



2 – 4 Kayuga Close, Caves Beach

Geotechnical Investigation Report

NSW Government Health Infrastructure

17 March 2026

→ The Power of Commitment



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Executive summary

Objectives and purpose

NSW Government Health Infrastructure (HI) has engaged GHD Pty Ltd (GHD) to undertake a Geotechnical Investigation at 2-4 Kayuga Close, Caves Beach NSW 2281 (the site), as part of a geotechnical assessment to support redevelopment and planning of the site. The NSW Health Infrastructure (HI) is planning to design and construct new ambulance station at the proposed site. The site currently comprises of two on grade warehouses, two grassed areas with trees adjacent Kayuga Close with the remainder of the site covered in hardstand as presented in Figure 1.

This report is part of GHD's contamination and geotechnical investigation project, assisting NSW Health Infrastructure deliver its Ambulance Infrastructure Program (AIP). The contamination scope and findings are outlined in a separate report (Contamination Detailed Site Investigation) prepared by GHD's contamination team. GHD understands Health Infrastructure is proposing to construct a new ambulance station at the site as part of the AIP.

The objectives of the geotechnical investigation were to assess the subsurface conditions encountered at five (5) locations, and to:

- Present the collected ground information, including borehole logs;
- Present the results of laboratory testing of samples collected during fieldwork;
- Provide geotechnical assessment and discussion.

Scope

The scope of work for the geotechnical investigation comprised drilling five (5) boreholes with laboratory testing and subsequent analysis of results and geotechnical interpretation and assessment.

Findings

Key findings of this investigation are:

- Five (5) boreholes were drilled to depths ranging from 8.00 to 8.95 metres below ground level (m bgl) and terminating due to achieving target depth or auger refusal.
- CB-BH01A and CB-BH03A were drilled during a separate mobilisation due to poor and unexpected conditions on site not allowing the entire scope to be completed.
- Boreholes encountered varying depths of fill from ground surface to 1.50 m bgl, alluvial soil from 1.00 to 8.50 m bgl and extremely weathered material from 8.50 to 8.95 m bgl at two locations (CB-BH02 and CB-BH03).
- A thick layer of very loose to loose Clayey Silty SAND/ SAND has been encountered in boreholes CB-BH01, CB-BH01A, CB-BH02 and CB-BH03.
- Groundwater inflow was encountered during auger drilling of soils at boreholes CB-BH01, CB-BH01A, CB-BH02, CB-BH03 and CB-BH03A at depths 1.0, 1.0, 1.2, 1.0 and 1.5 m bgl respectively.
- Existing wells were measured on site and encountered water at depths from 1.40 to 2.03 m bgl on 19 May 2025.
- Acid Sulfate Soil (ASS) testing was conducted at CB-BH03A due to site observations of shell fragments, brown staining and organic odours during borehole drilling.

Considerations for construction

Based on the findings of this investigation, GHD notes the following considerations for construction:

- Auger refusal was only encountered in CB-BH02 at 8.95 m bgl and terminated in extremely weathered material.
- Fill depth is relatively shallow from 0.12 to 1.50 m bgl encountered in investigation locations.
- The density and consistency of alluvial soil encountered in intrusive investigations varied greatly across the borehole locations and depths from very loose to very dense and firm to very stiff.
- Foundation design of proposed structure should consider the presence of a thick layer of very loose to loose Clayey Silty SAND/ SAND overlying medium dense to very dense SAND layer.
- Groundwater was observed in boreholes at relatively shallow depth during site investigations.
- Based on the intrusive investigations the Caves Beach site would be classified as Class Ce or Shallow Soil Site (Ce) in accordance with AS1170.4 Structural design actions.
- If excavation of material for construction of foundation is extended below the groundwater table or dewatering of groundwater is required, an ASS Management Plan will be required to manage the spoil.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.4 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Background

NSW Government Health Infrastructure (HI) has engaged GHD Pty Ltd (GHD) to undertake a Geotechnical Investigation at 2-4 Kayuga Close, Caves Beach NSW 2281 (the site), as part of a geotechnical assessment to support redevelopment and planning of the site. The NSW Health Infrastructure (HI) is planning to design and construct new ambulance station at the proposed site. The site currently comprises of two on grade warehouses, two grassed areas with trees adjacent Kayuga Close with the remainder of the site covered in hardstand as presented in Figure 1.

This report is part of GHD's contamination and geotechnical investigation project, assisting NSW Health Infrastructure deliver its Ambulance Infrastructure Program (AIP). The contamination scope and findings are outlined in a separate report (Contamination Detailed Site Investigation) prepared by GHD's contamination team. GHD understands Health Infrastructure is proposing to construct a new ambulance station at the site as part of the AIP.

The geotechnical scope informing the design of the new ambulance station involved drilling six (5) boreholes, as outlined in GHD's proposal titled Geotechnical & Contamination Consultant Services (5 Sites). RFT No: HI24608, dated 12 December 2024:

- CB-BH01
- CB-BH01A
- CB-BH02
- CB-BH03
- CB-BH03A

1.2 Purpose of this report

The objectives of the geotechnical investigation were to assess the subsurface conditions encountered at five (5) locations, and to:

- Present the collected ground information, including borehole logs;
- Present the results of laboratory testing of samples collected during fieldwork;
- Provide geotechnical assessment and discussion.

1.3 Scope of work

The scope of work for the geotechnical investigation comprised of the following:

- Drilling a borehole at the five (5) identified locations with standard penetration tests (SPT).
- Laboratory testing including:
 - Index tests (IT), including moisture content determination (MC), particle size analysis (PSA), Atterberg Limits (AL) which will be carried out on representative samples;
 - CBR with optimum moisture content (OMC) and maximum dry density (MDD);
 - Aggressivity tests including determination of sulphate, chloride, pH and electrical resistivity (or electrical conductivity) on soil samples.
 - Linear Shrinkage conducted on fine-grained soils (clays and silts).
 - Emerson Classification
 - Shrink Swell test
- Analysis of results.
- Geotechnical interpretation and assessment.

1.4 Limitations of this report

This report has been prepared by GHD for NSW Government Health Infrastructure and may only be used and relied on by NSW Government Health Infrastructure for the purpose agreed between GHD and NSW Government Health Infrastructure as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than NSW Government Health Infrastructure arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

GHD has prepared this report on the basis of information provided by NSW Government Health Infrastructure and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Site description

2.1 General

The site is located in Caves Beach, New South Wales. Site investigations works were undertaken along the proposed ambulance station. The site has two warehouse with some grass areas and hardstand to support movement of heavy vehicles. The site is relatively flat with limited exposed geological features. General photos of the site location are shown in Figure 1.



Figure 1 Site location Caves Beach

2.2 Geology

The anticipated surface geology at each of the proposed borehole locations was acquired from the NSW Seamless Geology Map (Geological Survey of New South Wales, Version: 2025.05.20) via the MinView web portal. The site location is underlain by Coastal Deposits – backbarrier flat facies (QP_bf), part of the Quaternary-aged Coastal Deposits unit (Q_b). This formation comprises fine to medium grained quartz-lithic sand containing carbonate and humic components of marine origin, with associated indurated sand, silt, clay, gravel, organic mud, and peat. The geological map is presented in Figure 2 below.

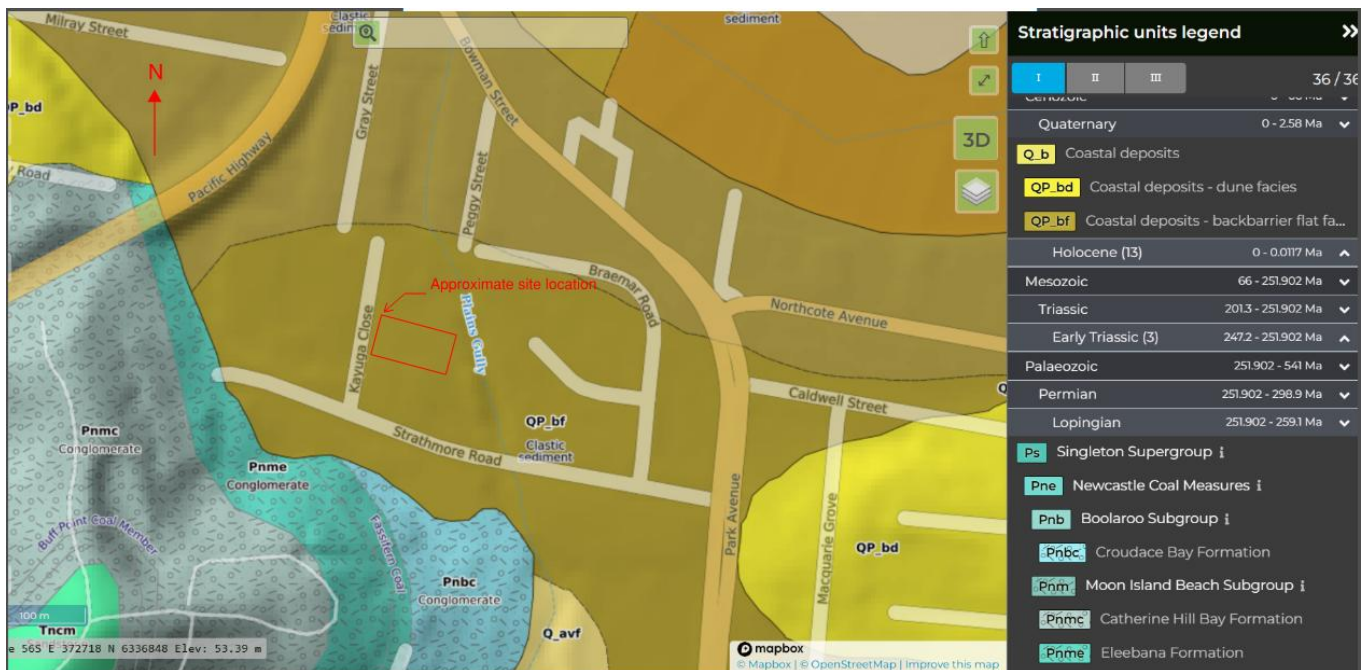


Figure 2 Local Geology - Caves Beach

2.3 Acid sulfate soil (ASS)

Acid Sulfate Soil (ASS) are naturally occurring sediments that consist of soil containing iron sulphides that, when oxidised (such as dewatering or excavation) generate sulphuric acid. ASS are commonly referenced as being either:

- Actual Acid Sulfate Soil (AASS): being soils that have previously been subject to oxidation, and have already generated acid conditions, or
- Potential Acid Sulfate Soils (PASS): being soil that have been maintained in substantially anaerobic conditions

ASS are predominantly of estuarine origin and deposited within near coastal areas at or near sea level (where anaerobic conditions have been maintained in recent geological history). The site ASS risk was acquired using the State Government of NSW and NSW Department of Climate Change, Energy, the Environment and Water 1998 Acid Sulfate Soils Risk map (sourced from The Sharing and Enabling Environment Data Portal). The ASS risk map with the approximate site location is shown in Figure 3.

Correspondingly, Department of Land and Water Conservation Acid Sulfate Soils (ASS) Risk Map Series indicates immediate areas north and east of the site having the following ASS probability:

- High probability (H2) 1 – 3 m below ground surface.
- Low probability (L2) 1 – 3 m below ground surface.

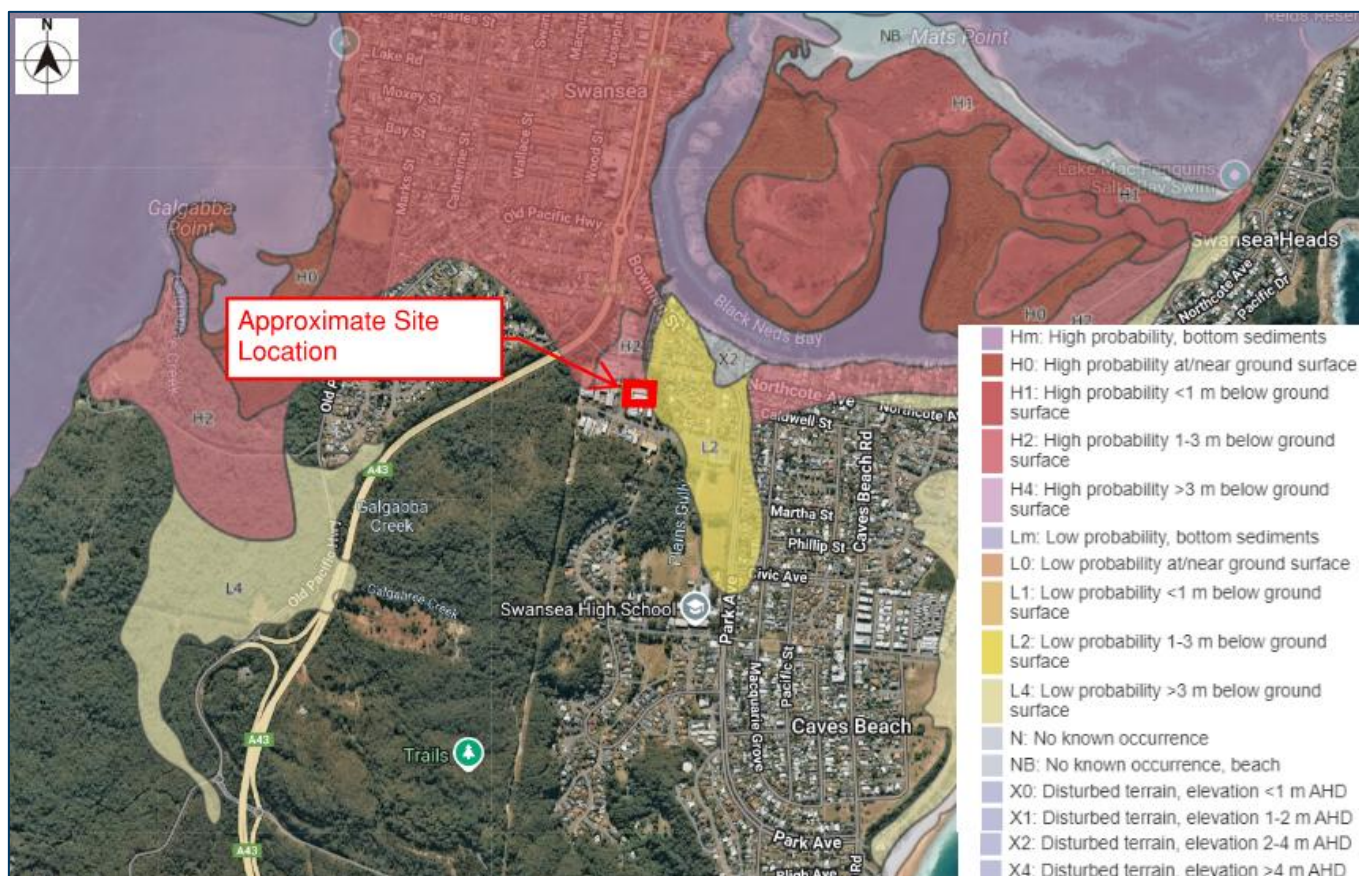


Figure 3 Acid sulfate soil risk map

3. Geotechnical investigation

3.1 Preliminaries

Prior to attending site and in accordance with GHD's occupational health and safety policy, a Job Safety and Environmental Assessment (JSEA) was prepared for the site work. The site staff were briefed on the requirements set out in the JSEA prior to commencing fieldwork.

A project safety briefing for site personnel was completed prior to commencement of the field investigation. Relevant plans of buried utilities obtained from the 'Before You Dig Australia' (BYDA) service and relevant architectural drawings of proposed development supplied by client were collated and reviewed. Prior to the sub-surface investigation commencing, scanning for underground utilities and setting out of the test locations clear of buried services were completed with a suitably qualified service locator.

3.2 Fieldwork

Fieldwork was undertaken on 19 and 29 May 2025 and involved the drilling of five (5) boreholes. The borehole location plan is presented in Appendix B.

The fieldwork was carried out under full-time supervision of a suitably qualified GHD engineering geologist.

The encountered soil profiles were logged by an experienced engineering geologist in accordance with Australian Standards (AS 1726:2017) and GHD's standard procedures. Borehole logs are shown in Appendix C. The logs are preceded by standard sheets in Appendix A which explains the terms, symbols and abbreviations used.

Where possible, representative samples were collected for geotechnical and contamination laboratory testing.

The contamination test results, assessment and waste classification will be included in a separate report prepared by GHD contamination team and those details have been excluded in this geotechnical investigation report.

Upon completion of drilling, boreholes were backfilled to surface level and their coordinates and reduced levels (RL) were recorded by the supervising GHD field staff using a handheld GPS device with a typical accuracy of ± 5 m. The borehole coordinates and RL's are listed in Table 1 below.

Table 1 Summary of boreholes

Borehole ID	Approx. Easting (m)	Approx. Northing (m)	Approx. RL's (m)	Depth (m)	Termination reason
CB0-BH01	372911.81	6337061.90	2.60	8.00	Target depth
CB-BH01A	372913.89	6337061.86	2.60	8.00	Target depth
CB-BH02	372891.90	6337030.61	2.80	8.95	Target depth
CB-BH03	372938.91	6337044.00	2.80	8.65	Target depth
CB-BH03A	372892.79	6337030.41	2.90	8.00	Target depth

3.3 Geotechnical laboratory testing

Selected samples recovered from site were submitted to GHD's NATA accredited laboratory for materials testing. The test methods and number of tests undertaken for geotechnical testing are listed in Table 2.

The laboratory test results are summarised in Section 4.3 and laboratory test certificates are contained in Appendix D.

Table 2 *Geotechnical laboratory test methods and scheduled quantities*

Test	Test method	Total number of tests
Moisture Content	AS1289.2.1.1	3
Atterberg Limits; or Particle Size Distribution	AS1289.3.1.1, AS1289.3.2.1 & AS1289.3.3.1 AS1289. 5.1.1	3
Aggressivity Suite (pH, chloride, sulphate, conductivity and resistivity)	Inorg-001, Inorg-002 & Inorg-081	3
California Bearing Ratio (CBR) with Optimum Moisture Content (OMC) and Maximum Dry Density (MDD)	AS1289.5.1.1 – 2017 & AS1289.6.1.1 – 2017	2
Emerson Class	AS1289.3.8.1	3
Shrink Swell Index	AS1289.7.1.1	2

4. Geotechnical investigation results

4.1 Subsurface conditions

A summary of the soil units encountered during the drilling investigation and the corresponding depth ranges are provided in Table 3. Further details on the subsurface conditions are provided in the engineering logs of the boreholes in Appendix C. Depths shown in Table 3 below and the borehole logs are metres below ground level (m bgl).

Table 3 Summary of subsurface conditions

Origin	Description	Depth range of unit (m bgl)				
		CB-BH01	CB-BH1A	CB-BH02	CB-BH03	CB-BH03A
Concrete	Concrete	0.00 to 0.17	0.00 to 0.20	0.00 to 0.20	0.00 to 0.12	0.00 to 0.20
Fill	SAND/ Clayey SAND: fine to coarse grained, pale grey, brown, grey; Clay, low plasticity.	0.17 to 1.00	0.20 to 0.50 1.00 to 1.50	NE	0.50 to 1.00	0.20 to 1.50
	Sandy CLAY/ Gravelly Sandy CLAY: low plasticity, brown, pale brown, grey, black; Sand, fine to coarse grained; Gravel, fine to coarse, angular to sub-rounded.	NE	0.50 to 1.00	0.20 to 1.00	0.12 to 0.50	NE
Alluvial	CLAY/ Sandy CLAY: low plasticity, dark brown, pale brown, grey, pale grey; Sand, fine to coarse grained, firm to very stiff.	1.00 to 1.50	NE	1.00 to 4.00	1.00 to 2.00	1.50 to 1.95
	Clayey Silty SAND/ SAND: fine to coarse grained, black, dark brown, pale grey, dark grey; Clay, low plasticity, very loose to loose.	1.50 to 7.00	1.50 to 7.00	4.00 to 7.00	2.00 to 4.00	NE
	SAND: fine to coarse grained, pale grey, dark grey, medium dense to very dense.	7.00 to 8.00 ^(A)	7.00 to 8.00 ^(A)	7.00 to 8.50 ^(A)	4.00 to 8.50	1.95 to 8.00 ^(A)
Extremely Weathered Material	Clayey SAND: fine to coarse grained, brown; Clay, low plasticity, very dense.	NE	NE	8.50 to 8.95 ^(A)	8.50 to 8.65 ^(A)	NE

Notes:

NE Not Encountered

^(A) Full depth range of this unit at the borehole was not identified due to borehole termination depth

m bgl Metres below ground level

4.2 Groundwater

Due to heavy rainfall on site during intrusive investigations, groundwater inflow was difficult to determine accurately. Groundwater inflow was encountered during auger drilling of soils at boreholes CB-BH01, CB-BH01A, CB-BH02, CB-BH03 and CB-BH03A at depths 1.0, 1.0, 1.2, 1.0 and 1.5 m bgl respectively. Existing groundwater wells were noted on site and measurements were taken from nearby wells. Groundwater levels of 1.40, 1.68 and 2.03 m bgl were measured from existing boreholes BH01, BH04 and BH06 respectively on the 19 May 2025.

It should be noted that groundwater levels are likely to fluctuate with variations in climatic, rainfall, tidal effect and site conditions over the year.

4.3 Laboratory testing results

4.3.1 Geotechnical laboratory testing

Recovered soil samples from the site were submitted to GHD's NATA accredited laboratory for geotechnical testing, and for aggressivity suite testing to external NATA accredited laboratory, Envirolab.

A summary of the geotechnical laboratory test results has been included in the tables below and the geotechnical laboratory test results are presented in Appendix D. These should be read in conjunction with the Geotechnical Standard Sheets in Appendix A, which explains the limitations of the test procedures.

Moisture content, Atterberg limit and linear shrinkage results are summarised below in Table 4.

Table 4 Summary of moisture content and Atterberg limit test results

Borehole ID	Sample depth range (m bgl)	Unit	Moisture (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
CB-BH01A	1.50 – 1.95	Alluvial	17.7	N/A	NP	NP

Moisture content and particle size distribution test results are summarised in Table 5.

Table 5 Summary of moisture content and particle size distribution test results

Borehole ID	Sample depth range (m bgl)	Unit	Moisture (%)	Gravel (%)	Sand (%)	Clay / Silt (%)
CB-BH02	1.00 – 1.45	Alluvial	12.8	3	59	38
CB-BH03A	2.00 – 2.45	Alluvial	17.2	0	91	9

Shrink Swell test results are summarised in Table 6.

Table 6 Summary of shrink swell test results

Borehole ID	Sample depth range (m bgl)	FMC (MC) (%)	Final Swell (MC) (%)	Shrink-swell index Iss (%)	Dry Density at FMC (t/m ³)
CB-BH02	2.5 – 2.8	16.5	15	0	1.72
CB-BH01A	5.0 – 5.5	16	14.9	0	1.72

The shrink-swell index values indicate that the soil is slightly reactive, which may experience only slight ground movement from moisture change. The site classification based on soil reactivity is Class "S" as per Table 2.1 of Australian Standard AS2870-2011.

California Bearing Ratio (CBR) test results are summarised in Table 7.

Table 7 Summary of California Bearing Ratio test results

Borehole ID	Sample depth range (m bgl)	Standard Maximum Dry Density (MDD) (t/m ³)	Standard Optimum Moisture Content (OMC) (%)	CBR at 5.0mm (%)	Swell (%)
CB-BH01	1.0 – 1.4	1.93	11.5	10	0
CB-BH03	1.0 – 1.1	1.83	13.5	5	0.5

Emerson Classification test results are summarised in Table 8.

Table 8 Summary of Emerson Class test results

Borehole ID	Sample depth range (m bgl)	Unit	Soil Description	Emerson Class Number
CB-BH01A	3.00 – 3.45	Alluvial	SAND	4
CB-BH02	0.50 – 0.56	Fill	CLAY	5
CB-BH03A	1.00 – 1.45	Fill	Clayey SAND	2

4.3.2 Soil aggressivity

Aggressivity suite test results are summarised below in Table 9.

Table 9 Summary of aggressivity suite test results

Borehole ID	Sample depth range (m bgl)	Unit	pH	Electrical conductivity (µS/cm)	Resistivity (ohm.m)	Chloride (mg/kg)	SO ₄ (mg/kg or mg/L)
CB-BH01A	2.00 – 2.45	Alluvial	7.0	330	30	<10	120
CB-BH02	5.50 – 5.95	Alluvial	6.7	240	41	<10	340
CB-BH03A	0.50 – 0.95	Fill	6.8	260	39	22	210

4.3.3 Acid sulfate soil (ASS) test results

ASS testing was conducted at CB-BH03A due to site observations of shell fragments, brown staining and organic odours during borehole drilling. ASS test results are included separately in GHD's Contamination Detailed Site Investigation report *12657833_REP_0_Caves Beach_DSI_Rev A_250801.PDF*, dated 01 August 2025, under Table C3 of Appendix C.

5. Geotechnical assessment

5.1 Geotechnical model

Based on results of in-situ and lab testing presented in Section 4, as well as available published correlations and experience on similar soils, typical geotechnical parameters for the various materials encountered for use in the proposed redevelopment of the site are provided in Table 10 below.

The following ground model descriptions are based on encountered subsurface conditions within the boreholes undertaken at the proposed redeveloped site.

Table 10 Soil units – overall project

Material origin	Unit reference	Typical description
Fill	1A	SAND/ Clayey SAND: fine to coarse grained, pale grey, brown, grey; Clay, low plasticity loose to medium dense.
	1B	Sandy CLAY/ Gravelly Sandy CLAY: low plasticity, brown, pale brown, grey, black; Sand, fine to coarse grained; Gravel, fine to coarse, angular to sub-rounded, very stiff.
Alluvial Soil	2A	Clayey Silty SAND/ SAND: fine to coarse grained, black, dark brown, pale grey, dark grey; Clay, low plasticity, very loose to loose.
	2B	Clayey Silty SAND/ SAND: fine to coarse grained, black, dark brown, pale grey, dark grey; Clay, low plasticity, medium dense to very dense.
	2C	CLAY/ Sandy CLAY: low plasticity, dark brown, pale brown, grey, pale grey; Sand, fine to coarse grained, firm to stiff.
	2D	CLAY/ Sandy CLAY: low plasticity, dark brown, pale brown, grey, pale grey; Sand, fine to coarse grained, very stiff.
Extremely Weathered Material	3	Clayey SAND: fine to coarse grained, brown; Clay, low plasticity, very dense.

5.2 Geotechnical design parameters

Based on the results of in-situ and lab testing discussed in Section 4.3, published correlations and experience with similar soils, typical geotechnical parameters for the materials encountered during the investigation, for use in design of the proposed ambulance station are provided in Table 11 below.

Table 11 *Soil design parameters*

Soil type	Unit	Material / Consistency	Unit Weight (γ) (kN/m ³)	Elastic Modulus (MPa)	Effective Cohesion (c') (kPa)	Effective Friction Angle (ϕ') (°)	Undrained Shear Strength (c_u) (kPa)
Fill	1A	SAND/ Clayey SAND - loose to medium dense	17 - 19	10 - 30	-	30 - 32	-
	1B	Sandy CLAY/ Gravelly Sandy CLAY – very stiff	20	30 - 60	5 - 8	27 - 28	100 - 200
Alluvial Soil	2A	Clayey Silty SAND/ SAND – very loose to loose	16 -17	2 - 10	-	25 - 30	-
	2B	Clayey Silty SAND/ SAND – medium dense to very dense	18 - 20	30 - 60	-	30 - 35	-
	2C	CLAY/ Sandy CLAY – firm to stiff	17 - 19	12 - 30	2 - 5	26 - 27	40 - 100
	2D	CLAY/ Sandy CLAY – very stiff	20	30 - 60	5 - 8	27 - 28	100 - 200
Extremely Weathered Material	3	Clayey SAND – very dense	20	60	-	35	-

5.3 Foundations

5.3.1 Shallow footing

The footing system for the proposed ambulance building will be selected by the structural engineer based on the design loads, acceptable settlements and adequate bearing capacity. The car parking area will be lightly loaded structures and as such, shallow footings will most likely be the preferred footing solution.

5.3.2 Pile foundation

Pile foundation design should be carried out in accordance with the Australian Standard AS 2159-2009 – Piling Design and Installation. AS 2159 requires that the ultimate design geotechnical strength ($R_{d,g}$) is not less than the design action effect (E_d). The design geotechnical strength is calculated as the ultimate geotechnical strength ($R_{d,ug}$) multiplied by a geotechnical strength reduction factor (ϕ_g).

The assessment of individual risk ratings for risk factors as set out in Table 4.3.2 (A) of AS 2159-2009 will need to be undertaken by the designer of the foundations. For all piles where the basic geotechnical strength reduction factor is greater than 0.40, AS2159-2009 requires the integrity of the pile shaft to be assessed by testing and inspection.

For piles subject to uplift loads, the geotechnical design strength shall be multiplied by a factor of 0.7 in addition to the geotechnical strength reduction factor. The uplift capacity should also be checked against a cone pull-out failure mode assuming a cone angle of 60°, considering the submerged weight of the soil or rock and adopting a factor of safety larger than 1.0 against pull-out.

With regards to serviceability limit state, the design of pile sockets (in compression) shall address the vertical slip displacements between concrete shaft and competent soil / rock layer. In addition, the side shear resistance is coupled with the end bearing load displacement behaviour in order to predict load displacement behaviour of the complete socket.

5.3.3 Site classification

A site sub-soil classification for seismic design has been carried out in accordance with the requirements of AS1170.4 – Structural Design Actions, Clause 4: Earthquake Actions in Australia. The classification is based on the subsurface conditions encountered during the geotechnical investigation, supported by in-situ SPT – N values and laboratory testing results.

The geotechnical model indicates that the site is underlain by layer of fill and alluvial soils overlying extremely weathered material at depths of approximately 8.50 to 8.95 m bgl. The SPT – N values indicate consistency and density of encountered soil layer as firm and very loose or better.

The depths of soil layers encountered in boreholes do not exceed those listed in Table 4.1 of AS1170.4.

Based on the above factual information, the assessed site sub-soil classification at Caves Beach is Class Ce or Shallow Soil Site (Ce). Construction considerations

5.3.4 Excavation and replacement

The existing very loose to loose soil within the construction footprint could be excavated (as required) and replaced with engineered fill (i.e. placed and compacted to an engineering specification) or compacted in-situ to ensure adequate performance. This option has the advantage that a uniform, compacted material could be constructed enabling shallow building footings to be easily constructed. Intrusive investigations on site encountered relatively shallow fill to depths from ground surface to 1.50 m bgl. Alluvial soil encountered in the boreholes ranged in density and cohesiveness from very loose to very dense and firm to very stiff. The depth of alluvial soil varied across investigation locations and the bottom depth of the unit could not be determined in CB-BH01, CB-BH01A and CB-BH03A. Extremely weathered material was noted in CB-BH02 and CB-BH03 from 8.50 to 8.95 m bgl.

This foundation option assumes that this excavation can be accommodated on the proposed site and would not adversely impact on or is restricted by any underground service or adjacent building footings. It further assumes that appropriate measures will be undertaken to keep the groundwater level below the base of excavation (if encountered).

If excavation of material for construction of foundation is extended below the groundwater table or dewatering of groundwater is required, an ASS Management Plan will be required to manage the spoil.

The fill materials identified by the geotechnical investigations would be readily excavated by conventional earthmoving equipment, such as a backhoe and excavator.

Temporary works batter stability is to be undertaken during excavation and to allow for adequate compaction of granular fill using conventional compaction plant against the side slopes of the excavation.

5.3.5 Material suitability

If required, fill to support structures and pavements should be placed under an earthworks specification, adopting the highest level of requirements of AS3798 – Guidelines on Earthworks for Commercial and Residential Developments. In summary, we provide the following general information for engineered fill:

- Material selected for use as engineered fill must be uncontaminated and compactable, and free of deleterious material such as organics, waste and building rubble. Non-reactive material such as low clay content ripped sandstone should be used.
- The subgrade for any fill should be inspected and approved by a geotechnical engineer prior to placement (i.e. subject to proof rolling). Any soft or heaving areas should be locally over-excavated and replaced with suitable engineered fill, placed and compacted in layers in accordance with a specification prepared by a geotechnical engineer adopting the requirements of AS3798 specifications as applicable.
- Fill supporting minor loads as defined by AS 3798 (i.e. floor loads to 20 kPa and isolated strip and strip footings to 100kPa) should be placed to a minimum of 98% Standard Dry Density Ratio, at a moisture content -3% to +1% of Standard Optimum Moisture Content.

The frequency of in-situ density testing and inspection should be in accordance with the requirements of AS 3798, Guidelines on Earthworks for Commercial and Residential Developments for concentrated operations (refer to Table 8.1 of AS 3798).

5.4 Durability

Soil samples were collected during the investigation for the purpose of assessing the aggressiveness to buried concrete structures. Testing for aggressivity included pH, chloride, conductivity and sulfates. The laboratory test report is enclosed in Appendix D.

The assessment and exposure classification has been carried out in accordance with Australian Standards:

- AS3600:2018 Concrete Structures
- AS2159:2009 Piling – Design and Installation

A summary of the aggressivity test results on soil samples is presented in Table 9.

Soil condition A (high permeability soil) has been assumed in the assessment given the variability in soils and uncertainty with groundwater. The laboratory test results indicate that the soil samples tested are 'Mild' to concrete in accordance with Table 6.4.2(c) AS2159-2009.

Resistivity laboratory results indicate the soils are 'Mild' to steel in accordance with Table 6.5.2(c) AS2159-2009.

Based on Table 4.8.1 of AS3600-2018, the assessed exposure classification of concrete is A2 for soil condition A – high permeability soil (considering the lowest pH value of 6.7 in borehole CB-BH02).

6. References

- Standards Australia. (2007). *AS3798-2007 Guidelines on Earthworks for Commercial and Residential Developments*.
- Standards Australia. (2009). *AS2159-2009 Piling – Design and Installation*. Standards Australia.
- Standards Australia. (2011). *AS2870-2011 Residential Slabs and Footings*.
- Standards Australia. (2017). *AS1726-2017 Geotechnical Site Investigations*.
- Standards Australia. (2018). *AS3600-2018 Concrete Structures*.
- Standards Australia. (2024). *AS1170.4-2024 Structural design actions - Earthquake actions in Australia*.

Appendices

Appendix A

GHD Standard Sheets

GENERAL NOTES



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The report contains the results of a geotechnical investigation or study conducted for a specific purpose and client. The results may not be used or relied on by other parties, or used for other purposes, as they may contain neither adequate nor appropriate information. In particular, the investigation does not cover contamination issues unless specifically required to do so by the client.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the report are excluded unless they are expressly stated to apply in the report.

TEST HOLE LOGGING

The information on the test hole logs (boreholes, test pits, exposures etc.) is based on a visual and tactile assessment, except at the discrete locations where test information is available (field and/or laboratory results). The test hole logs include both factual data and inferred information. Moreover, the location of test holes should be considered approximate, unless noted otherwise (refer report). Reference should also be made to the relevant standard sheets for the explanation of logging procedures (Soil and Rock Descriptions, Core Log Sheet Notes etc.).

GROUNDWATER

Unless otherwise indicated, the water depths presented on the test hole logs are the depths of free water or seepage in the test hole recorded at the given time of measuring. The actual groundwater depth may differ from this recorded depth depending on material permeabilities (i.e. depending on response time of the measuring instrument). Further, variations of this depth could occur with time due to such effects as seasonal, environmental and tidal fluctuations or construction activities such as a change in ground surface level. Confirmation of groundwater levels, phreatic surfaces or piezometric pressures can only be made by appropriate surveys, instrumentation techniques and monitoring programmes.

INTERPRETATION OF RESULTS

The discussion or recommendations contained within this report normally are based on a site evaluation from discrete test hole data, often with only approximate locations (e.g. GPS). Generalised, idealised or inferred subsurface conditions (including any geotechnical cross-sections) have been assumed or prepared by interpolation and/or extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in ground conditions do occur in the natural environment, particularly between discrete test hole locations or available observation sites. Additionally, certain design or construction procedures may have been assumed in assessing the soil-structure interaction behaviour of the site. Furthermore, conditions may change at the site from those encountered at the time of the geotechnical investigation through construction activities and constantly changing natural processes.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed or reported should be referred to GHD for appropriate assessment and comment.

GEOTECHNICAL VERIFICATION

Verification of the geotechnical assumptions and/or model is an integral part of the design process - investigation, construction verification, and performance monitoring. Variability is a feature of the natural environment and, in many instances, verification of soil or rock quality, or foundation levels, is required. There may be a requirement to extend foundation depths, to modify a foundation system and/or to conduct monitoring as a result of this natural variability. Allowance for verification by appropriate geotechnical personnel must be recognised and programmed for construction.

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FOUNDATIONS

Where referred to in the report, the soil or rock quality, or the recommended depth of any foundation (piles, caissons, footings etc.) is an engineering estimate. The estimate is influenced, and perhaps limited, by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The material quality and/or foundation depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications should provide for variations in the final depth, depending upon the ground conditions at each point of support, and allow for geotechnical verification.

REPRODUCTION OF REPORTS

Where it is desired to reproduce the information contained in our geotechnical report, or other technical information, for the inclusion in contract documents or engineering specification of the subject development, such reproductions must include at least all of the relevant test hole and test data, together with the appropriate Standard Description sheets and remarks made in the written report of a factual or descriptive nature.

Reports are the subject of copyright and shall not be reproduced either totally or in part without the prior written consent of GHD. GHD expressly disclaims responsibility to any person other than the client arising from or in connection with this report.

CORE LOG SHEET NOTES



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The intention of Core Log Sheets is to present factual information measured from the core or as recorded in the field. Some interpretative information is inevitable in the location of core loss, description of weathering and identification of drilling induced fractures. This should be noted in the use of Core Log Sheets and remembered in their utilisation.

DRILLING AND CASING

The types of drilling used to advance the drill hole are recorded for relevant intervals. The types of drilling may include: NMLC coring, NQTT (NQ triple tube wire line), HW, HX, NW and NX casing, wash boring (tri-cone roller bit, TC drag bit, TC blade bit), or auger drilling (V-bit, TC drag bit).

The relevant progress is shown by abbreviated dates in the column.

WATER

Water lost or water made during drilling is recorded and subsequent readings of water levels in the borehole or piezometers are recorded here with dates of observation.

DRILL DEPTH AND CORE LOSS

Drilling intervals are shown by depth increments and horizontal marker lines. Core loss is measured as a percentage of the drill run. If the location of the core loss is known or strongly suspected, it is shown in a region of the column bounded by dashed horizontal lines. If unknown, core loss is assigned to the bottom of a coring run.

SAMPLES AND FIELD TESTS

The location of samples taken for testing or the location of field tests are indicated by the appropriate symbol from the GLOSSARY OF SYMBOLS Standard Sheet (or as applicable for the project) and are shown at the relevant location or over the relevant depth interval.

DEPTH (RL)

Changes in rock types or the locations of piezometer tips, samples, test intervals or other depths are shown as appropriate in terms of depth from the hole collar or in terms of RL.

For inclined holes the depths shown on the log refer to the drilled length along the borehole. The RL, where used, is the only transformed reference to true vertical depth.

STRATA

Rock types are presented graphically using the symbols shown on the GLOSSARY OF SYMBOLS Standard Sheet or as assigned for the project.

DESCRIPTION

The rock type is described in accordance with the ROCK DESCRIPTION AND CLASSIFICATION Standard Sheet.

WEATHERING

Weathering is described, by code letters, in accordance with the ROCK DESCRIPTION AND CLASSIFICATION Standard Sheet. A weathering term or range of terms is usually assigned to various strata.

It is noted, however, that the assignment of a term of weathering is subjective and is normally used for identification and does not imply engineering behaviour (such behaviour being controlled principally by rock substances strength and defect frequency - collectively, rock mass strength). Consequently, boundaries are often not shown and weathering may even not be reported where potentially misleading.

ESTIMATED STRENGTH

The strength of the rock substance is estimated by a combination of Point Load testing and tactile appraisal in accordance with the ROCK DESCRIPTION AND CLASSIFICATION Standard Sheet. The estimated strength is presented in a histogram form. Both axial and diametric point load test results can be presented using the symbols on the GLOSSARY OF SYMBOLS Standard Sheet and the variation between axial and diametric values is indicative of anisotropy or fissility of the rock unit.

NATURAL FRACTURES

The identification of natural fractures requires an endeavour to exclude drilling induced breaks in the core and, as such, can be somewhat subjective. Natural fractures exist prior to coring the rock, whereas artificial fractures occur either during coring, during placing core in the core boxes, or during examination or transportation, or core after being boxed.

The log of Natural Fractures is presented as a combination of Fracture Spacing, Visual and Description columns. Coding is presented on the GLOSSARY OF SYMBOLS Standard Sheet.

SOIL DESCRIPTION AND CLASSIFICATION



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Soil is described in general accordance with Australian Standard AS 1726-2017 (Geotechnical Site Investigations) in terms of visual and tactile properties, with potential refinement by laboratory testing. AS 1726 defines soil as particulate materials that occur in the ground and can be disaggregated or remoulded by hand in air or water without prior soaking. Classification of the soil is undertaken following description. The terms provided herein are reproduced summaries from Clause 6.1, AS1726-2017, Geotechnical investigations, which should be referred to for further detail.

SOIL DESCRIPTION

The soil description includes a) Composition, b) Condition, c) Structure, d) Origin and e) Additional observations. 'FILL', 'TOPSOIL' or a 'MIXTURE OF SOIL AND COBBLES / BOULDERS' (with dominant fraction first) is denoted at the start of a soil description where applicable.

a. Soil Composition (soil name, colour, plasticity or particle characteristics, secondary and then minor components)

Soil Name: A soil is termed a coarse grained soil where the dry mass of sand and gravel particles exceeds 65% of the total. Soils with more than 35% fines (silt or clay particles) are termed fine grained soils. The soil name is made up of the primary soil component (in BLOCK letters), prefixed by applicable secondary component qualifiers. Minor components are applied as a qualifiers to the soil name (using the words 'with' or 'trace').

Particles are differentiated on the basis of size. 'Boulders' and 'cobbles' are outside the soil particle range, though their presence (and proportions) is noted. While individual particles may be designated as silt or clay based on grain size, fine grained soils are characterised as silt or clay based on tactile behaviour or Atterberg Limits, and not the relative composition of silt or clay sized particles.

Colour: The prominent colour is noted, followed by (spotted, mottled, streaked etc.) then secondary colours as applicable. Roughly equally proportioned colours are prefixed by (spotted, mottled, streaked etc.). Colour is described in its moist condition, though both wet and dry colours may also be provided if appropriate.

Plasticity: Fine grained soils are designated within standard ranges of plasticity based on tactile assessment or laboratory assessment of the Liquid Limit.

Particle Characteristics: The particle shape, particle distribution and particle size range within a coarse grained soil is described using standard terms. Particle composition may be described using rock or mineral names, with specific terms for carbonate soils.

Secondary and Minor Components: The primary soil is described and modified by secondary and minor components, with assessed ranges as tabulated.

Carbonate Soils: Carbonate content can be assessed by use of dilute '10%' HCl solution. Resulting clear sustained effervescence is interpreted as a Carbonate soil (approximately >50% carbonate), while weak or sporadic effervescence indicates Calcareous soil (< 50% carbonate). No effervescence is interpreted as a non-calcareous soil.

Organic and Peat Soils: Where identified, organic content is noted. Organic soil (2% to 25% organic matter) is usually identified by colour (usually dark grey/black) and odour (i.e. 'mouldy' or hydrogen sulphide odour). Peat (>25% organic matter) is identified by a spongy feel and fibrous texture. Peat soils' decomposition may be described as 'fibrous' (little / no decomposition), 'pseudo-fibrous' (moderate decomposition) or 'amorphous' (full decomposition).

Fraction	Components		Particle Size (mm)
Oversize	BOULDERS		> 200
	COBBLES		63 - 200
Coarse grained soil particles	GRAVEL	Coarse	19 – 63
		Medium	6.7 – 19
		Fine	2.36 – 6.7
	SAND	Coarse	0.6 – 2.36
		Medium	0.21 – 0.6
		Fine	0.075 – 0.21
Fine grained soil particles	SILT		0.002 – 0.075
	CLAY		< 0.002

Plasticity Terms (Fine Grained Soils)		Laboratory Liquid Limit Range
Silt	Clay	
N/A	N/A	(Non Plastic)
Low Plasticity	Low Plasticity	≤ 35%
	Medium Plasticity	> 35% and ≤ 50%
High Plasticity	High Plasticity	> 50%

Particle Distribution Terms (Coarse Grained Soils)	
Well graded	Good representation of all particle sizes
Poorly graded	One or more intermediate sizes poorly represented
Gap graded	One or more intermediate sizes absent
Uniform	Essentially of one size

Particle Shape Terms (Coarse Grained Soils)		
Rounded	Sub-angular	Flaky or Platy
Sub-rounded	Angular	Elongated

Secondary and Minor Components for Coarse Grained Soils			
Fines (%)	Modifier (as applicable)	Accessory coarse (%)	Modifier (as applicable)
≤ 5	'trace silt/clay'	≤ 15	'trace sand/gravel'
> 5, ≤ 12	'with clay/silt'	> 15, ≤ 30	'with sand/gravel'
> 12	prefix 'silty/clayey'	> 30	prefix 'gravelly/sandy'

Secondary and Minor Components for Fine Grained Soils	
% Coarse	Modifier (as applicable)
≤ 15	Add "trace sand/gravel"
> 15, ≤ 30	Add "with sand/gravel"
> 30	Prefix soil "sandy/gravelly"

SOIL DESCRIPTION AND CLASSIFICATION



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b. Soil Condition (moisture, relative density or consistency)

Moisture: Fine grained soils are described relative to plastic or liquid limits, while coarse grained soils are assessed based on appearance and feel. The observation of seepage or free water is noted on the test hole logs.

Moisture - Coarse Grained Soils			Moisture - Fine Grained Soils		
Term		Tactile Properties	Term		Tactile Properties
Dry	D	Non-cohesive, free running	Moist, dry of plastic limit	('w < PL')	Hard and friable or powdery
Moist	M	Feels cool, darkened colour, tends to stick together	Moist, near plastic limit	('w ≈ PL')	Can be moulded
			Moist, wet of plastic limit	('w > PL')	Weakened, free water forms on hands with handling
Wet	W	Feels cool, darkened colour, tends to stick together, free water forms when handling	Wet, near liquid limit	('w ≈ LL')	Highly weakened, tends to flow when tapped
			Wet, wet of liquid limit	('w > LL')	Liquid consistency, soil flows

Relative Density (Non Cohesive Soils): The Density Index is inherently difficult to assess by visual or tactile means, and is normally assessed by penetration testing (e.g. SPT, DCP, PSP or CPT) with published correlations. Assessment may be affected by moisture and *in situ* stress conditions. Density Index assessment may be refined by combination of *in situ* density testing and laboratory reference maximum and minimum density ranges.

Consistency (Cohesive Soils): May be assessed by direct measurement (shear vane, CPT etc.), or approximate tactile correlations. Cohesive soils include fine grained soils, and coarse grained soils with sufficient fine grained components to induce cohesive behaviour. A 'design shear strength' must consider the mode of testing, the *in situ* moisture content and potential for variations of moisture which may affect the shear strength.

Relative Density (Non-Cohesive Soils)			Consistency (Cohesive Soils)		
Term and (Symbol)		Density Index (%)	Term and (Symbol)		Undrained Shear Strength
Very Loose	(VL)	≤ 15	Very Soft	(VS)	Extrudes between fingers when squeezed
Loose	(L)	> 15 and ≤ 35	Soft	(S)	Can be moulded by light finger pressure
Medium Dense	(MD)	> 35 and ≤ 65	Firm	(F)	Can be moulded by strong finger pressure
Dense	(D)	> 65 and ≤ 85	Stiff	(St)	Cannot be moulded by fingers
Very Dense	(VD)	> 85	Very Stiff	(VSt)	Can be indented by thumb nail
Consistency assessment can be influenced by moisture variation			Hard	(H)	Can be indented with difficulty by thumb nail
			Friable	(Fr)	Easily crumbled or broken into small pieces by hand

c. Structure (zoning, defects, cementing)

Zoning: The *in situ* zoning is described using the terms below. 'Intermixed' may be used for an irregular arrangement.

'layer' (a continuous zone across the exposed sample)

'pocket' (an irregular inclusion of different material).

'lens' (a discontinuous layer with lenticular shape)

'interbedded' or 'interlaminated' (alternating soil types)

Defects: Described using terms below, with dimension orientation and spacing described where practical.

'parting' (an open or closed surface or crack sub parallel to layering with little / no tensile strength - open or closed)

'softened zone' (in clayey soils, usually adjacent to a defect with associated higher moisture content)

'fissure' (as per a parting, though not parallel or sub parallel to layering – may include desiccation cracks)

'tube' (tubular cavity, singly or one of a large number, often formed from root holes, animal burrows or tunnel erosion)

'sheared seam' (zone of sub parallel near planar closely spaced intersecting smooth or slickensided fissures dividing the mass into lenticular or wedge shaped blocks)

'tube cast' (an infilled tube – infill may vary from uncemented through to cemented or have rock properties)

'sheared surface' (a near planar, curved or undulating smooth, polished or slickensided surface, indicative of displacement)

'infilled seam' (sheet like soil body cutting through the soil mass, formed by infilling of open defects)

Cementation: Soils may be cemented by various substances (e.g. iron oxides and hydroxides, silica, calcium carbonate, gypsum), and the cementing agent shall be identified if practical. Cemented soils are described as:

'uncemented' (UNC)

Clean grains exhibiting soil properties

'weakly cemented' (WEK)

easily disaggregated by hand in air or water

'moderately cemented' (MOD)

effort required to disaggregate the soil by hand in air or water

Materials extending beyond 'moderately cemented' are encompassed within the rock strength range. Where consistent cementation throughout a soil mass is identified as a duricrust, it is described in accordance with duricrust rock descriptors. Where alternate descriptors of cementation development are applied for consistency with regional practices or geology, or client requirements, these are outlined separately.

SOIL DESCRIPTION AND CLASSIFICATION



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d. Origin

An interpretation is provided based on observations of landform, geology and fabric, and may further include assignment of a stratigraphic unit. The use of terms 'possibly' or 'probably' indicates a higher degree of uncertainty regarding the assessed origin or stratigraphic unit. Typical origin descriptors include:

<i>Residual soil</i>	Formed directly from in situ weathering with no visible structure or fabric of the parent soil or rock.
<i>Extremely weathered material</i>	Formed directly from in situ weathering, with remnant and/or fabric from the parent rock.
<i>Alluvial soil</i>	Deposited by streams and rivers (may be applied more generically as transported by water).
<i>Estuarine soil</i>	Deposited in coastal estuaries, including sediments from inflowing rivers, streams, and tidal currents.
<i>Marine soil</i>	Deposited in a marine environment.
<i>Lacustrine soil</i>	Deposited in freshwater lakes.
<i>Aeolian soil</i>	Transported by wind.
<i>Colluvial soil</i>	Soil and rock debris transported down slopes by gravity (with or without assistance of water). Colluvium is typically applied to thicker / localised deposits, and slopewash for thinner / widespread deposits.
TOPSOIL	Surficial soil, typically with high levels of organic material. Topsoils buried by other transported soils are termed 'remnant topsoil'. Tree roots within otherwise unaltered soil does not characterise topsoil.
FILL	Any material which has been placed by anthropogenic processes (i.e. human activity).

e. Additional Observations

Additional observations may be included to supplement the soil description. Additional observations may consist of notations relating to soil characteristics (odour, contamination, colour changes with time), inferred geology (with delineation of soil horizons or geological time scale) or notes on sampling and testing application (including the reliability, recovery, representativeness, or condition of samples or test conditions and limitations). If the material is assessed to be not representative, terms such as 'poor recovery', 'non-intact', 'recovered as' or 'probably' are applied.

SOIL CLASSIFICATION

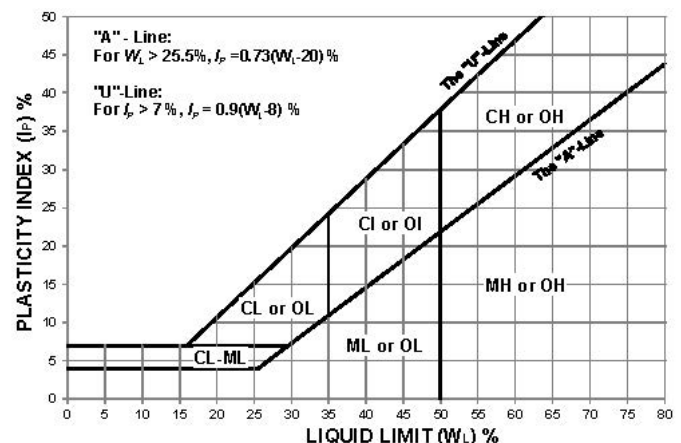
Classification allocates the material within distinct soil groups assigned a two character Group Symbol:

Coarse Grained Soils (sand and gravel: more than 65% of soil coarser than 0.075 mm)			Fine Grained Soils (silt and clay: more than 35% of soil finer than 0.075 mm)		
Major Division	Group Symbol	Soil Group	Major Division	Group Symbol	Soil Group
GRAVEL (more than half of the coarse fraction is > 2.36 mm)	GW	GRAVEL, well graded	SILT and CLAY (low to medium plasticity)	ML	SILT, low plasticity
	GP	GRAVEL, poorly graded		CL	CLAY, low plasticity
	GM	Silty GRAVEL		CI	CLAY, medium plasticity
	GC	Clayey GRAVEL		OL	Organic SILT
SAND (more than half of the coarse fraction is < 2.36 mm)	SW	SAND, well graded	SILT and CLAY (high plasticity)	MH	SILT, high plasticity
	SP	SAND, poorly graded		CH	CLAY, high plasticity
	SM	Silty SAND		OH	Organic CLAY / SILT
	SC	Clayey SAND	Highly Organic	Pt	PEAT

Coarse grained soils with fines contents between 5% and 12% are provided a dual classification comprising the two group symbols separated by a dash, e.g. for a poorly graded gravel with between 5% and 12% silt fines (poorly graded 'GRAVEL with silt'), the classification is GP-GM.

For the purpose of classification, poorly graded, uniform, or gap graded soils are all designated as poorly graded. Soils that are dominated by boulders or cobbles are described separately and are not classified.

Classification is routinely undertaken based on tactile assessment with the soil description. Refinement of soil classification may be applied using laboratory assessment, including particle size distribution and Atterberg Limits. Atterberg Limits testing is applied to the sample portion finer than 0.425 mm. Fine grained soil components are assessed on the basis of regions defined within the Modified Casagrande Chart.



ROCK DESCRIPTION AND CLASSIFICATION



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Rock is described in general accordance with Australian Standard AS 1726-2017 (Geotechnical site investigations) in terms of visual and tactile properties, with potential refinement by laboratory testing. AS 1726 defines rock as any aggregate of minerals and/or organic materials that cannot be disaggregated by hand in air or water without prior soaking. The rock description and classification distinguishes between rock material, defects, structure and rock mass.

ROCK DESCRIPTION AND CLASSIFICATION

a. Description of rock material (rock name, grain size and type, colour, texture and fabric, inclusions or minor components, moisture content and durability)

Rock Name: Simple rock names are used to provide a reasonable engineering description rather than a precise geological classification. The rock name is chosen on the basis of origin, with common types summarised below. Additional, non-exhaustive, terminology is included in AS 1726. Rock names not described within AS 1726 may be adopted, with geological characteristics typically noted within accompanying text.

Grain Size (mm)	Sedimentary				Metamorphic		Igneous		
	Clastic or Detrital	Carbonate		Pyroclastic	Foliated	Non-Foliated	Felsic	↔	Mafic
		Low Porosity	Porous						
>2.0	CONGLOMERATE (rounded grains in a finer matrix) BRECCIA (angular or irregular fragments in a finer matrix)	LIMESTONE (predominantly CaCO ₃)	CALCIRUDITE	AGGLOMERATE (rounded grains in a finer matrix) VOLCANIC BRECCIA (angular fragments in a finer matrix)	GNEISS	MARBLE (carbonate) QUARTZITE	GRANITE	DIORITE	GABBRO
2.0 – 0.06	SANDSTONE	Or	CALCARENITE	TUFF	SCHIST	SERPENTINITE	MICRO-GRANITE	MICRO-GRANITE	DOLERITE
0.06 – 0.002	MUDSTONE (silt and clay)	DOLOMITE (predominantly CaMgCO ₃)	CALCISILTITE	Fine grained TUFF	PHYLLITE or SLATE	HORNFELS	RHYOLITE	ANDESITE	BASALT
<0.002	CLAYSTONE (mostly clay)		CALCILUTITE						

Reproduced with modification from Tables 15, 16 and 17, Clause 6.2.3.1, AS 1726-2017, Geotechnical site investigations.

Grain size: For rocks with predominantly sand sized grains the dominant or average grain size is described as follows:

Rock type	Coarse grained	Medium grained	Fine grained
Sedimentary rocks	Mainly 0.6 mm to 2 mm	Mainly 0.2 mm to 0.6 mm	Mainly 0.06 mm (just visible) to 0.2 mm
Igneous and metamorphic rocks	Mainly >2 mm	Mainly 0.06 mm to 2 mm	Mainly <0.6 mm (just visible)

Colour assists in rock identification and interpolation. Rock colour is generally described in a “moist” condition, using simple terms (e.g. grey, brown, etc.) and modified as necessary by “pale”, “dark”, or “mottled”. Borderline colours may be described as a combination of these colours (e.g. red-brown).

Texture refers to the arrangement of, or the relationship between, the component grains or crystals (e.g. porphyritic, crystalline or amorphous).

Fabric refers to visible grain arrangement along a preferential orientation or a layering. Fabric may be noted as “indistinct” (little effect on strength) or “distinct” (rock breaks more easily parallel to the fabric). Common terms include “massive” or “flow banding” (igneous), “foliation” or “cleavage” (metamorphic). Sedimentary layering is described as “bedding” or (where thickness < 20 mm) “lamination”. The typical orientation, spacing or thickness of these structural features can be described directly in millimetres and metres. Further quantification of bedding thickness applied by GHD is as follows:

Bedding Term	Thickness
Very thickly bedded	>2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 to 200 mm
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	<6 mm

Features, Inclusions and Minor Components are typically only described when those features could influence the engineering behaviour of the rock. Described features may include: gas bubbles in igneous rocks; veins of quartz, calcite or other minerals; pyrite crystals and nodules or bands of ironstone or carbonate; cross bedding in sandstone; clast or matrix support in conglomerates and breccia.

Moisture content may be described by the feel and appearance of the rock, as follows: “dry” (looks and feels dry), “moist” (feels cool, darkened in colour, but no water is visible on the surface), or “wet” (feels cool, darkened in colour, water film or droplets visible on the surface). The moisture content of rock cored with water may not represent in situ conditions.

Durability of rock samples is noted where there is an observed tendency of samples to crack, breakdown in water or otherwise deteriorate with exposure.

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b. Classification of the rock material condition (strength, weathering and/or alteration)

Estimated Strength refers to the rock material and not the rock mass. The strength is defined in terms of uniaxial compressive strength (UCS), though is typically estimated by either tactile assessment or Point Load Strength Index (Is(50)) (measured perpendicular to planar anisotropy). A correlation between Is(50) and UCS is adopted for classification, though is not intended for design purposes without appropriate supporting assessment. A field guide follows:

Term and (Symbol)		UCS (MPa)	Is(50) (MPa)	Field Guide
Very Low	(VL)	0.6 – 2	0.03 - 0.1	Material crumbles under firm blows with sharp end of geological pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm thick can be broken by finger pressure.
Low	(L)	2 - 6	0.1 - 0.3	Easily scored with knife; indentations 1 to 3 mm show in the specimen with firm blows of a geological pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	(M)	6 - 20	0.3 - 1.0	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
High	(H)	20 - 60	1 - 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken by a geological pick with a single firm blow; rock rings under hammer.
Very High	(VH)	60 - 200	3 -10	Hand specimen breaks with geological pick after more than one blow; rock rings under hammer.
Extremely High	(EH)	>200	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Based on Table 19, Clause 6.2.4.1, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Material with strength less than “very low” is described using soil characteristics, with the presence of an original rock texture or fabric noted if relevant.

Weathering and Alteration: The process of weathering involves physical and chemical changes to the rock resulting from exposure near the earth’s surface. A subjective scale for weathering is applied as follows:

Term and (Symbol)		Description
Residual Soil	(RS)	Material has weathered to such an extent that it has soil properties. Mass structure and material texture and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely Weathered	(XW)	Material has weathered to such an extent that it has soil properties. Mass structure, material texture and fabric of original rock are still visible.
Highly Weathered	(HW)	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately Weathered	(MW)	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the original rock is not recognisable, but shows little or no change of strength from fresh rock.
Slightly Weathered	(SW)	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	(Fr)	Rock shows no sign of decomposition of individual minerals or colour changes.

Modified based on Table 20, Clause 6.2.4.2, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Where physical and chemical changes to the rock are caused by hot gases or liquids at depth, the process is called alteration. Unlike weathering, the distribution of altered material may occur at any depth and show no relationship to topography. Where alteration minerals are identified the terms “extremely altered” (XA), “highly altered” (HA), “moderately altered” (MA) and “slightly altered” (SA) can be used to describe the physical and chemical changes described above.

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c. Description of defects (defect type, orientation, roughness and shape, coatings and composition of seams, spacing, length, openness and thickness, block shape)

Defects often control the overall engineering behaviour of a rock mass. AS 1726 defines a defect as “a discontinuity, fracture, break or void in the material or materials across which there is little or no tensile strength”. Describing the type, character and distribution of natural defects is an essential part of the description of many rock masses.

Commonly described characteristics of defects within a rock mass include type, orientation, roughness and shape, coatings and composition of seams, aperture, persistence, spacing and block shape.

The degree of detail required for defect descriptions depends on project requirements. All defects judged of engineering significance for the site and project are described individually. Where appropriate, generalised descriptions for less significant, or multiple similar, defects can be provided for delineated parts of rock core or exposures. A general description of delineated defect sets is provided when sufficient orientation data is available.

Defect Type is described using the terms summarised below. On core logs, only natural defects across which the core is discontinuous are described (i.e. inferred artificial fractures such as drill breaks are excluded). Incipient defects are described using the relevant texture or fabric terms. Healed defects (those that have been re-cemented by minerals such as chlorite or calcite) are described using the prefix “healed” (e.g. healed joint).

Type and (Symbol)		Description	Diagram
Parting	(P)	A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering (e.g. bedding) or a planar anisotropy in the rock material (e.g. cleavage). May be open or closed.	
Joint	(J)	A surface or crack with no apparent shear displacement and across which the rock has little or no tensile strength, but which is not parallel or subparallel to layering or to planar anisotropy in the rock material. May be open or closed.	
Sheared Surface	(S)	A near planar, curved or undulating surface which is usually smooth, polished or slickensided and which shows evidence of shear displacement.	
Sheared Zone	(SZ)	Zone of rock material with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
Sheared Seam	(SS)	Seam of soil material with roughly parallel almost planar boundaries, composed of soil materials with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
Crushed Seam	(CS)	Seam of soil material with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock material which may be more weathered than the host rock. The seam has soil properties.	
Infilled Seam	(IS)	Seam of soil material usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1 mm thick may be described as a veneer or coating on a joint surface.	
Extremely Weathered Seam	(EW)	Seam of soil material, often with gradational boundaries. Formed by weathering of the rock material in place.	

Modified based on Table 22, Clause 6.2.5.2, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

Defect Orientation is recorded as the “dip” (maximum angle of the mean plane, measured from horizontal) and the “dip direction” (azimuth of the dip, measured clockwise from true north). Dip and dip direction is expressed in degrees, with two-digit and three-digit numbers respectively, separated by a slash (e.g. 45/090). For vertical boreholes, the defect dip is measured as the acute angle from horizontal. Rock core extracted from vertical boreholes is generally not oriented, so the dip direction cannot be directly measured. For non-oriented inclined boreholes, a defect “alpha” (α) angle is measured as the acute angle from the core axis. For vertical and non-oriented inclined boreholes, the dip direction can sometimes be estimated from the relationship of the defect to a well-defined site structure such as fabric. For oriented inclined boreholes, the measurement of the defect orientation is carried out and recorded in a form suited to the particular device being used and later processed to report true dip and dip direction.

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Roughness and Shape of the defect surface combine to have significant influence on shear strength. Standard descriptions and abbreviations include:

Roughness and (Symbol)		Description
Very Rough	(VR)	Many large surface irregularities (amplitude generally more than 1 mm). Feels like, or coarser than very coarse sand paper.
Rough	(RF)	Many small surface irregularities (amplitude generally less than 1 mm). Feels like fine to coarse sand paper.
Smooth	(SM)	Smooth to touch. Few or no surface irregularities.
Polished	(PO)	Shiny smooth surface.
Slickensided	(SL)	Grooved or striated surface, usually polished.

Shape and (Symbol)		Description
Planar	(PR)	The defect does not vary in orientation.
Curved	(CU)	The defect has a gradual change in orientation.
Undulating	(UN)	The defect has a wavy surface.
Stepped	(ST)	The defect has one or more well defined steps.
Irregular	(IR)	The defect has many sharp changes of orientation.

Although the surface roughness of defects can be described at small (10-100 mm) scales of observation, the overall shape of the defect surface can usually be observed only at medium (0.1-1 m) and large (>1 m) scale.

Where it is necessary to assess the shear strength of a defect, observations are generally made at multiple scales. Surface roughness may also be characterised by using the joint roughness coefficient (JRC) profiles established by Barton and Choubey (1977). Where large-scale observations are possible, further measurement of defect "waviness" (angle of the asperities relative to the overall dip angle of the plane) is made.

Coatings and Composition of Seams: Many defects have surface coatings, which can affect their shear strength. Standard descriptions include:

Coating and (Symbol)		Description
Clean	(CN)	No visible coating.
Stained	(SN)	No visible coating but surfaces are discoloured.
Veneer	(VN)	A visible coating of soil or mineral substance, but too thin to be measured may be patchy.
Coating	(CT)	A visible coating up to 1 mm thick. Soil material greater than 1 mm thick is described using defect terms (e.g. infilled seam). Rock material greater than 1 mm thick is described as a vein (Vn).

Common Minerals and (Symbol)	
Clay	(CLAY)
Calcite	(Ca)
Carbonaceous	(X)
Chlorite	(Kt)
Iron Oxide	(Fe)
Micaceous	(Mi)
Manganese	(Mn)
Pyrite	(Py)
Quartz	(Qz)

The composition of seams are described using soil description terms as given on the SOIL DESCRIPTION AND CLASSIFICATION Standard Sheet. Where possible the mineralogy of coatings is identified. Common mineral coatings include:

Aperture: Defects across which there is little or no tensile strength can be either "open" (Op) or "closed" (Cl). For rock core, the width of the "open" defect is measured whilst still in the core barrel splits. The descriptor "tight" (Ti) can only apply to healed or incipient defects (i.e. veins, foliation, etc.).

Persistence and Spacing of defects is described directly in millimetres and metres. If the measurement of defect persistence is limited by the extent of the exposure, the end conditions are noted (i.e. 0, 1 or 2 defect ends observed). The spacing between defects of similar orientation (i.e. within a specific defect set) is recorded when possible. The frequency of defects within rock core can be measured as either: the spacing between successive defects; or the "Fracture Index", which is the number of defects per metre of core.

Spacing Term	Thickness
Very wide	>2 m
Wide	0.6 to 2 m
Medium	0.2 to 0.6 m
Closely	60 to 200 mm
Very closely	20 to 60 mm
Extremely closely	6 to 20 mm

Block Shape: Where it is considered significant, block shape can be described using the subjective terms as follows:

Block Shape	Description
Polyhedral	Irregular discontinuities without arrangement into distinct sets, and of small persistence.
Tabular	One dominant set of parallel discontinuities, for example bedding planes, with other non-continuous joints; thickness of blocks much less than length or width.
Prismatic	Two dominant sets of discontinuities, approximately orthogonal and parallel, with a third irregular set; thickness of blocks much less than length or width.
Equidimensional	Three dominant sets of discontinuities, approximately orthogonal, with occasional irregular joints, giving equidimensional blocks.
Rhomboidal	Three (or more) dominant, mutually oblique, sets of joints giving oblique-shaped, equidimensional blocks.
Columnar	Several, usually more than three sets of continuous, parallel joints usually crossed by irregular joints; lengths much greater than other dimensions.

Modified based on Table 23, Clause 6.2.5.7, AS 1726-2017, Geotechnical site investigations. Refer to source document for further detail.

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d. Interpreted stratigraphic unit

Stratigraphic units may be interpreted and reported, in accordance with The Australian Stratigraphic Units Database (ASUD). The terms “possibly” or “probably” indicate increased uncertainty in this interpretation.

e. Geological structure

After describing the rock material and defects, an interpretation of the nature and configuration of rock mass defects may be presented in logs, charts, 2D sections and 3D models (e.g. dipping strata, folds, unconformities, weathering profiles, defect sets, geological faults, etc.).

PARAMETERS RELATED TO CORE DRILLING

Drill Depth and Core Loss: Drilling intervals are shown on GHD Core Log Sheets by depth increments and horizontal marker lines.

“Core loss”, or its inverse “total core recovery” (TCR), is measured as a percentage of the core run. If the location of the core loss is known, or strongly suspected, it is shown in a region of the column bounded by dashed horizontal lines. If unknown, core loss is assigned to the bottom of a core run.

Rock Quality Designation (RQD), described by Deere et al. (1989), may be recorded on GHD Core Log Sheets.

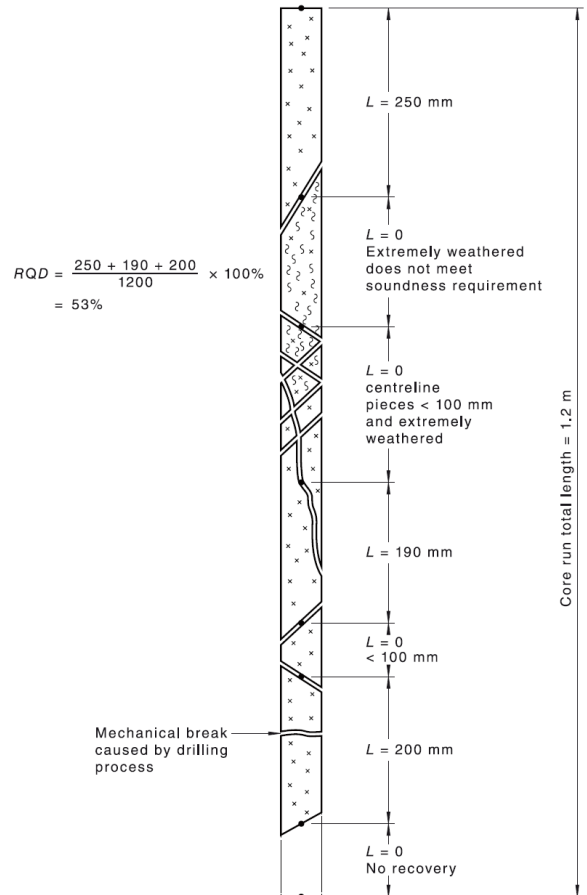
For certain projects, such as tunnelling or underground mining investigations, rock mass ratings or classifications can be required as part of the design process. The RQD forms a component of these rock mass ratings and provides a quantitative estimate of rock mass quality from rock core logs.

The rock core must be “N” sized (nominally 50 mm) or greater for derivation of RQD. The RQD is expressed as a percentage of intact rock core (excluding residual soil and extremely weathered rock) greater than 100 mm in length over the total selected core length.

Deere et al. (1989) recommends measuring lengths of core along the centreline, as shown right.

RQD is expressed as:

$$RQD = \frac{\sum \text{Length of sound core pieces} > 100 \text{ mm in length}}{\text{Length of core run}} \times 100\%$$



RQD measurement procedure
(reproduced from Figure 13, Clause 6.2.9.4, AS 1726- 2017, Geotechnical site investigations)

ROCK MASS CLASSIFICATION

Rock mass classification schemes may be used to represent the engineering characteristics of a rock mass. A large variety of classification schemes have been developed by various authors, ranging from simple to complex. All of the schemes are limited in their application and many rock mass classification systems assume that the rock mass is isotropic, which is rarely the case.

References

- Standards Australia (2017). AS 1726-2017. Geotechnical Site Investigations.
- Barton, N. and Choubey, V. (1977). The Shear Strength of Rock Joints in Theory and Practice. Rock Mechanics 10, 1-54.
- Springer. Deere, D.U. and Deere, D.W. (1989). Rock Quality Designation (RQD) After Twenty Years. Contract Report GL-89-1. Army Corps of Engineers. Washington DC, 1989.

GLOSSARY OF SYMBOLS



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This standard sheet should be read in conjunction with all test hole log sheets and any idealised geological sections prepared for the investigation report.

Sampling and Testing							
Symbol		Description		Symbol		Description	
D		Small Disturbed Grab Sample		C		Core Sample (suffixed by diameter in mm)	
B		Bulk Disturbed Sample		P		Piston Sample	
LB		Large Bulk Disturbed Sample		ES		Soil sample for environmental testing	
U(50)		Undisturbed Push In Sample (suffixed by sample size or tube diameter in mm if applicable)		EW		Water Sample for environmental testing	
SPT		Standard Penetration Test (with blows per 0.15 m)		CONCC		Concrete Core	
N = #		SPT Value				Water Inflow (make)	
N = Ref		SPT Refusal				Water Outflow (loss)	
HB		SPT Hammer Bouncing				Temporary Water Level	
RW/HW		SPT Rod Weight / Hammer Weight				Final Water Level	
PP		Pocket/Hand Penetrometer (suffixed by value kPa)				Point Load Test (axial)	
SV		Shear Vane Test (suffixed by value in kPa)				Point Load Test (diametric)	
Drilling Method							
AD/T		Auger Drilling with TC Bit		HSA		Hollow Stem Auger	
AD/V		Auger Drilling with V Bit		NMLC		NMLC Barrel	
AUGS		Solid Stem Auger		NQ3		NQ Wireline Barrel	
DT		Diatube		PQ3		PQ Wireline Barrel	
E		Excavator		RR		Rock Roller	
HA		Hand Auger		VC		Vibrocore	
HMLC		HMLC Barrel		VE		Vacuum Excavation	
HQ3		HQ Wireline Barrel		WB		Washbore	
Discontinuities (Coding)							
Defect Type		Orientation					
J	Joint	For vertical non-oriented core ... “Dip” angle (e.g. 5°) measured relative to horizontal.					
P	Parting	For inclined non-oriented core ... “Angle” measured relative to core axis.					
S	Sheared Surface	For inclined oriented core ... “Dip” angle and “Dip Direction” angle (e.g. 45°/225° mag.).					
SS	Sheared Seam	Orientation (con’t)		Roughness		Shape	
CS	Crushed Seam	VT	Vertical	PO	Polished	PR	Planar
SZ	Sheared Zone	HZ or 0°	Horizontal	SM	Smooth	CU	Curved
IS	Infilled Seam	d / °	Degrees	RF	Rough	UN	Undulating
EW	Weathered Seam			VR	Very Rough	ST	Stepped
				SL	Slickensided	IR	Irregular
Other Discontinuity Types Suffix							
BP	Bedding Plane	CB	Cross Bedding	CL	Cleavage		
FB	Flow Banding	FL	Foliation	LT	Lamination		
Others		Coating		Infilling / Common Materials			
DB	Drilling Break	CN	Clean	CLAY	Clay	Mi	Micaceous
DL	Drill Lift	SN	Stained	Ca	Calcite	Mn	Manganese
HB	Handling Break	VN	Veneer	X	Carbonaceous	Py	Pyrite
MB	Mechanical Break	CT	Coating	Kt	Chlorite	Qz	Quartz
OP	Open			Fe	Iron Oxide		
CL	Closed						

Ref: DS6.5.3 Rev 5 Date: 03/02/2025

GLOSSARY OF SYMBOLS



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SOIL SYMBOLS

Main Components				Minor Components			
	SILT		TOPSOIL		Silty CLAY		Sandy SILT
	CLAY		FILL		Sandy CLAY		Gravelly SILT
	SAND		COBBLES		Gravelly CLAY		Silty SAND
	GRAVEL		BOULDERS		Clayey GRAVEL		Gravelly SAND
<i>Note: Additional soil symbols may be allocated for a particular project upon request.</i>					Silty GRAVEL		Sandy GRAVEL

ROCK SYMBOLS

Sedimentary							
	MUDSTONE		SILTSTONE		SANDSTONE		LIMESTONE
	BRECCIA		CONGLOMERATE		AGGLOMERATE		FERRICRETE
Igneous							
	ANDESITE		BASALT		DACITE		DIORITE
	GRANITE		IGNIMBRITE		RHYOLITE		
Metamorphic							
	GNEISS		GREYWACKE		METASEDIMENT		PHYLLITE
	QUARTZITE		SCHIST		SLATE		
<i>Note: Additional rock symbols may be allocated for a particular project upon request.</i>							

GENERAL

Samples extracted during the fieldwork stage of a site investigation may be “disturbed” or “undisturbed” (as generally indicated on the test hole logs) depending upon the nature and purpose of the sample as well as the method of extraction, transportation, extrusion and testing. This aspect should be taken into account when assessing test results, which must of necessity, reflect the effects of such disturbance.

All soil properties (as measured by laboratory testing) exhibit inherent variability and thus a certain statistical number of tests is required in order to predict an average property with any degree of confidence. The site variability of soil strata, future changes in moisture and other conditions and the discrete sampling positions must also be considered when assessing the representative nature of the laboratory programme.

Certain laboratory test results provide interpreted soil properties as derived by conventional mathematical procedures. The applicability of such properties to engineering design must be assessed with due regard to the site, sample condition, procedure and project in hand.

TESTING

Laboratory testing is normally carried out in accordance with Australian Standard AS 1289 as amended, or in NSW, Roads and Maritime Services (RMS) standards when specified. The routine Australian Standard tests are as follows:

Moisture Content	AS1289 2.1.1	Collectively known as Atterberg Limits
Liquid Limit	AS1289 3.1.1	
Plastic Limit	AS1289 3.2.1	
Plasticity Index	AS1289 3.3.1	
Linear Shrinkage	AS1289 3.4.1	Collectively, Dispersive Classification
Particle Density	AS1289 3.5.1	
Particle Size Distribution	AS1289 3.6.1, 3.6.2 and 3.6.3	
Emerson Class Number	AS1289 3.8.1	
Percent Dispersion	AS1289 3.8.2	Collectively, Dispersive Classification
Pinhole Dispersion Classification	AS1289 3.8.3	
Hole Erosion (HE)	GHD Method	
No Erosion Filter (NEF)	GHD Method	
Organic Matter	AS1289 4.1.1	Collectively, Dispersive Classification
Sulphate Content	AS1289 4.2.1	
pH Value	AS1289 4.3.1	
Resistivity	AS1289 4.4.1	
Standard Compaction	AS1289 5.1.1	Collectively, Dispersive Classification
Modified Compaction	AS1289 5.2.1	
Dry Density Ratio	AS1289 5.4.1	
Minimum Density	AS1289 5.5.1	
Density Index	AS1289 5.6.1	Collectively, Dispersive Classification
California Bearing Ratio	AS1289 6.1.1 and 6.1.2	
Shear Box	AS1289 6.2.2	
Undrained Triaxial Shear	AS1289 6.4.1 and 6.4.2	
One Dimensional Consolidation	AS1289 6.6.1	Collectively, Dispersive Classification
Permeability Testing	AS1289 6.7.1, 6.7.2 and 6.7.3	

Where tests are used which are not covered by appropriate standard procedures, details are given in the report.

LABORATORY TESTING



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LABORATORIES

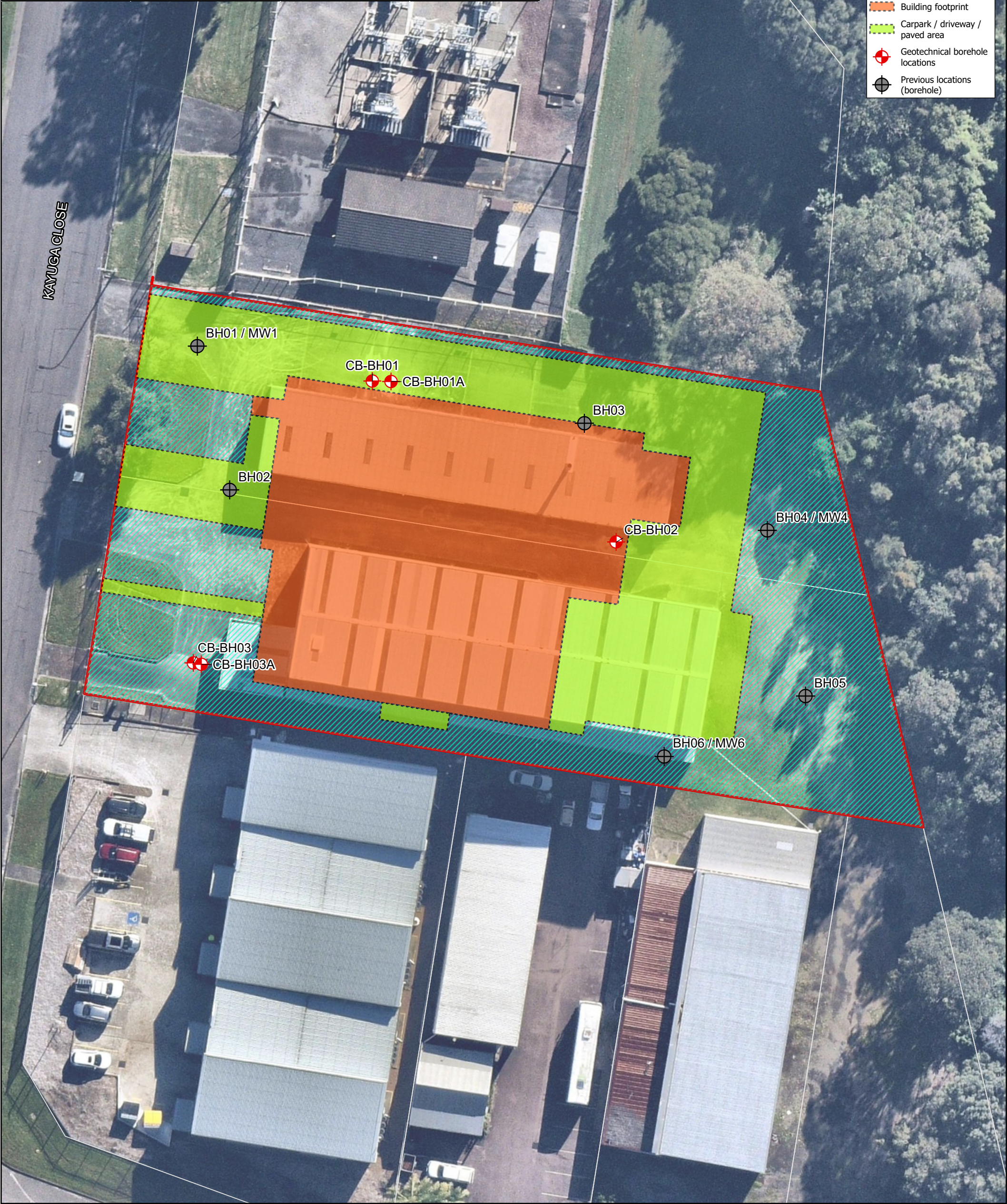
Our Australian laboratories are NATA accredited to AS ISO / IEC17025 for the listed tests.

The oedometer, triaxial and shear box equipment are fully automated for continuous operation using computer controlled data acquisition, processing and plotting systems.

Appendix B

Geotechnical Test Location Plan

Test ID	Reduced Level, RL (m)	Easting	Northing
CB-BH01	2.6	372911.8052	6337061.8989
CB-BH01A	2.6	372913.8867	6337061.8636
CB-BH03	2.8	372891.9001	6337030.6085
CB-BH02	2.8	372938.9143	6337044.0042
CB-BH03A	2.9	372892.7946	6337030.4098



Appendix C

Geotechnical Logs

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
	CC				0.17 (2.43)		-	CONCRETE: .		-	
				ES: 0.50-0.95m PID = 0 ppm			-	[FILL] SAND: medium to coarse grained, pale grey (FILL).	W	-	
1				B: 1.00-1.45m D: 1.00-1.45m ES: 1.00-1.45m PID = 0.1 ppm	1.00 (1.60)		CL	CLAY: low plasticity, dark brown; with sand, fine to coarse grained; trace gravel (ALLUVIAL SOIL).	w = LL	St	
				D: 1.50-1.95m ES: 1.50-1.70m SPT: 1.50-1.95 m Q/1/1 N=2 PID = 0.1 ppm	1.50 (1.10)		SC	Clayey Silty SAND: fine to coarse grained, black, dark brown; Clay, low plasticity; trace gravel (ALLUVIAL SOIL).		VL	
2					2.00 (0.60)			SAND: fine to coarse grained, pale grey, dark grey (ALLUVIAL SOIL).			1.40 m, groundwater was measured at 1.40m bgl in nearby existing well at BH01 1.50 m, organic odour 1.50 m, SPT recovery 450mm
	AD/T	Nli Casing	Groundwater Not Observed	ES: 3.00-3.20m PID = 0.1 ppm					W	L	
3											
							SP				
4											
										VL	
5											

Client Name: NSW Government Health Infrastructure

Project Name: NSW Ambulance Infrastructure Program – Geotechnical and Contamination Consultant Services

Location: 2-4 Kayuga Close, Caves Beach NSW 2281

Position: 372911.8 E 6337061.9 N GDA2020 / MGA zone 56

Rig Type: Comacchio GEO 306

Date Started: 19/5/2025

Surface RL: 2.60 m AHD

Mounting: Track

Date Completed: 19/5/2025

Contractor: Stratacore

Logged by: UT

Angle from Horizontal/Azimuth: 90°/-

Driller: BM

Checked By: AM

Date: 8/7/2025

BOREHOLE LOG SHEET

HOLE No. CB-BH01

SHEET 2 OF 2

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
								[FILL / TOPSOIL / COBBLES / BOULDERS / -] SOIL NAME: primary component plasticity / particle / behavioural characteristics, colour, secondary component, minor component, structure (ORIGIN) OR ROCK NAME: grain size and type, colour, fabric, texture, inclusions or minor components, strength, weathering, alteration, defects (INTERPRETED STRATIGRAPHIC UNIT / GEOLOGICAL STRUCTURE)			
				D: 5.00-5.20m				SAND: fine to coarse grained, pale grey, dark grey (ALLUVIAL SOIL). 5.00m with shell fragments, trace rootlets.			5.00 m, organic odour
6	AD/T	Nil Casing	Groundwater Not Observed				SP		W	VL	
7										L	
										MD	
8					8.00 (-5.40)			CB-BH01 terminated at 8.00m. Target depth Backfilled at completion			
9											
10											

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
	CC						-	CONCRETE: .			
					0.20 (2.40)		-	[FILL] Clayey SAND: fine to coarse grained, brown; Clay, low plasticity; with gravel, sub-rounded to angular (FILL).	W		
				D: 0.50-0.95m SPT: 0.50-0.95 m 8/9/7 N=16	0.50 (2.10)		-	[FILL] Sandy CLAY: low plasticity, brown-pale brown and grey; Sand, fine to coarse grained; with gravel (FILL).	w = LL	-	0.50 m, SPT recovery 450mm
1				D: 1.00-1.45m ES: 1.00m SPT: 1.00-1.45 m 5/5/5 N=10	1.00 (1.60)		-	[FILL] Clayey SAND: fine to coarse grained, brown and grey; Clay, low plasticity (FILL).	W		1.00 m, SPT recovery 450mm
				D: 1.50-1.95m ES: 1.50m SPT: 1.50-1.95 m 4/5/3 N=8 ES: 1.50m	1.50 (1.10)		SP	1.45m becoming pale grey Clayey Silty SAND: fine to coarse grained, black; Clay, low plasticity; trace rootlets (ALLUVIAL SOIL).	W	L	1.40 m, groundwater was measured at 1.40m deep in nearby existing BH01 1.50 m, organic odour 1.50 m, SPT recovery 450mm
2				ES: 2.00m SPT: 2.00-2.45 m 2/1/4 N=5 D: 2.00-2.45m	2.00 (0.60)			SAND: fine to coarse grained, very dark grey; with clay, low plasticity; with shell fragments (ALLUVIAL SOIL).			2.00 m, SPT recovery 450mm
	AD/T	NII Casing	Groundwater Not Observed								
3				D: 3.00-3.45m SPT: 3.00-3.45 m 2/3/5 N=8 ES: 3.00m						L	3.00 m, SPT recovery 450mm
									W		
4				D: 4.00-4.50m							
				ES: 4.50m SPT: 4.50-4.95 m 2/1/2 N=3						VL	4.50 m, SPT recovery 450mm
5											

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
	CC						-	CONCRETE: .		-	
					0.20 (2.60)		-	[FILL] Gravelly Sandy CLAY: low plasticity, pale brown; Gravel, fine, angular to sub-rounded; Sand, fine to coarse grained (FILL).			
				D: 0.50-0.56m ES: 0.50-0.95m SPT: 0.50-0.80 m 17/14 for 150 mm N=ref PID = 0.3 ppm B: 0.56-1.00m D: 0.56-1.00m B: 0.80-1.00m ES: 0.90-1.00m	0.50 (2.30)		-	[FILL] CLAY: low plasticity, black mottled dark brown, pale brown; trace sand; trace gravel (FILL).	w = LL	-	0.50 m, slight organic odour 0.50 m, SPT recovery 60mm
1				D: 1.00-1.45m ES: 1.00-1.45 m SPT: 1.00-1.45 m 6/8/7 N=15 PID = 0.7 ppm	1.00 (1.80)		-	Sandy CLAY: low plasticity, pale brown and grey; Sand, fine to medium grained (ALLUVIAL SOIL).			1.00 m, slight organic odour 1.00 m, SPT recovery 450mm
	AD/T									St	1.68 m, groundwater was measured at 1.68m bgl in nearby existing well at BH04
		Nil Casing	Groundwater Not Observed	D: 2.50-2.95m ES: 2.50-2.95m U75: 2.50m SPT: 2.50-2.95 m 2/3/2 N=5 PID = 0.4 ppm			CL	2.50m becoming pale brown, dark grey	w = LL		2.50 m, SPT recovery 450mm
3										F	
4				D: 4.00-5.50m	4.00 (-1.20)			SAND: fine to coarse grained, pale grey; with shell fragments (ALLUVIAL SOIL).			
	WB						SP		W	L	
5											

BOREHOLE LOG SHEET

HOLE No. CB-BH02

SHEET 2 OF 2

Angle from Horizontal/Azimuth: 90°/-

Driller: BM

Checked By: AM

Logged by: UT

Date: 8/7/2025

[illegible]

Project Number:

12657833

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
1	CC	Nli Casing	Groundwater Not Observed		0.12 (2.68)		-	CONCRETE: .		-	0.50 m, slight organic odour 0.50 m, SPT recovery 450mm 1.00 m, SPT recovery 450mm <

Client Name: NSW Government Health Infrastructure

Project Name: NSW Ambulance Infrastructure Program – Geotechnical and Contamination Consultant Services

Location: 2-4 Kayuga Close, Caves Beach NSW 2281

Position: 372891.9 E 6337030.6 N GDA2020 / MGA zone 56

Rig Type: Comacchio GEO 306

Date Started: 19/5/2025

Surface RL: 2.80 m AHD

Mounting: Track

Date Completed: 19/5/2025

Contractor: Stratacore

Logged by: UT

Angle from Horizontal/Azimuth: 90°/-

Driller: BM

Checked By: AM

Date: 8/7/2025

BOREHOLE LOG SHEET

HOLE No. CB-BH03

SHEET 2 OF 2

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
								[FILL / TOPSOIL / COBBLES / BOULDERS / -] SOIL NAME: primary component plasticity / particle / behavioural characteristics, colour, secondary component, minor component, structure (ORIGIN) OR ROCK NAME: grain size and type, colour, fabric, texture, inclusions or minor components, strength, weathering, alteration, defects (INTERPRETED STRATIGRAPHIC UNIT / GEOLOGICAL STRUCTURE)			
	AD/T	Nil Casing	Groundwater Not Observed	D: 5.50-5.70m			SP	SAND: fine to coarse grained, dark grey; trace clay; trace rootlets (ALLUVIAL SOIL).	W	VD	5.50 m, organic odour, dark brown staining
6								5.50m becoming very dark brown			
7				D: 7.00-7.20m				7.00m becoming dark brown			7.00 m, organic odour
8				D: 8.00-8.20m							8.00 m, organic odour
				SPT: 8.50-8.65 m 0 for 150 mm N=ref	8.50 (-5.70) 8.65 (-5.85)		SC	Clayey SAND: medium to coarse grained, grey-brown; Clay, low plasticity (EXTREMELY WEATHERED MATERIAL).			8.50 m, SPT recovery 0mm
9								CB-BH03 terminated at 8.65m. Target depth Backfilled at completion			
10											

DRILLING					MATERIAL					COMMENTS	
Scale (m)	Drilling Method	Casing	Water	Samples & Field Tests	Depth (m) (RL m)	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Relative Density	Comments & Observations
	CC						-	CONCRETE: .		-	
1				D: 0.50-0.95m SPT: 0.50-0.95 m 7/8/7 N=15 D: 0.50m	0.20 (2.70)		-	[FILL] Clayey SAND: fine to coarse grained, brown and grey; Clay, low plasticity; with gravel, sub-rounded to angular (FILL).			0.50 m, SPT recovery 450mm
				D: 1.00-1.45m ES: 1.00m SPT: 1.00-1.45 m 5/3/4 N=7 D: 1.00m			-	1.00m No gravel	W	-	1.00 m, SPT recovery 450mm
				D: 1.50-1.95m SPT: 1.50-1.95 m 3/4/4 N=8	1.50 (1.40)		CL	Sandy CLAY: low plasticity, pale grey to very dark grey with black; Sand, fine to coarse grained (ALLUVIAL SOIL).	w = LL	F	1.50 m, SPT recovery 450mm
2				D: 2.00-2.45m SPT: 2.00-2.45 m 4/5/5 N=10 B: 2.00-2.80m ES: 2.00m	1.95 (0.95)			SAND: fine to coarse grained, dark grey; trace silt; with shell fragments (ALLUVIAL SOIL).			2.00 m, SPT recovery 450mm
3	AD/T	NII Casing	Groundwater Not Observed	D: 3.00-3.45m SPT: 3.00-3.45 m 2/7/6 N=13 ES: 3.00m			SP		M	MD	3.00 m, SPT recovery 450mm
				D: 4.00-4.45m SPT: 4.00-4.45 m 3/7/13 N=20 ES: 4.00m							4.00 m, organic odour 4.00 m, SPT recovery 450mm
5											

BOREHOLE LOG SHEET

HOLE No. CB-BH03A

SHEET 2 OF 2

Angle from Horizontal/Azimuth: 90°/-

Driller: BM

Checked By: AM

Logged by: UT

Date: 8/7/2025

GHD St Leonards
Level 11, 558 Pacific Highway,
St Leonards, New South Wales, 2065



Project Number:

12657833

Appendix D

Laboratory Test Results – Geotechnical



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501193

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-06
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
SANDY SILT: trace gravel, dark brown
BH / TP No. CB-BH01A
Depth (m) 1.50 - 1.95

Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	17.7	
Date Tested		12/06/2025	
Sample History	AS 1289.1.1	Oven-Dried	
Preparation	AS 1289.1.1	Dry Sieved	
Linear Shrinkage (%)	AS 1289.3.4.1	Not Tested	
Liquid Limit (%)	AS 1289.3.1.2	N/A	
Plastic Limit (%)	AS 1289.3.2.1	NP	
Plasticity Index (%)	AS 1289.3.3.1	NP	
Date Tested		26/06/2025	

Comments

NP = Non Plastic



Material Test Report

Report No: SYD2501190

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

Sample Details

GHD Sample No SYD25-0232-03
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
Sandy SILT : trace gravel, light brown
BH / TP No. CB-BH02
Depth (m) 1.00 - 1.45

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	12.8	
Date Tested		12/06/2025	

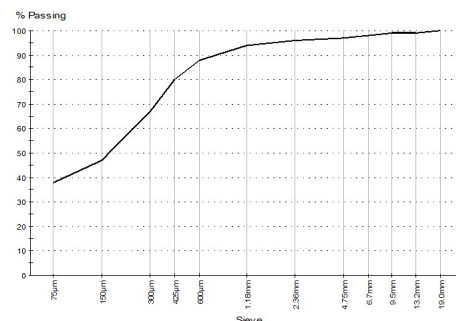
Particle Size Distribution

Method: AS 1289.3.6.1
Drying By: Oven
Date Tested: 26/06/2025

Note: Sample Washed

Sieve Size	% Passing	Limits
19.0mm	100	
13.2mm	99	
9.5mm	99	
6.7mm	98	
4.75mm	97	
2.36mm	96	
1.18mm	94	
600µm	88	
425µm	80	
300µm	67	
150µm	47	
75µm	38	

Chart



Comments

N/A



Material Test Report

Report No: SYD2501198

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-11
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
SAND with silt or clay trace gravel dark brown
BH / TP No. CB-BH03A
Depth (m) 2.00 - 2.45

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	17.2	
Date Tested		12/06/2025	
Curvature Coefficient	AS 1289.3.6.1	2.16	
Uniformity Coefficient		3.70	

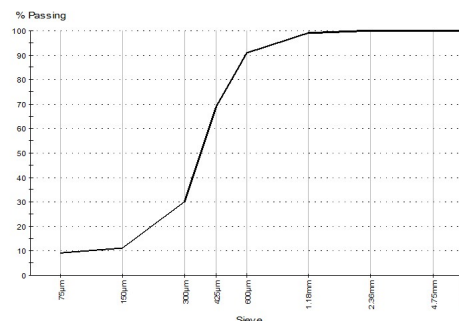
Particle Size Distribution

Method: AS 1289.3.6.1
Drying By: Oven
Date Tested: 26/06/2025

Note: Sample Washed

Sieve Size	% Passing	Limits
6.7mm	100	
4.75mm	100	
2.36mm	100	
1.18mm	99	
600µm	91	
425µm	69	
300µm	30	
150µm	11	
75µm	9	

Chart



Comments

N/A



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501194

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-07
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
SAND with clay dark brown
BH / TP No. CB-BH01A
Depth (m) 3.00 - 3.45

Test Results

Description	Method	Result	Limits
Emerson Class Number	AS 1289.3.8.1	4	
Soil Description		SAND with clay	
Type of Water		distilled	
Temperature of Water (°C)		22	
Date Tested		24/06/2025	

Comments

N/A



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501188

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-01
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
CLAY trace sand & gravel, mottled dark brown, light brown
BH / TP No. CB-BH02
Depth (m) 0.50 - 0.56

Test Results

Description	Method	Result	Limits
Emerson Class Number	AS 1289.3.8.1	5	
Soil Description		CLAY: trace gravel	
Type of Water		distilled	
Temperature of Water (°C)		22	
Date Tested		24/06/2025	

Comments

N/A



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501197

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-10
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
CLAY trace sand & gravel, mottled dark brown, light grey
BH / TP No. CB-BH03A
Depth (m) 1.00 - 1.45

Test Results

Description	Method	Result	Limits
Emerson Class Number	AS 1289.3.8.1	2	
Soil Description		CLAY: trace sand	
Type of Water		distilled	
Temperature of Water (°C)		22	
Date Tested		24/06/2025	

Comments

N/A



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501189

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-02
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
CLAY: with sand, trace gravel, dark brown
BH / TP No. CB-BH01
Depth (m) 1.0 / 1.2 combined

Test Results

Description	Method	Result	Limits
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	1.93	
Standard OMC (%)		11.5	
Retained Sieve (mm)		19	
Oversize Material (%)		1	
Curing Time (h)		48	
LL Method		Visual / Tactile Assessment	
Date Tested		27/06/2025	
CBR at 5.0mm (%)	AS 1289.6.1.1 - 2017	10	
Dry Density before Soaking (t/m ³)		1.89	
Density Ratio before Soaking (%)		98.0	
Moisture Content before Soaking (%)		11.7	
Moisture Ratio before Soaking (%)		102.5	
Dry Density after Soaking (t/m ³)		1.89	
Density Ratio after Soaking (%)		98.0	
Swell (%)		0.0	
Moisture Content of Top 30mm (%)		12.4	
Moisture Content of Remaining Depth (%)		12.8	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		1	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Curing Time (h)		48	
Plasticity Method		Visual/Tactile Assessment	
Date Tested		7/07/2025	

Comments

N/A



Sydney Laboratory
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax: (02) 9462 4710

Material Test Report

Report No: SYD2501192

Issue No: 1

Client: Health Infrastructure
PO Box 1060
North Sydney NSW 1060

Project: 12657833



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NATA Accreditation Approved Signatory: D.P. Brooke

No: 679

Date of Issue: 9/07/2025

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Sample Details

GHD Sample No SYD25-0232-05
Sampled By Sampled by GHD Geotechnical
NSW Ambulance. Caves Beach
Client Location Caves Beach
SANDY CLAY: trace gravel, light brown
BH / TP No. CB-BH03
Depth (m) 1.0 - 1.1

Test Results

Description	Method	Result	Limits
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	1.83	
Standard OMC (%)		13.5	
Retained Sieve (mm)		19	
Oversize Material (%)		0	
Curing Time (h)		48	
LL Method		Visual / Tactile Assessment	
Date Tested		27/06/2025	
CBR at 5.0mm (%)	AS 1289.6.1.1 - 2017	5	
Dry Density before Soaking (t/m ³)		1.80	
Density Ratio before Soaking (%)		98.5	
Moisture Content before Soaking (%)		13.4	
Moisture Ratio before Soaking (%)		99.0	
Dry Density after Soaking (t/m ³)		1.79	
Density Ratio after Soaking (%)		97.5	
Swell (%)		0.5	
Moisture Content of Top 30mm (%)		15.9	
Moisture Content of Remaining Depth (%)		14.4	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		0	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Curing Time (h)		48	
Plasticity Method		Visual/Tactile Assessment	
Date Tested		7/07/2025	

Comments

N/A

Soil Properties - Shrink Swell Index Report

Report No.: SYD2501191

Client: Health Infrastructure
Project: NSW Ambulance
Location: Caves Beach NSW

Job No. : 12657833
Borehole No. : -
Depth : -
LM Sample ID : -

METHOD: GHD in house method (referenced to an Australian Standard)

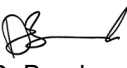
Client Sample ID : -

Sample History - sampled by GHD Geotechnical

GHD Sample No	BH	Depth (m)	Date sampled	Date Tested	Initial MC (%)	Final Swell MC (%)	I _{ss}		comments
SYD25-0232-04	CB-BH02	2.5 - 2.8	-	7/07/2025	16.5	15	0	Sand	Dry Density - 1.72 t/m³ @ FMC
SYD25-0232-08	CB-BH01A	5.0 - 5.5	-	8/07/2025	16	14.9	0	Sand	Dry Density - 1.72 t/m³ @ FMC

Comments:

Shrinkage and Swell specimen remoulded using approximately 90% compactive effort

Tested By:	DB
Date Tested:	as above
Checked By:	JV
Approved Signatory:	
Date:	D. Brooke 9/07/2025



GHD Pty Ltd

Unit 5 / 43 Herbert St, Artarmon NSW, 2065
Telephone: (02) 9462 4860

GEOTECHNICAL TESTING SERVICES

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CERTIFICATE OF ANALYSIS 383691

Client Details

Client	GHD Pty Ltd
Attention	David Brooke
Address	Unit 5 / 43 Herbert St, Artarmon, NSW, 2064

Sample Details

Your Reference	<u>12657833, NSW Ambulance - Caves Beach</u>
Number of Samples	3 Soil
Date samples received	19/06/2025
Date completed instructions received	19/06/2025

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Report Details

Date results requested by	26/06/2025
Date of Issue	24/06/2025
NATA Accreditation Number 2901. This document shall not be reproduced except in full.	
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Results Approved By

Diego Bigolin, Inorganics Supervisor

Authorised By

Nancy Zhang, Laboratory Manager

Misc Inorg - Soil				
Our Reference		383691-1	383691-2	383691-3
Your Reference	UNITS	CB-BH02	CB-BH01A	CB-BH03A
Depth		5.50-5.95	2.00-2.45	0.50-0.95
Type of sample		Soil	Soil	Soil
Date prepared	-	23/06/2025	23/06/2025	23/06/2025
Date analysed	-	23/06/2025	23/06/2025	23/06/2025
pH 1:5 soil:water	pH Units	6.7	7.0	6.8
Electrical Conductivity 1:5 soil:water	µS/cm	240	330	260
Chloride, Cl 1:5 soil:water	mg/kg	<10	<10	22
Sulphate, SO4 1:5 soil:water	mg/kg	340	120	210
Resistivity in soil*	ohm m	41	30	39

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA 22nd ED 2510 and Rayment & Lyons. Resistivity is calculated from Conductivity (non NATA). Resistivity (calculated) may not correlate with results otherwise obtained using Resistivity-Current method, depending on the nature of the soil being analysed.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Waters samples are filtered on receipt prior to analysis. Alternatively determined by colourimetry/turbidity using Discrete Analyser.

QUALITY CONTROL: Misc Inorg - Soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			23/06/2025	[NT]	[NT]	[NT]	[NT]	23/06/2025	[NT]
Date analysed	-			23/06/2025	[NT]	[NT]	[NT]	[NT]	23/06/2025	[NT]
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	[NT]	[NT]	99	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	102	[NT]
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	93	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	101	[NT]
Resistivity in soil*	ohm m	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

Air volumes are typically provided by customers (often as flow rate(s) and sampling time(s) and/or simply volumes) sampled or exposure times (determines 'volume' passive badges are exposed to)). Hence in such circumstances the volume measurement is inevitably not covered by Envirolab's NATA accreditation. An exception may occur where Envirolab Newcastle does the sampling where accreditation exists for certain types of sampling and hence volume determination(s). Note air volumes are often used to determine concentrations for dust and/or analyses on filters, sorbents and in impingers. For canister sampling, the air volume is covered by Envirolab's NATA accreditation.

Urine Analysis - The BEI values listed are taken from the 2022 edition of "TLVs and BEIs Threshold Limits" by ACGIH.



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