than 5% — GW, GP, SW, SP
More than 12% — GM, GC, SM, SC
5 to 12% — Borderline cases requiring use of dual symbol

Find-grained soils More than half of the material is smaller than 75um sieve size	Identification Procedures of Fractions Smaller than 380 um Sieve Size: Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slit plasticity	Give typical name: indicative degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions Example: *Clayey Silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; *(ML)*
	Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
	Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	
Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts	
	High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	
	Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils	Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity Chart
For laboratory classification of fine-grained soils

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines
2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity

APPENDIX B – AGS 2007 GUIDELINES

ATTACHMENT 1: 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

ATTACHMENT 1: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

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

RISK LEVEL IMPLICATIONS

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

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

ATTACHMENT 2 - DEFINITION OF TERMS AND LANDSLIDE RISK

(Australian Geomechanics Vol 42 No 1 March 2007)

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

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any year.

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

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

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

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

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

Landslide Activity – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (e.g. seasonal) or continuous (in which case the slide is “active”).

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

Landslide Risk – The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

Landslide Susceptibility – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

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

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an “objective” or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

Qualitative Risk Analysis – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative Risk Analysis – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

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

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

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

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

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

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

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

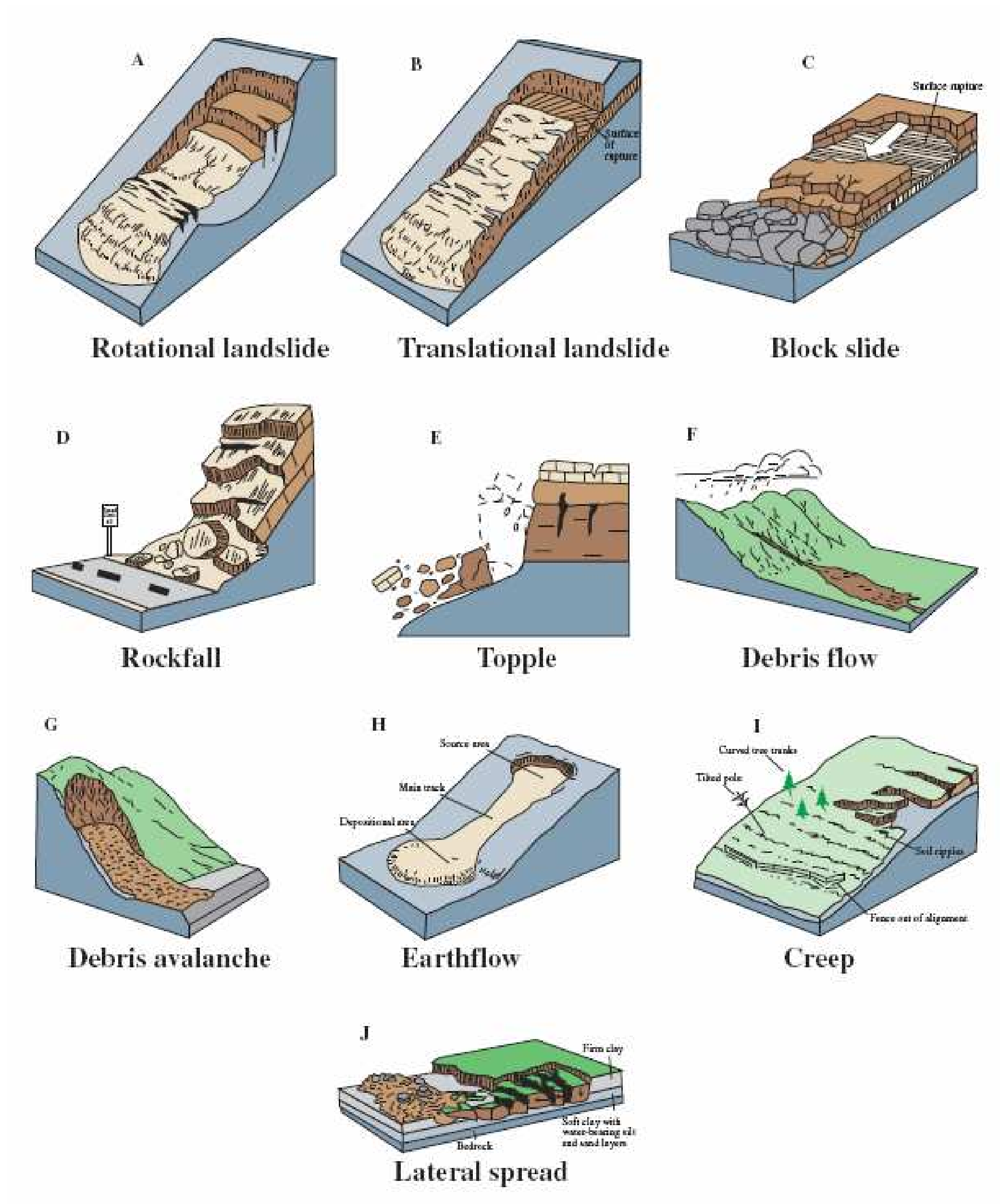
Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

Susceptibility – see Landslide Susceptibility

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

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

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



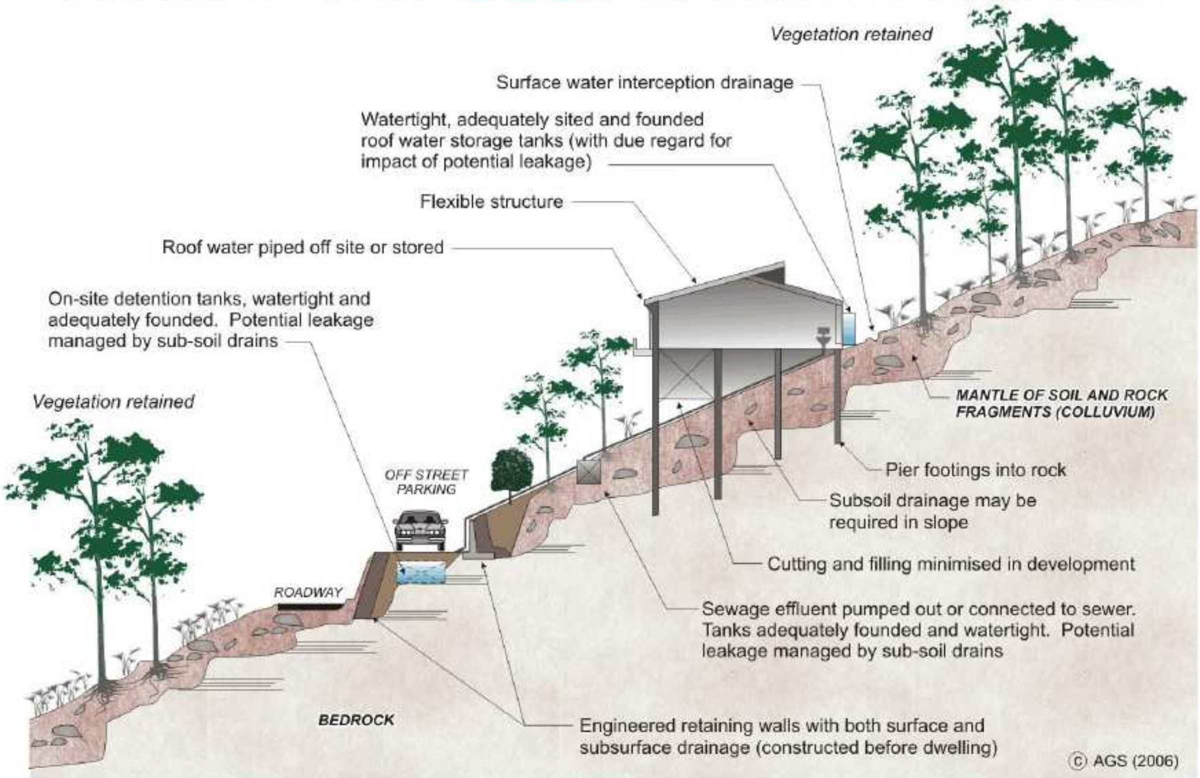
ATTACHMENT 3 MAJOR TYPES OF LANDSLIDES

ATTACHMENT 4

SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto 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