

GEOTECHNICAL INVESTIGATION & ACID SULFATE SOILS (ASS) ASSESSMENT

FOR

NSW LAND AND HOUSING CORPORATION

12 - 16 Stuart Street, Warrawong, New South Wales

Report No: 22/1316

Project No: 31684/6216D-G

April 2022

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DRAWING NO. 22/1316 – BOREHOLE AND PENETROMETER LOCATIONS

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1. INTRODUCTION

This report presents the results of a Geotechnical Investigation carried out by STS Geotechnics Pty Limited (STS) for the proposed new residential development to be constructed at 6 Owen Avenue, Wyong. At the time of writing this report STS were not provided with architectural drawings for the project. The report has been prepared assuming site development will be limited to one and two storey residential buildings without basement excavation.

The purpose of the investigation was to provide information on:

- Site conditions and regional geology,
- Subsurface conditions
- Site Classification according to AS2870/AS2159 (soil reactivity),
- Foundation design parameters including foundation options,
- Exposure classification/soil aggressiveness according to AS2870, and
- Acid Sulfate Soils (ASS) assessment and need for an ASS Management Plan.

The investigation was undertaken in accordance with STS proposal P22-149 dated 10th March 2022.

Our scope of work did not include a contamination assessment.

2. NATURE OF THE INVESTIGATION

2.1. Fieldwork

The fieldwork consisted of drilling five (5) boreholes numbered BH1 to BH5 inclusive, at the locations shown on attached Drawing No. 22/1316. Restricted site access dictated the borehole locations. Except for BH2 and BH6, the boreholes were drilled using a utility mounted Edson RP70 Drilling rig, owned, and operated by STS. Because there was no access for the drilling rig, BH2 and BH6 were drilled using a hand auger. Soil strengths were assessed by carrying out a Dynamic Cone Penetrometer (DCP) test adjacent to each borehole location.

Drilling operations were undertaken by one of STS's senior technical officers who also logged the subsurface conditions encountered.

Representative soil samples were collected from the boreholes for subsequent laboratory testing.

2.2. Laboratory Testing

To assess the soil for its aggressiveness, selected representative soil sample was tested to determine the following:

- pH,
- Sulphate content (SO_4),
- Chloride content (Cl) and
- Electrical Conductivity (EC).

To assist with determining the site classification, Shrink Swell tests were carried out on representative samples retrieved from the site.

Detailed test reports are given in Appendix B.

3. GEOLOGY AND SITE CONDITIONS

The Wollongong-Port Hacking geological series map at a scale of 1:100,000 shows the site is underlain by Permian Age Budgong Sandstone Formation within the Shoalhaven Group. Materials within this formation typically comprise sandstone. The site is near the geological boundary with Permian Age Dapto Latite Member. Rocks within this formation comprise latite.

The site is roughly rectangular in shape and has an area of about 1975m². At the time of the fieldwork, the site was occupied by residential dwelling. Site vegetation comprises grasses and trees. The ground surface falls approximately 2 metres to the east.

The site is bound by Stuart Street to the southeast and residential dwellings in the adjoining properties.

4. SUBSURFACE CONDITIONS

When assessing the subsurface conditions across a site from a limited number of boreholes, there is the possibility that variations may occur between test locations. The data derived from the site investigation programme are extrapolated across the site to form a geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour regarding the proposed development. The actual condition at the site may differ from those inferred, since no subsurface exploration programme, no matter how comprehensive, can reveal all subsurface details and anomalies, particularly on a site such as this where there have been previous developments.

The subsurface conditions generally consist of topsoil overlying silty clays. The topsoil is present from the surface to depths of 0.3 to 0.4 metres. Soft, becoming stiff to very stiff with depth, silty clays underlie the topsoil to the depth of drilling, 3.0 metres.

Groundwater was not observed during drilling works, however, moist to wet material were noted in the boreholes.

The subsurface conditions observed are recorded on the borehole logs given in Appendix A. An explanation of the terms used on the logs is also given in Appendix A. Notes relating to geotechnical reports are also attached.

5. GEOTECHNICAL DISCUSSION

5.1. Site Classification (AS2870)

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

To assist with determining the site classification, a shrink/swell test was carried out on a representative sample retrieved from the site. The detailed test report is attached and summarised in Table 5.1.

Table 5.1 – Shrink Swell Test Summary

Location	Depth (m)	Material Description	Shrink/Swell Index (% per ΔpF)
BH1	0.7 – 0.9	Brown silty clay	5.2
BH2	0.7 – 0.9	Brown silty clay	7.1
BH4	0.7 – 0.9	Brown silty clay	5.6

Because there are trees and existing dwellings present, abnormal moisture conditions (AMC) prevail at the site. (Refer to Section 1.3.3 of AS2870).

Because of the AMC and low strength soils present, the site is classified a *Problem Site (P)*. Because of the depth of low strength soil present, it is not appropriate to reclassify the site.

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

5.2. Foundation Design Parameters

We do not recommend founding any structural loads within topsoil.

Pad and/or strip footings founded in the natural firm and firm to stiff soils may be proportioned using an allowable bearing pressure of 50 and 100 kPa, respectively. The minimum depth of founding must comply with the requirements of AS2870. To overcome the presence of trees, the foundations should be designed in accordance with the procedures given in Appendices H and CH of AS2870-2011.

If a higher load carrying capacity is required, piles founded in stiff to very stiff silty clay materials may be proportioned using an allowable end bearing pressure of 300 kPa, provided their depth to diameter ratio exceeds a value of 4. An allowable adhesion value of 20 kPa may be adopted for the portion of the shaft below a depth of 0.5 metres.

To ensure the bearing values given can be achieved, care should be taken to ensure the base of the excavations is free of all loose material prior to concreting. To this end, it is recommended that all excavations be concreted as soon as possible, preferably immediately after excavating, cleaning, inspecting and approval. Pier excavations should not be left open overnight. The possibility of groundwater inflow needs to be considered when drilling the piers and pouring concrete. The moist to wet conditions noted in the boreholes suggest that augered pile excavations will likely fill with water if left open. The site conditions are best suited to either steel screw piers or continuous flight auger (CFA) cement or grout injected piles. If conventional augered cast in place piles are to be used, it is recommended that a trial be carried to ensure the excavations can be kept water free prior to placing the concrete.

Because of the low strength soils present, the site is considered unsuitable for slab on ground construction. Piles will be required to suspend the slab. The slab may be proportioned using movements consistent with an *extremely reactive (E)* classification.

During foundation construction, should the subsurface conditions vary to those inferred in this report, a suitably experienced geotechnical engineer should review the design and recommendations given above to determine if any alterations are required.

5.3. Soil Aggressiveness

The aggressiveness or erosion potential of an environment in building materials, particularly concrete and steel is dependent on the levels of soil pH and the types of salts present, generally sulfates and chlorides. To determine the degree of aggressiveness, the test values obtained are compared to Tables 6.4.2 (C) and 6.5.2 (C) in AS2159 – 2009 Piling – Design and Installation. The test results are summarised in Table 5.2.

Table 5.2 – Soil Aggressiveness Summary

Sample No.	Location	Depth (m)	pH	Sulfate (mg/kg)	Chloride (mg/kg)	Electrical Conductivity (dS/m)	
						EC _{1:5}	EC _e
S1	BH1	0.4	7.4	120	190	0.144	1.3
S2	BH2	0.4	7.1	160	160	0.140	1.3
S3	BH6	0.4	7.1	140	350	0.095	0.9

The soils on the site are cohesive and above groundwater. Therefore, soil conditions B are considered appropriate (AS2159).

In accordance with AS2159-2009 the exposure classification for the onsite soils is non-aggressive to both concrete and steel. In accordance with AS2870-2011 the soils are classified as A1.

Reference to DLWC (2002) “Site Investigations for Urban Salinity” indicates that EC_e values of 0.9 and 1.3 dS/m is consistent with the presence of non-saline soils.

6. ACID SULFATE SOIL ASSESSMENT

6.1. Introduction

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

The relatively specific conditions under which acid sulfate soils are formed usually limit their occurrence to low lying parts of coastal floodplains, rivers, and creeks. This includes areas with saline or brackish water such as deltas, coastal flats, backswamps and seasonal or permanent

freshwater swamps that were formerly brackish. Due to flooding and stormwater erosion, these sulfidic sediments may continue to be re-distributed through the sands and sediments of the estuarine floodplain region. Sulfidic sediment may be found at any depth in suitable coastal sediments – usually beneath the water table.

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

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

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

6.2. Presence of ASS

Reference to Wollongong Council LEP, indicates that the site is in a Class 5 area with respect to ASS.

The Wollongong ASS Risk Map (Edition Two, December 1997) indicates that the property is within an area with no known occurrence of ASS. It should be noted that maps are a guide only.

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

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

6.3. Assessment

Available maps suggest that the proposed site has a surface elevation of about RL 10 to 12 metres AHD and the site is underlain by Permian Age formations. The observed site conditions are not consistent with the geomorphic criteria necessary for the presence of ASS. No groundwater was observed in the boreholes during the site drilling, and as no basement levels are proposed, site development will not result in the lowering of the groundwater where nearby ASS may be present and will therefore not expose ASS to oxidation. Based on our onsite observations, it is our opinion that the proposed construction will not intercept any ASS nor cause lowering of any groundwater. Therefore, land management activities are unlikely to be affected by ASS materials.

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

7. FINAL COMMENTS

During construction, should the subsurface conditions vary from those inferred above, we would be contacted to determine if any changes should be made to our recommendations. The exposed bearing surfaces for footings should be inspected by a geotechnical engineer to ensure the allowable pressure given has been achieved.

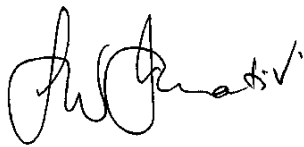
The above classification has been made assuming that all footings will bear in either natural ground or in controlled filling. Prior to the placement of any filling the existing surface should be stripped of all vegetation and topsoil.

If excavations for rainwater or detention tanks are to be made within 6 metres of the building foundations, advice should be sought regarding their effect on the foundations.

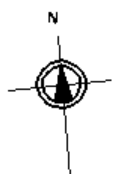
Placing absorption trenches on the high side of the property may create abnormal moisture conditions for the foundations (Refer to Section 1.3.3 of AS2870). This could have a negative effect on the foundation performance and more than likely alter the site classification provided above.

This report has been prepared assuming that no trees other than those noted will be present on the site. If future tree planting is planned, e.g., there is a landscaping plan, their effect on the foundation performance must be considered.

This report has been prepared assuming the site development will be limited to one or two storey residential buildings. The information and interpretation may not be relevant if the design proposal changes (e.g., to a five-storey building involving major cuts during the site preparation). If changes occur, we would be pleased to review the report and advise on the adequacy of the investigation.



*Senior Geotechnical Engineer
STS Geotechnics Pty Limited*



STS Geotechnics Pty. Ltd.

Scale: Unknown

Date: April 2022

Client: NSW LAND & HOUSING CORPORATION

**GEOTECHNICAL INVESTIGATION
12-16 STUART STREET, WARRAWONG
BOREHOLE AND PENETROMETER LOCATIONS**

Project No.
31684/6216D-G

Drawing No: 22/1316

NOTES RELATING TO GEOTECHNICAL REPORTS

Introduction

These notes have been provided to outline the methodology and limitations inherent in geotechnical reporting. The issues discussed are not relevant to all reports and further advice should be sought if there are any queries regarding any advice or report.

When copies of reports are made, they should be reproduced in full.

Geotechnical Reports

Geotechnical reports are prepared by qualified personnel on the information supplied or obtained and are based on current engineering standards of interpretation and analysis.

Information may be gained from limited subsurface testing, surface observations, previous work and is supplemented by knowledge of the local geology and experience of the range of properties that may be exhibited by the materials present. For this reason, geotechnical reports should be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Where the report has been prepared for a specific purpose (eg. design of a three-storey building), the information and interpretation may not be appropriate if the design is changed (eg. a twenty storey building). In such cases, the report and the sufficiency of the existing work should be reviewed by STS Geotechnics Pty Limited in the light of the new proposal.

Every care is taken with the report content, however, it is not always possible to anticipate or assume responsibility for the following conditions:

- Unexpected variations in ground conditions. The potential for this depends on the amount of investigative work undertaken.
- Changes in policy or interpretation by statutory authorities.
- The actions of contractors responding to commercial pressures.

If these occur, STS Geotechnics Pty Limited would be pleased to resolve the matter through further investigation, analysis or advice.

Unforeseen Conditions

Should conditions encountered on site differ markedly from those anticipated from the information contained in the report, STS

Geotechnics Pty Limited should be notified immediately. Early identification of site anomalies generally results in any problems being more readily resolved and allows re-interpretation and assessment of the implications for future work.

Subsurface Information

Logs of a borehole, recovered core, test pit, excavated face or cone penetration test are an engineering and/or geological interpretation of the subsurface conditions. The reliability of the logged information depends on the drilling/testing method, sampling and/or observation spacings and the ground conditions. It is not always possible or economic to obtain continuous high quality data. It should also be recognised that the volume or material observed or tested is only a fraction of the total subsurface profile.

Interpretation of subsurface information and application to design and construction must take into consideration the spacing of the test locations, the frequency of observations and testing, and the possibility that geological boundaries may vary between observation points.

Groundwater observations and measurements outside of specially designed and constructed piezometers should be treated with care for the following reasons:

- In low permeability soils groundwater may not seep into an excavation or bore in the short time it is left open.
- A localised perched water table may not represent the true water table.
- Groundwater levels vary according to rainfall events or season.
- Some drilling and testing procedures mask or prevent groundwater inflow.

The installation of piezometers and long term monitoring of groundwater levels may be required to adequately identify groundwater conditions.

Supply of Geotechnical Information or Tendering Purposes

It is recommended tenderers are provided with as much geological and geotechnical information that is available and that where there are uncertainties regarding the ground conditions, prospective tenders should be provided with comments discussing the range of likely conditions in addition to the investigation data.

APPENDIX A – BOREHOLE LOGS AND EXPLANATION SHEETS

Client: NSW Land & Housing Corporation		Project / STS No. 31684/6216D-G		BOREHOLE NO.: BH 1		
Project: 12-16 Stuart Street, Warrawong		Date: April 6, 2022		Sheet 1 of 1		
Location: Refer to Drawing No. 22/1316		Logged: TS Checked By: IW				
W A T E R L E V E	S A M P L E S	DEPTH (m)	DESCRIPTION OF DRILLED PRODUCT (Soil type, colour, grain size, plasticity, minor components, observations)	S Y M B O L	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	M O I S T U R E
			TOPSOIL: SILTY CLAY: grey, low plasticity, trace of gravel	CL	-	M
	S1 @ 0.4 m	0.5	SILTY CLAY: dark grey mottled brown, medium plasticity	CL	FIRM TO STIFF	M-W
	U50	1.0				
		1.5	SILTY CLAY: brown mottled grey, medium plasticity	CL	FIRM TO STIFF	M-W
		2.0			STIFF	
		2.5			STIFF TO VERY STIFF	
			BOREHOLE DISCONTINUED AT 3.0 M			
D - disturbed sample U - undisturbed tube sample B - bulk sample WT - level of water table or free water N - Standard Penetration Test (SPT) S - jar sample				Contractor: STS Equipment: Edson RP70 Hole Diameter (mm): 100 Angle from Vertical (°): 0 Drill Bit: Spiral		
NOTES: See explanation sheets for meaning of all descriptive terms and symbols						

Client: NSW Land & Housing Corporation		Project / STS No. 31684/6216D-G		BOREHOLE NO.: BH 2		
Project: 12-16 Stuart Street, Warrawong		Date: April 6, 2022		Sheet 1 of 1		
Location: Refer to Drawing No. 22/1316		Logged: TS Checked By: IW				
W A T E R L E	S A M P L E S	DEPTH (m)	DESCRIPTION OF DRILLED PRODUCT (Soil type, colour, grain size, plasticity, minor components, observations)	S Y M B O L	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	M O I S T U R E
	S2 @ 0.4 m		TOPSOIL: SILTY CLAY: grey, low plasticity, trace of gravel	CL	-	M
		0.5	SILTY CLAY: dark grey mottled brown, medium plasticity	CL	SOFT	M-W
	U50				FIRM	
		1.0				
		1.5	SILTY CLAY: brown mottled grey, medium plasticity	CL	FIRM STIFF	M-W
		2.0				
		2.5	SILTY CLAY: orange brown mottled grey, medium plasticity	CL	STIFF STIFF TO VERY STIFF	M
			BOREHOLE DISCONTINUED AT 3.0 M			
D - disturbed sample U - undisturbed tube sample B - bulk sample WT - level of water table or free water N - Standard Penetration Test (SPT) S - jar sample				Contractor: STS Equipment: Edson RP70 Hole Diameter (mm): 100 Angle from Vertical (°): 0 Drill Bit: Spiral		
NOTES: See explanation sheets for meaning of all descriptive terms and symbols						

Client: NSW Land & Housing Corporation		Project / STS No. 31684/6216D-G		BOREHOLE NO.: BH 3		
Project: 12-16 Stuart Street, Warrawong		Date: April 6, 2022		Sheet 1 of 1		
Location: Refer to Drawing No. 22/1316		Logged: TS Checked By: IW				
W A T E R L E V E L	S A M P L E S	DEPTH (m)	DESCRIPTION OF DRILLED PRODUCT (Soil type, colour, grain size, plasticity, minor components, observations)	S Y M B O L	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	M O I S T U R E
			TOPSOIL: SILTY CLAY: grey, low plasticity, trace of gravel	CL	-	M
		0.5	SILTY CLAY: dark grey mottled brown, medium plasticity	CL	SOFT	M-W
		1.0	HAND AUGER REFUSAL AT 0.6 M		VARIABLE BETWEEN SOFT AND FIRM TO STIFF	
		1.5			STIFF	
		2.0				
		2.5			STIFF TO VERY STIFF	
D - disturbed sample U - undisturbed tube sample B - bulk sample WT - level of water table or free water N - Standard Penetration Test (SPT) S - jar sample				Contractor: STS Equipment: Hand Auger Hole Diameter (mm): 100 Angle from Vertical (°): 0 Drill Bit: Spiral		
NOTES: See explanation sheets for meaning of all descriptive terms and symbols						

Client: NSW Land & Housing Corporation		Project / STS No. 31684/6216D-G		BOREHOLE NO.: BH 4		
Project: 12-16 Stuart Street, Warrawong		Date: April 6, 2022		Sheet 1 of 1		
Location: Refer to Drawing No. 22/1316		Logged: TS Checked By: IW				
W A T E R L E	S A M P L E S	DEPTH (m)	DESCRIPTION OF DRILLED PRODUCT (Soil type, colour, grain size, plasticity, minor components, observations)	S Y M B O L	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	M O I S T U R E
			TOPSOIL: SILTY CLAY: grey, low plasticity, trace of gravel	CL	-	M
		0.5	SILTY CLAY: dark grey mottled brown, medium plasticity	CL	FIRM	M-W
	U50				FIRM TO STIFF	
		1.0				
		1.5			STIFF	
		2.0				
		2.5				
			SILTY CLAY: orange brown mottled grey, medium plasticity	CL	STIFF TO VERY STIFF	M
			BOREHOLE DISCONTINUED AT 3.0 M			
D - disturbed sample U - undisturbed tube sample B - bulk sample WT - level of water table or free water N - Standard Penetration Test (SPT) S - jar sample				Contractor: STS Equipment: Edson RP70 Hole Diameter (mm): 100 Angle from Vertical (°): 0 Drill Bit: Spiral		
NOTES: See explanation sheets for meaning of all descriptive terms and symbols						

Client: NSW Land & Housing Corporation		Project / STS No. 31684/6216D-G		BOREHOLE NO.: BH 5		
Project: 12-16 Stuart Street, Warrawong		Date: April 6, 2022		Sheet 1 of 1		
Location: Refer to Drawing No. 22/1316		Logged: TS Checked By: IW				
W A T E R L E	S A M P L E S	DEPTH (m)	DESCRIPTION OF DRILLED PRODUCT (Soil type, colour, grain size, plasticity, minor components, observations)	S Y M B O L	CONSISTENCY (cohesive soils) or RELATIVE DENSITY (sands and gravels)	M O I S T U R E
	S3 @ 0.4 m		TOPSOIL: SILTY CLAY: dark grey, low plasticity	CL	-	M
		0.5	SILTY CLAY: dark grey mottled brown, medium plasticity	CL	FIRM	M-W
		1.0	HAND AUGER REFUSAL AT 0.8 M		FIRM	
		1.5			FIRM TO STIFF	
		2.0			STIFF	
		2.5			STIFF TO VERY STIFF	
D - disturbed sample U - undisturbed tube sample B - bulk sample WT - level of water table or free water N - Standard Penetration Test (SPT) S - jar sample				Contractor: STS Equipment: Hand Auger Hole Diameter (mm): 100 Angle from Vertical (°): 0 Drill Bit: Spiral		
NOTES: See explanation sheets for meaning of all descriptive terms and symbols						

Dynamic Cone Penetrometer Test Report

Project: 12-16 STUART STREET, WARRAWONG

Client: NSW LAND & HOUSING CORPORATION

Address: 31-39 Macquarie Street, Parramatta

Test Method: AS 1289.6.3.2

Project No.: 31684/6216D-G

Report No.: 22/1315

Report Date: 11/04/2022

Page: 1 of 1

Site No.	P1	P2	P3	P4	P5	
Location	Refer to Drawing No. 22/1316	Refer to Drawing No. 22/1316	Refer to Drawing No. 22/1316	Refer to Drawing No. 22/1316	Refer to Drawing No. 22/1316	
Date Tested	6/4/2022	6/4/2022	6/4/2022	6/4/2022	6/4/2022	
Starting Level	Surface Level	Surface Level	Surface Level	Surface Level	Surface Level	
Depth (m)	Penetration Resistance (blows / 150mm)					
0.00 - 0.15	1	1	1	1	1	
0.15 - 0.30	1	1	2	1	1	
0.30 - 0.45	2	1	1	2	2	
0.45 - 0.60	3	1	1	3	2	
0.60 - 0.75	3	1	3	2	2	
0.75 - 0.90	2	2	3	2	3	
0.90 - 1.05	3	3	2	3	2	
1.05 - 1.20	3	3	1	4	4	
1.20 - 1.35	4	2	5	4	4	
1.35 - 1.50	4	4	4	5	4	
1.50 - 1.65	5	5	4	6	4	
1.65 - 1.80	6	6	5	5	5	
1.80 - 1.95	5	6	6	5	4	
1.95 - 2.10	5	5	6	6	5	
2.10 - 2.25	6	5	5	5	6	
2.25 - 2.40	6	6	6	5	6	
2.40 - 2.55	5	8	6	5	9	
2.55 - 2.70	7	3	7	7	5	
2.70 - 2.85	7	7	7	8	6	
2.85 - 3.00	6/D	7/D	7/D	7/D	8/D	
3.00 - 3.15						
3.15 - 3.30						
3.30 - 3.45						
3.45 - 3.60						
3.60 - 3.75						

Remarks: * Pre drilled prior to testing

Approved Signatory.....
Orlando Mendoza - Laboratory Manager

Technician: TS

E1. CLASSIFICATION OF SOILS

E1.1 Soil Classification and the Unified System

An assessment of the site conditions usually includes an appraisal of the data available by combining values of engineering properties obtained by the site investigation with descriptions, from visual observation of the materials present on site.

The system used by STS Geotechnics Pty Ltd (STS) in the identification of soil is the Unified Soil Classification system (USC) which was developed by the US Army Corps of Engineers during World War II and has since gained international acceptance and has been adopted in its metricated form by the Standards Association of Australia.

The Australian Site Investigation Code (AS1726-2017, Appendix D) recommends that the description of a soil includes the USC group symbols which are an integral component of the system.

The soil description should contain the following information in order:

Soil composition

- SOIL NAME and USC classification symbol (IN BLOCK LETTERS)
- plasticity or particle characteristics
- colour
- secondary and minor constituents (name estimated proportion, plasticity or particle characteristics, colour)

Soil condition

- moisture condition
- consistency or density index

Soil structure

- structure (zoning, defects, cementing)

Soil origin

interpretation based on observation eg FILL, TOPSOIL, RESIDUAL, ALLUVIUM.

E1.2 Soil Composition

- (a) Soil Name and Classification Symbol

The USC system is summarised in Figure E1.2.1. The primary division separates soil types on the basis of particle size into:

- Coarse grained soils - more than 50% of the material less than 60 mm is larger than 0.06 mm (60 µm).
- Fine grained soils - more than 50% of the material less than 60 mm is smaller than 0.06 mm (60 µm).

Initial classification is by particle size as shown in Table E1.2.1. Further classification of fine grained soils is based on plasticity.

TABLE E1.2.1 - CLASSIFICATION BY PARTICLE SIZE

NAME	SUB-DIVISION	SIZE
Clay (1)		< 2 µm
Silt (2)		2 µm to 60 µm
Sand	Fine Medium Coarse	60 µm to 200 µm 200 µm to 600 µm 600 µm to 2 mm
Gravel (3)	Fine Medium Coarse	2 mm to 6 mm 6 mm to 20 mm 20 mm to 60 mm
Cobbles (3)		60 mm to 200 mm
Boulders (3)		> 200 mm

Where a soil contains an appropriate amount of secondary material, the name includes each of the secondary components (greater than 12%) in increasing order of significance, eg sandy silty clay.

Minor components of a soil are included in the description by means of the terms “some” and “trace” as defined in Table E1.2.2.

TABLE E1.2.2 - MINOR SOIL COMPONENTS

TERM	DESCRIPTION	APPROXIMATE PROPORTION (%)
Trace	presence just detectable, little or no influence on soil properties	0-5
Some	presence easily detectable, little influence on soil properties	5-12

The USC group symbols should be included with each soil description as shown in Table E1.2.3

TABLE E1.2.3 - SOIL GROUP SYMBOLS

SOIL TYPE	PREFIX
Gravel	G
Sand	S
Silt	M
Clay	C
Organic	O
Peat	Pt

The group symbols are combined with qualifiers which indicate grading, plasticity or secondary components as shown on Table E1.2.4

TABLE E1.2.4 - SOIL GROUP QUALIFIERS

SUBGROUP	SUFFIX
Well graded	W
Poorly Graded	P
Silty	M
Clayey	C
Liquid Limit <50% - low to medium plasticity	L
Liquid Limit >50% - medium to high plasticity	H

(b) Grading

“Well graded”	Good representation of all particle sizes from the largest to the smallest.
“Poorly graded”	One or more intermediate sizes poorly represented
“Gap graded”	One or more intermediate sizes absent
“Uniformly graded”	Essentially single size material.

(c) Particle shape and texture

The shape and surface texture of the coarse grained particles should be described.

Angularity may be expressed as “rounded”, “sub-rounded”, “sub-angular” or “angular”.

Particle **form** can be “equidimensional”, “flat” or “elongate”.

Surface texture can be “glassy”, “smooth”, “rough”, “pitted” or “striated”.

(d) Colour

The colour of the soil should be described in the moist condition using simple terms such as:

Black	White	Grey	Red
Brown	Orange	Yellow	Green
Blue			

These may be modified as necessary by “light” or “dark”. Borderline colours may be described as a combination of two colours, eg red-brown.

For soils that contain more than one colour terms such as:

- Speckled Very small (<10 mm dia) patches
- Mottled Irregular
- Blotched Large irregular (>75 mm dia)
- Streaked Randomly oriented streaks

(e) Minor Components

Secondary and minor components should be individually described in a similar manner to the dominant component.

E1.3 Soil Condition

(a) Moisture

Soil moisture condition is described as “dry”, “moist” or “wet”.

The moisture categories are defined as:

Dry (D) - Little or no moisture evident. Soils are running. Moist (M) - Darkened in colour with cool feel. Granular soil particles tend to adhere. No free water evident upon remoulding of cohesive soils.

In addition the moisture content of cohesive soils can be estimated in relation to their liquid or plastic limit.

(b) Consistency

Estimates of the consistency of a clay or silt soil may be made from manual examination, hand penetrometer test, SPT results or from laboratory tests to determine undrained shear or unconfined compressive strengths. The classification of consistency is defined in Table E1.3.1.

TABLE E1.3.1 - CONSISTENCY OF FINE-GRAINED SOILS

TERM	UNCONFINED STRENGTH (kPa)	FIELD IDENTIFICATION
Very Soft	<25	Easily penetrated by fist. Sample exudes between fingers when squeezed in the fist.
Soft	25 - 50	Easily moulded in fingers. Easily penetrated 50 mm by thumb.
Firm	50 - 100	Can be moulded by strong pressure in the fingers. Penetrated only with great effort.
Stiff	100 - 200	Cannot be moulded in fingers. Indented by thumb but penetrated only with great effort.
Very Stiff	200 - 400	Very tough. Difficult to cut with knife. Readily indented with thumb nail.
Hard	>400	Brittle, can just be scratched with thumb nail. Tends to break into fragments.

Unconfined compressive strength as derived by a hand penetrometer can be taken as approximately double the undrained shear strength ($q_u = 2 c_u$).

(c) Density Index

The insitu density index of granular soils can be assessed from the results of SPT or cone penetrometer tests. Density index should not be estimated visually.

TABLE E1.3.2 - DENSITY OF GRANULAR SOILS

TERM	SPT N VALUE	STATIC CONE VALUE q_c (MPa)	DENSITY INDEX (%)
Very Loose	0 - 3	0 - 2	0 - 15
Loose	3 - 8	2 - 5	15 - 35
Medium Dense	8 - 25	5 - 15	35 - 65
Dense	25 - 42	15 - 20	65 - 85
Very Dense	>42	>20	>85

E1.4 Soil Structure

(a) Zoning

A sample may consist of several zones differing in colour, grain size or other properties. Terms to classify these zones are:

Layer - continuous across exposure or sample

Lens - discontinuous with lenticular shape

Pocket - irregular inclusion

Each zone should be described, their distinguishing features, and the nature of the interzone boundaries.

(b) Defects

Defects which are present in the sample can include:

- fissures
- roots (containing organic matter)
- tubes (hollow)
- casts (infilled)

Defects should be described giving details of dimensions and frequency. Fissure orientation, planarity, surface condition and infilling should be noted. If there is a tendency to break into blocks, block dimensions should be recorded

E1.5 Soil Origin

Information which may be interpretative but which may contribute to the usefulness of the material description should be included. The most common interpreted feature is the origin of the soil. The assessment of the probable origin is based on the soil material description, soil structure and its relationship to other soil and rock materials.

Common terms used are:

“Residual Soil” - Material which appears to have been derived by weathering from the underlying rock. There is no evidence of transport.

“Colluvium” - Material which appears to have been transported from its original location. The method of movement is usually the combination of gravity and erosion.

“Landslide Debris” - An extreme form of colluvium where the soil has been transported by mass movement. The material is obviously distributed and contains distinct defects related to the slope failure.

“Alluvium” - Material which has been transported essentially by water. usually associated with former stream activity.

“Fill” - Material which has been transported and placed by man. This can range from natural soils which have been

placed in a controlled manner in engineering construction to dumped waste material. A description of the constituents should include an assessment of the method of placement.

E1.6 Fine Grained Soils

The physical properties of fine grained soils are dominated by silts and clays.

The definition of clay and silt soils is governed by their Atterberg Limits. Clay soils are characterised by the properties of cohesion and plasticity with cohesion defines as the ability to deform without rupture. Silts exhibit cohesion but have low plasticity or are non-plastic.

The field characteristics of clay soils include:

- dry lumps have appreciable dry strength and cannot be powdered
- volume changes occur with moisture content variation
- feels smooth when moist with a greasy appearance when cut.

The field characteristics of silt soils include:

- dry lumps have negligible dry strength and can be powdered easily
- dilatancy - an increase in volume due to shearing - is indicated by the presence of a shiny film of water after a hand sample is shaken. The water disappears upon remoulding. Very fine grained sands may also exhibit dilatancy.
- low plasticity index
- feels gritty to the teeth

E1.7 Organic Soils

Organic soils are distinguished from other soils by their appreciable content of vegetable matter, usually derived from plant remains.

The soil usually has a distinctive smell and low bulk density.

The USC system uses the symbol Pt for partly decomposed organic material. The O symbol is combined with suffixes “O” or “H” depending on plasticity.

Where roots or root fibres are present their frequency and the depth to which they are encountered should be recorded. The presence of roots or root fibres does not necessarily mean the material is an “organic material” by classification.

Coal and lignite should be described as such and not simply as organic matter.

APPENDIX B – LABORATORY TEST RESULTS

Shrink Swell Index Report

Project: 12-16 STUART STREET, WARRAWONG

Client: **NSW LAND & HOUSING CORPORATION**

Address: 31-39 Macquarie Street, Parramatta

Test Method: AS 1289.7.1.1

Project No.: 31684

Report No.: 22/1343

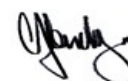
Report Date: 20/04/2022

Page: 1 of 1

Sampling Procedure: AS 1289.1.3.1 Clause 3.1.3.2 - Thin Walled Sampler

STS / Sample No.		6216D-L/1	6216D-L/2	6216D-L/3			
Sample Location		Borehole 1 Refer to Drawing No. 22/1316	Borehole 2 Refer to Drawing No. 22/1316	Borehole 4 Refer to Drawing No. 22/1316			
Material Description		Silty Clay, brown, trace of sand	Silty Clay, brown, trace of gravel/sand	Silty Clay, brown, trace of sand			
Depth (m)		0.7 - 0.9	0.7 - 0.9	0.7 - 0.9			
Sample Date		6/04/2022	6/04/2022	6/04/2022			
Shrink	Moisture Content (%)	47.1	46.1	38.8			
	Soil Crumbling	Nil	Nil	Nil			
	Extent of Cracking	Open Cracks	Nil	Fine Cracks			
	Strain (%)	9.2	12.9	9.9			
Swell	Moisture Content Initial (%)	48.3	45.7	40.8			
	Moisture Content Final (%)	47.6	48.9	42.8			
	Strain (%)	0.3	0.0	0.5			
Inert Inclusions (%)		<15	<20	<15			
Shrink Swell Index (%)		5.2	7.1	5.6			

Remarks:



Approved Signatory.....

Technician: DH

Orlando Mendoza - Laboratory Manager

CERTIFICATE OF ANALYSIS

Work Order	: ES2212396	Page	: 1 of 4
Client	: STS Geotechnics	Laboratory	: Environmental Division Sydney
Contact	: ENQUIRES STS	Contact	: Customer Services ES
Address	: Unit 14/1 Cowpasture Place Wetherill Park 2164	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: 30055/31684/31724	Date Samples Received	: 08-Apr-2022 12:30
Order number	: 2022-0114	Date Analysis Commenced	: 08-Apr-2022
C-O-C number	: ----	Issue Date	: 13-Apr-2022 11:15
Sampler	: TS/AB		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 9		
No. of samples analysed	: 9		



Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

<i>Signatories</i>	<i>Position</i>	<i>Accreditation Category</i>
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW



General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	30055/8311	30055/8315	30055/8316	30055/8321	31684/S1
Sampling date / time					07-Apr-2022 00:00	07-Apr-2022 00:00	07-Apr-2022 00:00	07-Apr-2022 00:00	07-Apr-2022 00:00
Compound	CAS Number	LOR	Unit		ES2212396-001	ES2212396-002	ES2212396-003	ES2212396-004	ES2212396-005
				Result	Result	Result	Result	Result	Result
EA002 : pH (Soils)									
pH Value	----	0.1	pH Unit		5.8	5.9	6.2	5.7	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		----	----	----	----	7.5
EA010: Conductivity									
Electrical Conductivity @ 25°C	----	1	µS/cm		30	25	23	22	----
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		----	----	----	----	144
EA055: Moisture Content									
Moisture Content	----	1.0	%		19.6	18.1	14.4	24.4	----
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	0.1	%		----	----	----	----	28.2
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		40	30	40	30	120
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		----	----	----	----	190



Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	31684/S2	31684/S3	31724/S1	31724/S2	----
Sampling date / time					07-Apr-2022 00:00	07-Apr-2022 00:00	07-Apr-2022 00:00	07-Apr-2022 00:00	----
Compound	CAS Number	LOR	Unit		ES2212396-006	ES2212396-007	ES2212396-008	ES2212396-009	-----
				Result	Result	Result	Result	Result	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		7.1	7.1	8.6	8.7	----
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		140	95	405	410	----
EA055: Moisture Content (Dried @ 105-110°C)									
Moisture Content	----	0.1	%		28.3	25.8	9.4	10.5	----
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		160	140	250	260	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		480	390	210	240	----