GREEN GEOTECHNICS

GEOTECHNICAL INVESTIGATION & ACID SULFATE SOILS ASSESSMENT

FOR

DELVE DESIGN

9 ALLINGTON CRESCENT, ELANORA HEIGHTS

REPORT GG10613.001

24th MAY 2022

Geotechnical Investigation for proposed alterations and additions to an existing residential dwelling at 9 Allington Crescent, Elanora Heights.

Prepared for

Delve Design
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Thornleigh NSW 2120

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24th May 2022

Document Authorisation

Our Ref: GG10613.001

For and on behalf of Green Geotechnics

Matthew Green
Principal Engineering Geologist

Document Control

Revision	Description	Format	Date	Author	Distributed to
-	Final	PDF	24/05/2022	MG	Delve Design (Client)

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1. INTRODUCTION

This report presents the results of a combined Geotechnical Investigation & Acid Sulfate Soils Assessment undertaken by Green Geotechnics Pty Limited for proposed alterations and additions to an existing residential dwelling at 9 Allington Crescent, Elanora Heights, NSW. The investigation was commissioned by Delve Design by return acceptance of Proposal PROP-2022-0174, dated 13th May 2022.

We understand that the development will comprise the construction of a lower ground floor garage, store and cellar space together with alterations and additions to the upper floor level. The lower ground floor will extend below the existing dwelling and will require excavating below the existing ground surface. As part the development a swimming pool will also constructed in the rear garden.

Further, we understand that the site is located within a Class 5 Acid Sulfate Soils area, and therefore a preliminary assessment will be required as part of the DA submission.

The purpose of the investigation was to:

- assess the subsurface conditions over the site, including groundwater levels,
- provide a Site Classification to AS2870,
- assess the founding condition of the existing perimeter brick walls,
- comment on excavation conditions including vibration control during rock excavation,
- provide recommendations for underpinning and temporary propping requirements during excavation of the subfloor space,
- provide recommendations regarding the appropriate foundation system for the site including design parameters,
- provide retaining wall design parameters and recommendations for cuts in sandstone bedrock,
- carry out a Preliminary Acid Sulfate Soils Assessment, and
- assess the requirement for an Acid Sulfate Soils Management Plan.

2. FIELDWORK DETAILS

The fieldwork was carried out on the 23rd May 2022 and comprised a detailed site walkover together with the drilling of three (3) boreholes numbered BH1, BH2 and BH3, and one test pit numbered TP1. Due to restricted site access the boreholes were drilled using hand auger equipment. BH1 was drilled in the front garden area, close to the position of the proposed new store room. BH2/TP1 was drilled/excavated adjacent to the southern boundary wall and BH3 was drilled in the rear garden area.

The site location is shown in the attached Figure A. The borehole and test pit 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 provided on Figure C.

The strength of the soils encountered at each borehole and test pit were assessed by undertaking a Dynamic Cone Penetrometer (DCP) test at each borehole location.

Groundwater observations were made in all boreholes during drilling, on completion of drilling and a short time after completion of drilling. No longer term monitoring of groundwater was carried out.

The fieldwork was completed in the full-time presence of our principal engineering geologist who set out the boreholes, nominated the sampling and testing, and prepared the borehole 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 43 in DP 219787 and is roughly rectangular in shape with an area of approximately 699m^2. At the time of the fieldwork the site was occupied by a one and two storey brick rendered residence with tile roof. The dwelling includes a single level clad extension and deck to the rear together with a subfloor storage space beneath the existing lounge. The subfloor storage space has a headroom of around 1.1 metres. There is also a small shed in the north west corner of the rear garden.

The existing dwelling has brick foundations comprising perimeter walls and internal brick columns. The existing floor level of the ground floor is approximately RL87.2 metres AHD.

Site vegetation comprised grass laws, garden beds with small plans and shrubs, and two large mature trees. The ground surface across the site falls approximately 4 metres to the east from RL89 metres AHD adjacent to the shed in the rear garden area to RL85 metres AHD at the kerb level of Allington Crescent.

There is an outcrop of sandstone bedrock in the rear garden area. The bedrock is distinctly bedded, with the bedding dipping at around 15° to the north east. The bedrock was assessed to be medium strength, fine to medium grained sandstone bedrock belonging to the Hawkesbury Sandstone formation.

To the east of the site is Allington Crescent and to the west are the rear gardens of No.33 Kalang Road. To the north of the site is No.11 Allington Crescent, a one and two storey brick rendered residence and to the south is No.7 Allington Crescent, a two storey brick rendered residence. The residences to the north and south are set back 1 to 2 metres from the site boundaries.

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.

The subsurface conditions encountered at each test location are summarised below:

BH1: BH1 encountered an upper layer of topsoil/fill to a depth of 0.25 metres overlying natural silty sands and clayey sands which extend to a depth of 0.9 metres. The natural sandy soils were assessed to be residual in nature and loose becoming medium dense with depth. Hand auger refusal occurred in BH1 on sandstone bedrock at a depth of 0.9 metres. The soils below a depth of 0.25 metres were assessed to be moist to wet, and water accumulated in the borehole at a depth of 0.25 metres shortly after drilling.

BH2/TP1: BH2 encountered an upper layer of fill to a depth of 0.25 metres overlying natural clayey silty sands which extend to a depth of 0.67 metres. The natural sandy soils were assessed to be residual in nature and loose becoming medium dense with depth. Hand auger refusal occurred in BH2/TP1 on sandstone bedrock at a depth of 0.67 metres. Some seepage was observed at the fill/natural interface during excavation.

The existing building foundations are constructed of concrete and are founded at a depth of approximately 0.53 metres on a medium dense residual clayey silty sand.

BH3: BH3 encountered an upper layer of topsoil/fill to a depth of 0.45 metres overlying natural silty sands which extend to a depth of 0.64 metres. The natural sandy soils were assessed to be colluvial in nature and loose to medium dense. Hand auger refusal occurred in BH3 on sandstone bedrock at a depth of 0.64 metres. The upper topsoil/fill materials were assessed to be moist to wet and water accumulated in the borehole at a depth of 0.2 metres shortly after drilling.

4. GEOTECHNICAL RECOMMENDATIONS

4.1 Primary Geotechnical Considerations

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

- Bulk excavation for the lower ground floor extension and potential ground loss as a result of excavations, resulting in damage to the existing structures,
- Rock excavation and the generation of ground borne vibrations, and
- Foundation design for structural loads for the additions.

4.2 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 loose sands, the site is classified as a ***Problem Site (P).*** However, provided the recommendations given in Section 4.5 are adopted and footings are founded in the underlying sandstone bedrock, the site may be re-classified 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.

4.3 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 test pits, the proposed excavations for the lower ground floor extension and swimming pool are expected to encounter fill and natural sandy soils overlying shallow sandstone bedrock. The bedrock may include bands of medium and high strength rock.

Access to the excavation area is likely to be limited to hand tools or a small restricted headroom excavator. Excavators alone without assistance will not be able to remove any significant amount of the rock. Hydraulic breakers mounted on an excavator or hand held jack hammers will be required to break up the majority of the rock before it can be removed using an excavator or by hand.

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 or large demolition 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 4.1 – 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

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).).

4.4 Excavation Methodology

Based on the results of the geotechnical investigations, excavations for the lower ground floor extension and swimming pool are expected to encounter in-situ sandstone bedrock at relatively shallow depths.

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 front of the existing subfloor storage area, and then extend out towards the excavation perimeters.

The existing brick permitter walls and columns appear to be founded on natural residual sandy materials. It will therefore be necessary to progressively prop the ground floor trusses and beams as the excavation progresses. The temporary props should be founded on the underlying sandstone bedrock, preferably at the finished lower ground floor level. A minimum excavation setback of 1 metre must be maintained from a column, prior to the column being propped. Once a column is fully propped it may be removed and the excavation may progress.

An initial setback of 1 metre must also be maintained from the external building walls which are to remain. Subject to the outcomes of construction stage inspections it may be feasible to reduce this set back further if the existing walls are founded on competent sandstone bedrock which is free of adverse joints or seams. This however can only be determined by regular inspections during the bulk excavation process. Where the existing footings are founded on sandy soils, they will either need to be supported or unpinned. Any underpinning should extend to competent sandstone bedrock.

Underpinning footings founded in sandy soils has the potential to induce foundation settlement, and therefore should only be undertaken by experienced contractors who have previously carried out similar works in similar ground conditions.

The underpinning will need to be undertaken using a hit and miss approach to ensure a gap is maintained between adjoining sections of footing being underpinned. For preliminary design purposes we would recommend that an A/B/C underpin sequence be adopted, with a maximum underpin width of 800mm per section. This should however be subject to review during construction depending on the stability of the sandy soils during excavation.

Temporary 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.

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 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.

We understand that the lower ground floor excavations will be supported by engineer designed retaining walls in the long term. When considering the design of the retaining walls it will be necessary to allow for the loading from existing structures, any ground surface slope and the water table present.

For the design of temporary structures where some ground movement is acceptable, an active earth pressure coefficient (K_a) may be adopted. However, where adjoining structures are within the zone of influence of the excavation, or it is necessary to limit lateral deflections, it will be necessary to adopt at rest (K_o) conditions.

A triangular lateral earth pressure distribution should be adopted for cantilevered walls, and a rectangular or trapezoidal lateral earth pressure distribution should be adopted for walls that are progressively propped at their top and base, and/or where two or more rows of anchors are used.

Excavations on the subject site will be limited to around 2 to 3 metres depth, and therefore a triangular stress distribution is recommended.

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 4.2.

TABLE 4.2 – Retaining Wall Design Parameters

Material Unit	Unit Weight (kN/m^3)	Earth Pressure Coefficient		
		Active (K_a)[1]	At Rest (K_O)[1]	Passive (K_p)[2]
Topsoil / Fill	18	0.4	0.6	-
Natural Residual Sands	19	0.4	0.6	2.5
Sandstone Bedrock	22	-	-	3.5[3]

1. These values assume that some wall movement and relaxation of horizontal stress will occur due to the excavation. Actual in-situ K_0 values may be higher, particularly in the rock units.

2. Includes a reduction factor to the ultimate value of K_p to consider strain incompatibility between active and passive pressure conditions. Parameters assume horizontal backfill and no back of wall friction.

3. The values for rock assume no adversely dipping joints or other defects are present in the bedrock.

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. In this regard, we would recommend that subsoil drains be installed around the perimeter of the lower ground floor area. The subsoil drains should be wrapped in a non-clog geofabric and surrounded by a backfill of strong durable single sized washed aggregate. The subsoil drainage system should be designed to gravity discharge to the kerb and gutter system of Allington Crescent.

4.5 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 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 V. Footings or piles founded on Class V sandstone bedrock may be proportioned using an allowable end bearing pressure of 800 kPa. For piled foundations socketed into the bedrock, an allowable adhesion of 80 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 shallow 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. Drilling of rock sockets into the sandstone bedrock will require the use of large excavators equipped with rock augers. It should however be noted that water seepage was observed during drilling at both the fill/natural interface and the natural/rock interface, therefore some dewatering of bored piles should be anticipated together with some localised dewatering of deep pad/strip footings that extend below the fill/natural interface.

Bored pile footings should be drilled, cleaned, inspected and poured with minimal delay, on the same day. Water should be prevented from ponding in the base of footings as this will tend to soften the foundation material, resulting in further excavation and cleaning being required.

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.

5. 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.
- Inspect of underpinning and propping works as the excavation progresses.
- Inspection of the rock cut faces as they progress.
- Where required, quantitative monitoring of transmitted vibrations during rock excavation using rock hammers.
- 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.

6. ACID SULFATE SOILS ASSESSMENT

6.1 Introduction

ASS are the common name given to sediments and soils containing iron sulfides which, when exposed to oxygen generate sulfuric acid. Natural processes formed the majority of acid sulfate sediments when certain conditions existed in the Holocene geological period (the last 10,000 years). Formation conditions require the presence of iron-rich sediments, sulfate (usually from seawater), removal of reaction products such as bicarbonate, the presence of sulfate reducing bacteria and a plentiful supply of organic matter. It should be noted that these conditions exist in mangroves, salt marsh vegetation or tidal areas, and at the bottom of coastal rivers and lakes.

The relatively specific conditions under which acid sulfate soils are formed usually limit their occurrence to low lying parts of coastal floodplains, rivers and creeks. This includes areas with saline or brackish water such as deltas, coastal flats, backswamps and seasonal or permanent freshwater swamps that were formerly brackish. Due to flooding and stormwater erosion, these sulfidic sediments may continue to be re-distributed through the sands and sediments of the estuarine floodplain region. Sulfidic sediment may be found at any depth in suitable coastal sediments – usually beneath the water table.

Any lowering in the water table that covers and protects potential ASS will result in their aeration and the exposure of iron sulfide sediments to oxygen. The lowering in the water table can occur naturally due to seasonal fluctuations and drought or any human intervention, when carrying out any excavations during site development. Potential ASS can also be the exposed to air during physical disturbance with the material at the disturbance face, as well as the extracted material, both potentially being oxidised. The oxidation of iron sulfide sediments in potential ASS results in ASS soils.

Successful management of areas with ASS is possible but must take into account the specific nature of the site and the environmental consequences of development. While it is preferable that sites exhibiting acid sulfate characteristics not be disturbed, management techniques have been devised to minimise and manage impacts in certain circumstances.

When works involving the disturbance of soil or the change of groundwater levels are proposed in coastal areas, a preliminary assessment should be undertaken to determine whether acid sulfate soils are present and if the proposed works are likely to disturb these soils.

6.2 Prescence of ASS

Reference to the Hornsby – Mona Vale ASS Risk Map indicates the property is within an area where there are no known occurrences of ASS. It should however be noted that maps are a guide only.

The following geomorphic or site criteria are normally used to determine if acid sulfate soils are likely to be present:

- sediments of recent geological age (Holocene)
- soil horizons less than 5 in AHD
- marine or estuarine sediments and tidal lakes
- in coastal wetlands or back swamp areas

6.3 Assessment

The property is at an elevation of about RL85m AHD and is underlain by residual sandy soils overlying bedrock belonging to the Hawkesbury Sandstone Formation. This is not consistent with the geomorphic criteria necessary for the presence of ASS. Based on our onsite observations and the subsurface conditions exposed in the boreholes, it is our opinion that the proposed construction will not intercept any ASS. Based on the observations during drilling, it appears that any seepage into the basement would be minor and as a consequence, construction will not result in the lowering of any groundwater that may be present in the area.

Our assessment is the proposed construction will not require the preparation of an Acid Sulfate Soil Management Plan.

7. GENERAL RECOMMENDATIONS

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. Copyright in this report is the property of Green Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

REPORT INFORMATION

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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, DP 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, DP 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, DP 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

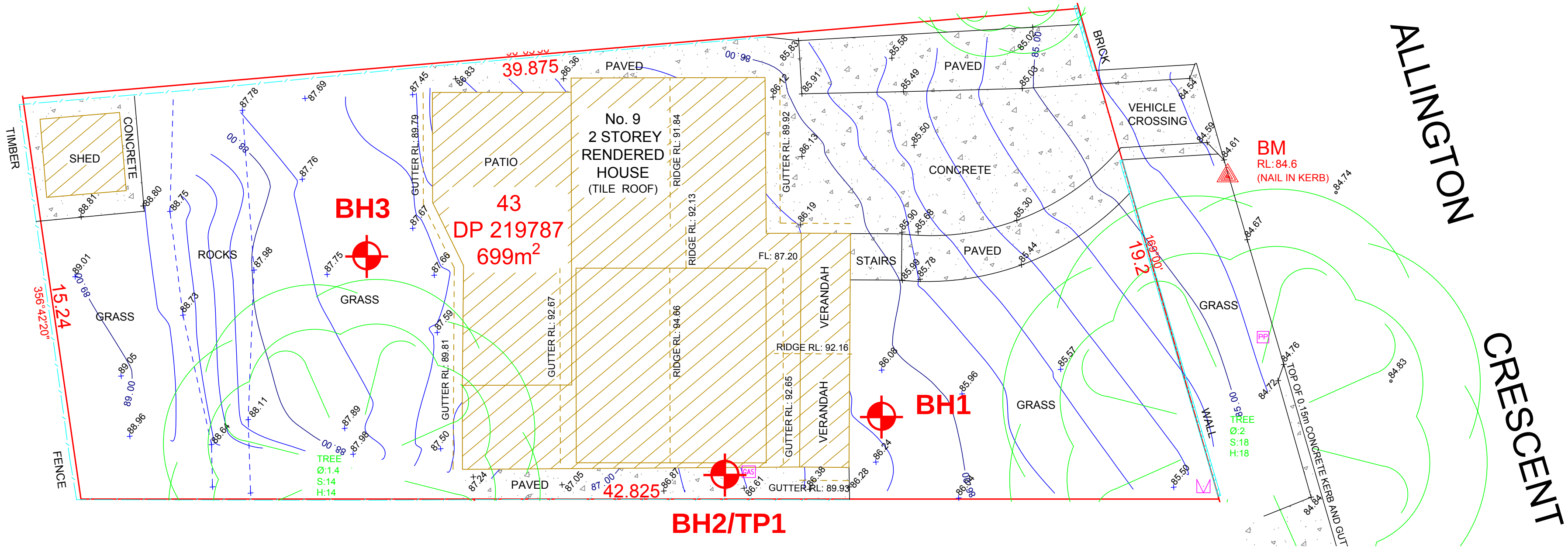
GREEN GEOTECHNICS	Project No: GG10613.001	Geotechnical Investigation 9 Allington Crescent, Elanora Heights **SITE LOCATION PLAN**	Figure No: GG10613.001A
	Client: Delve Design		Drawn By: MG
	Date: 24 May 2022		Scale: Unknown

Legend:

= Borehole

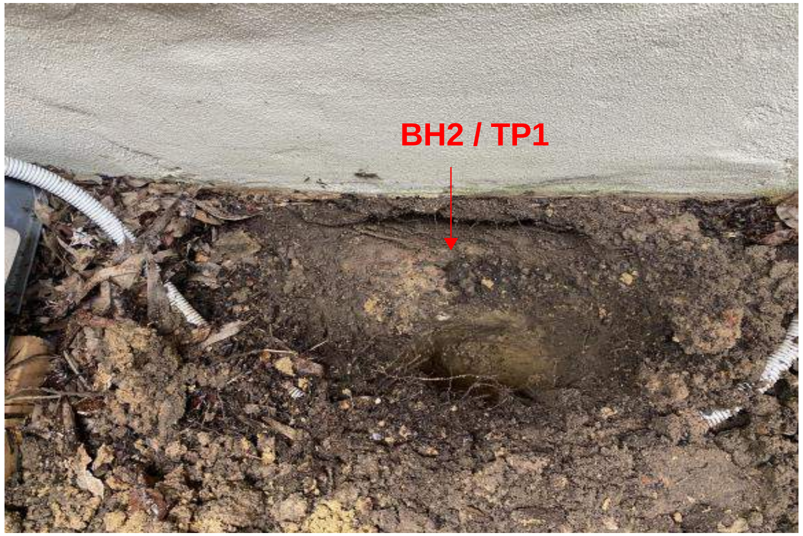
= DCP

= Test Pit



GREEN GEOTECHNICS	Project No: GG10613.001	Geotechnical Investigation 9 Allington Crescent, Elanora Heights	Figure No: GG10613.001B
	Client: Delve Design		Drawn By: MG
	Date: 24 May 2022	**TEST LOCATION PLAN**	Scale: Unknown

Position of BH1 in front garden area



Position of BH2 / TP1

Position of BH2 / TP1

Position of BH3 in rear garden area


Outcropping bedrock in rear garden area

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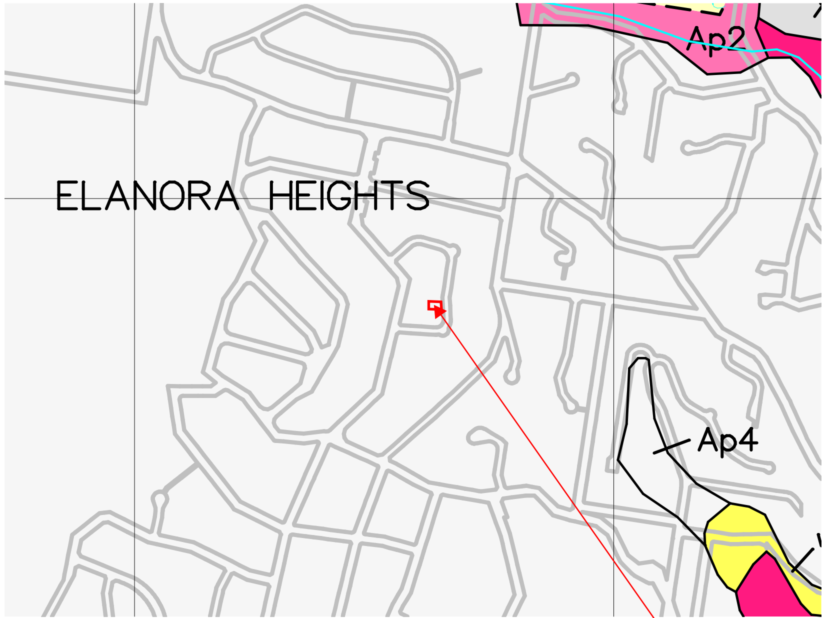
	Client: Delve Design		
	Date: 24 May 2022	**SITE PHOTOGRAPHS**	



Hornsby - Mona Vale Acid Sulfate Soils Risk Map

Acid Sulfate Soils Classification Mapping (Source ePlanning Spatial Viewer)

Subject Site

GREEN GEOTECHNICS	Project No: GG10613.001	Geotechnical Investigation 9 Allington Crescent, Elanora Heights	Figure No: GG10613.001D
	Client: Delve Design		Drawn By: MG
	Date: 24th May 2022	**ACID SULFATE SOILS MAPPING**	Scale: Unknown

APPENDIX A – BOREHOLE LOGS

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10613	Surface RL: 86.1m AHD	Date Logged : 23/05/2022	
Address: 9 Allington Crescent, Elanora Heights		Logged By: MG	BOREHOLE NO.: BH 1
Client: Delve Design		Checked By: MG	Sheet 1 of 1

WATER TABLE	SAMPLES	DEPTH (M)	DESCRIPTION (Soil type, colour, grain size, plasticity, minor components, observations)	USCS SYMBOL	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	MOISTURE
			TOPSOIL / FILL: Clayey Silty SAND: Brown, fine to medium grained with a trace of organics and gravel.	SM		M
After Drilling			Silty SAND: Grey to orange brown, fine to medium grained with a trace of clay.	SM	Loose	M-W
		0.5			Medium Dense	
			Clayey SAND: Orange to brown orange, fine to medium grained with low plasticity fines.	SC	Medium Dense	M
			HAND AUGER REFUSAL AT 0.9m ON SANDSTONE BEDROCK.			
		1.0				
		1.5				
		2.0				
		2.5				

D - Disturbed sample	U - Undisturbed tube sample	B - Bulk sample	Contractor: Green Geotechnics
S - Chemical Sample	SPT - Standard Penetration Test		Equipment: Hand Auger
WT - Standing Water Table	SP - Water Seepage Level		Hole Diameter (mm): 50
NOTES:	See explanation sheets for meaning of all descriptive terms and symbols		Angle from Vertical (°): 0°
			Drill Bit: Mild Steel

GEOTECHNICAL LOG - NON CORED BOREHOLE

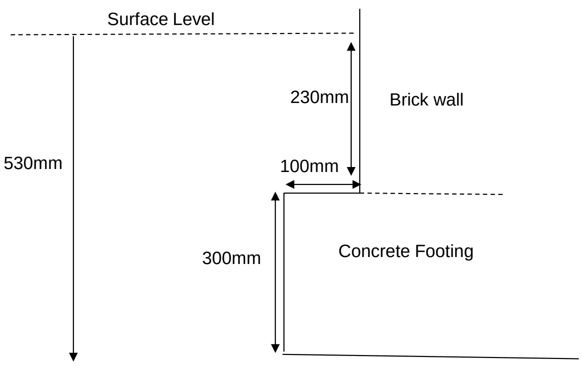
Project No: GG10613 | Surface RL: 86.6m AHD | Date Logged : 23/05/2022
Address: 9 Allington Crescent, Elanora Heights | Logged By: MG
Client: Delve Design | Checked By: MG

GREEN GEOTECHNICS

BOREHOLE NO.: BH 2

Sheet 1 of 1

WATER TABLE	SAMPLES	DEPTH (M)	DESCRIPTION (Soil type, colour, grain size, plasticity, minor components, observations)	USC SYMBOL	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	MOISTURE
			Fill: Silty SAND: Brown, fine to medium grained with rootlets and gravel.	SM		M-W
During Drilling		0.5	Clayey Silty SAND: Orange to grey brown becoming orange brown, fine to medium grained with low plasticity fines.	SM	Loose Medium Dense	M
		1.0 1.5 2.0 2.5	HAND AUGER REFUSAL AT 0.67m ON SANDSTONE BEDROCK.			



D - Disturbed sample	U - Undisturbed tube sample	B - Bulk sample	Contractor: Green Geotechnics
S - Chemical Sample	SPT - Standard Penetration Test		Equipment: Hand Auger
WT - Standing Water Table	SP - Water Seepage Level		Hole Diameter (mm): 50
NOTES:	See explanation sheets for meaning of all descriptive terms and symbols		Angle from Vertical (^{o}): 0°
			Drill Bit: Mild Steel

GEOTECHNICAL LOG - NON CORED BOREHOLE

GREEN GEOTECHNICS

Project No: GG10613 | Surface RL: 87.7m AHD | Date Logged : 23/05/2022

Address: 9 Allington Crescent, Elanora Heights | Logged By: MG

Client: Delve Design | Checked By: MG

BOREHOLE NO.: BH 3

Sheet 1 of 1

WATER TABLE	SAMPLES	DEPTH (M)	DESCRIPTION (Soil type, colour, grain size, plasticity, minor components, observations)	USC SYMBOL	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	MOISTURE
▼ After Drilling			TOPSOIL / FILL: Clayey Silty SAND: Brown to grey brown, fine to medium grained with a trace of organics and gravel.	SM		M-W
		0.5	Silty SAND: Pale grey, fine to medium grained with a trace of low plasticity fines.	SM	Loose to Medium Dense	M
			HAND AUGER REFUSAL AT 0.64m ON SANDSTONE BEDROCK.			
		1.0				
		1.5				
		2.0				
		2.5				

D - Disturbed sample | U - Undisturbed tube sample | B - Bulk sample

S - Chemical Sample | SPT - Standard Penetration Test

WT - Standing Water Table | SP - Water Seepage Level

NOTES: See explanation sheets for meaning of all descriptive terms and symbols

Contractor: Green Geotechnics

Equipment: Hand Auger

Hole Diameter (mm): 50

Angle from Vertical (^{o}): 0°

Drill Bit: Mild Steel

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

GREEN GEOTECHNICS

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
- Filling - 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
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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
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.
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 stained	FS	Rock substance unaffected by weathering but staining visible along defects.
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:

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

'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

GREEN
GEOTECHNICS

Introduction

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

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
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

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

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

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

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

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

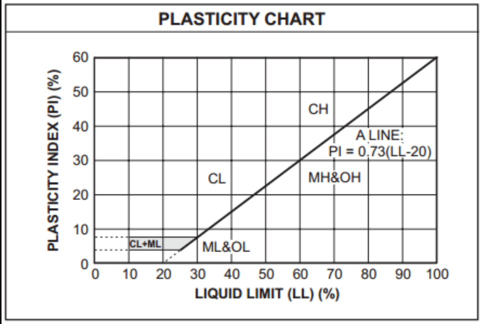
Other

fg	fragmented
bnd	band
qtz	quartz

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] (The 75um sieve size is about the particle visible to the naked eye)	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	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	$C_u = \frac{D_{60}}{D_{10}}$ 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	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics		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	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)*		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

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				Group Symbols	Typical Names	Information Required for Describing Soils
		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)			
	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
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	Example: *Clayey Silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; *(ML)*
	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

Dynamic Cone Penetrometer Test Report

Project Number: GG10613
Site Address: 9 Allington Crescent, Elanora Heights
Test Date: 23/05/2022

Test Method: **AS1289.6.3.2**
Technician: MG

Test No	BH1	BH2	BH3			
Starting Level	Surface	Surface	Surface			
Depth (m)	Penetration Resistance (blows / 150mm)					
0.00 - 0.15	1	1	1			
0.15 - 0.30	1	1	1			
0.30 - 0.45	2	3	3			
0.45 - 0.60	6	4	6			
0.60 - 0.75	7	9	Bounce at 0.6m			
0.75 - 0.90	8	Bounce at 0.75m				
0.90 - 1.05	Bounce at 0.9m					
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