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SYNERGY DEVELOPMENT GROUP PTY LTD

GEOTECHNICAL ASSESSMENT REPORT

21 ATKINSON STREET, LIVERPOOL, NSW

Report E23001 GA
17 June 2016

Report Distribution

Geotechnical Assessment Report

21 Atkinson Street, Liverpool, NSW

EI Report No. *E23001 GA*

Date: *17 June 2016*

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Revision	Details	Date	Amended By
	Original	17 June 2016	

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1 INTRODUCTION

1.1 BACKGROUND

At the request of Synergy Development Group Pty Ltd (Synergy), Environmental Investigations Australia Pty Ltd (EI) has carried out a Geotechnical Assessment (GA) for the proposed development at 21 Atkinson Street, Liverpool, NSW (the Site).

This GA report has been prepared to provide preliminary advice and recommendations to assist in the preparation of initial designs for the proposed development. The assessment has been carried out in accordance with the agreed scope of works outlined in EI's proposal referenced P13802.1, dated 20 April 2016.

1.2 PROPOSED DEVELOPMENT

To assist us with the preparation of this GA report, Synergy has supplied EI with:

- Architectural drawings prepared by Mosca Pserras Architects – Reference No. 15001, Drawing Nos. AP01 to AP13, dated 1 February 2016; and
- Detailed site survey prepared by Lawrence Group – Job Number 142981, Drawing No. DETL-001, Issue A, dated 14 October 2014.

Based on the above, we understand that the proposed development will involve the demolition of the existing site structures and the construction of three, eight to ten-storey mixed-use apartment buildings over a common three-level podium. The ground floor is proposed to have a finished floor level of Reduced Level (RL) 10.3m Australian Height Datum (AHD). Based on the levels shown on the survey plan, filling of about 0.5m will be required across the site to achieve the finish floor level. Local excavations will be required for footings, service trenches and lift overrun pits.

1.3 ASSESSMENT OBJECTIVES

The objective of the GA was to assess site surface and subsurface conditions, and to provide preliminary geotechnical advice and recommendations addressing the following:

- Construction considerations
- Site classification
- Earthworks
- Subgrade preparation and engineered fill
- Building foundation options, including;
  - Preliminary design parameters.
  - Earthquake loading factor in accordance with AS1170.4:2007.
- The requirement for additional geotechnical works.

1.4 SCOPE OF WORKS

The scope of works for the GA included:

- Preparation of a Work Health and Safety Plan;
- Review of relevant geological maps for the project area;
- Site walkover inspection by a Geotechnical Engineer to assess topographical features and site conditions;
- Scanning of proposed borehole locations for buried conductive services using a licensed service locator with reference to Dial Before You Dig (DBYD) plans;

- Auger drilling of two boreholes (BH1M and BH2) by a track-mounted drill rig using solid flight augers equipped with a 'Tungsten-Carbide' (T-C) bit. BH1M and BH2 were auger drilled to a depth of about 4.0m (or RL of about 5.7m AHD) and 10.8m BEGL (or RL of about -1.0m AHD), respectively. The approximate surface levels shown on the borehole logs were interpolated from spot levels shown on the supplied survey plan which formed the basis of **Figure 2**. Approximate borehole locations are shown **on Figure 2**;
- Standard Penetration Testing (SPT) was carried out during auger drilling of the boreholes to assess soil strength/relative densities. These were augmented, where possible, by hand penetrometer readings on cohesive soil samples collected in the SPT split tube sampler. Soil samples were sent to Macquarie Geotechnical Pty Ltd (Macquarie) and SGS Australia Pty Ltd (SGS), which are National Australian Testing Authority (NATA) accredited laboratories, for testing and storage.
- The strength of the shale bedrock in the augered sections of the boreholes was assessed by observation of the auger penetration resistance using a T-C drill bit, examination of the recovered rock cuttings, and rock moisture content tests. It should be noted that rock strengths assessed from augered boreholes are approximate and strength variances can be expected.
- Continuation of BH1M and BH2 using NMLC diamond coring techniques to termination depths of about 9.0m (or about RL 0.7m AHD) and 13.9m BEGL (or about RL -4.1m AHD), respectively. Rock cores recovered from the boreholes were boxed, logged, photographed and sent to Macquarie for point load strength index testing and storage. The test results are presented in **Appendix A** and **Appendix B**, and the rock core photographs are presented in **Appendix A**;
- Measurements of groundwater seepage/levels, where possible, in the augered sections of the boreholes during and shortly after completion of auger drilling.
- Installation of one PVC standpipe in BH1M to allow for long term groundwater monitoring; and
- Preparation of this GA report.

An EI Geotechnical Engineer was present on site to set out the borehole locations, direct the testing and sampling, log the subsurface conditions and record groundwater levels.

1.5 Assessment Constraints

The GA was limited by the intent of the assessment and the presence of existing site structures covering the majority of the site. The discussions and advice presented in this report are preliminary and intended to assist in the preparation of initial designs for the proposed development. Further geotechnical investigations should be carried out prior to final design and following demolition to confirm the geotechnical and groundwater models, and the design parameters provided in this report.

2 SITE DESCRIPTION

2.1 SITE DESCRIPTION AND IDENTIFICATION

The site identification details and associated information are presented in **Table 2-1** below while the site locality is shown on **Figure 1.**

Table 2-1 Summary of Site Information

Information	Detail
Street Address	21 Atkinson Street, Liverpool, NSW 2170
Lot and Deposited Plan (DP) Identification	Lot 101 in DP 777404
Local Government Authority	Liverpool City Council
Parish	St Luke
County	Cumberland
Current Zoning	R4 – High Density Residential (Liverpool Local Environment Plan 2008)
Site Description	At the time of our assessment, the majority of the site was occupied by a two-storey glass and concrete commercial building and warehouse. The building appeared to be in good external condition upon a cursory inspection. The south and east of the building were concrete covered, which appeared to be in good condition. A grassed area located to the north of the building. A low height fill embankment was located north of the building which fell towards the south at an angle of about 10°. At the south-western corner of the site, a 4m high concrete retaining wall retained up to 3m of soil. The concrete block retaining wall appeared to be in good condition.
Site Area	The site area is approximately 5412m^2 (based on the provided site survey map referenced above).

2.2 LOCAL LAND USE

The site is situated within an area of mixed use. Current uses on surrounding land are described in **Table 2-2** below.

Table 2-2 Summary of Local Land Use

Direction Relative to Site	Land Use Description
North	Shepherd Street, a two-lane asphaltic-concrete road, followed by two to four-storey brick residential buildings with no basements. The residential buildings have a setback of about 20m from the northern site boundary.
East	Shepherd Street, followed by three-storey residential brick buildings with no basements. The residential buildings have a setback of about 24m from the eastern site boundary.
South	Atkinson Street, a two-lane asphaltic-concrete road, followed by an industrial warehouse. The warehouse has a setback of about 20m from the southern site boundary. Beyond Atkinson Street in the south-eastern direction lies a construction site for an eight to ten-storey apartment building with three basement levels. At the time of the assessment, excavation was taking place and was supported by a combination of soldier pile and secant pile shoring wall systems with two rows of anchors, and shotcrete panels. The construction site has a setback of about 30m from the south-eastern site boundary.
West	Immediately west of the site, a Sydney Trains T2 and T5 rail corridor, running in a roughly north-south direction. The corridor consists of three lines and is located on a ballast embankment at a higher level than the site. The closest rail line has a setback of about 7m from the western site boundary.

2.3 REGIONAL SETTING

The site topography and geological information for the locality is summarised in **Table 2-3** below**.**

Table 2-3 Topographic and Geological Information

Attribute	Description
Topography	Regionally, the topography falls towards the north-northeast at an angle of about 2-3°. The site levels slopes down from RL of 13.0m AHD at the south-western corner of the site to RL 8.4m AHD at the northern corner.
Regional Geology	Information on regional sub-surface conditions, referenced from the Department of Mineral Resources Geological Map Penrith 1:100,000 Geological Series Sheet 9030 (DMR 1991) indicates the site to lie on the border of Bringelly Shale to the west and Tertiary Pliocene aged fluvial soil to the east. Bringelly Shale consists of shale, carbonaceous claystone, laminite, fine to medium grained lithic sandstone, and rare coal, while the fluvial soil consists of clayey quatzose sand, and clay.

3 ASSESSMENT RESULTS

3.1 STRATIGRAPHY

For the development of a site-specific geotechnical model, the observed stratigraphy during the GA has been grouped into four geotechnical units, with Unit 4 subdivided into two sub-units. A summary of the subsurface conditions across the site, interpreted from the assessment results, is presented in **Table 3-1** below. More detailed descriptions of subsurface conditions at each borehole location are available on the borehole logs presented in **Appendix A**. The details of the method of soil and rock classification, explanatory notes and abbreviations adopted on the borehole logs are also presented in **Appendix A**.

Table 3-1 Summary of Subsurface Conditions

Unit	Material [2]	Depth to top of Unit (m BEGL) [1]	Approximate RL of top of Unit (m AHD) [1]	Observed Thickness (m)	Material Description [2]	Comments
1	**Fill / Topsoil**	Surface	9.7 and 9.8	0.5 and 2.5	CONCRETE over FILL or Topsoil / Fill	Concrete pavement of 120mm thickness overlying silty clayey fill with gravel was observed in BH1. Silty sand topsoil with roots, rootlets, and gravel overlying silty gravel and gravelly silty clay fill with slag was observed in BH2. Based on our observations, the fill in BH1 appeared to be well compacted, while the fill in BH2 appeared to be poorly compacted. In the absence of any records that document the placement, control and compaction of the fill, the fill is considered 'uncontrolled'.
2	**Residual Soil**	0.5	9.2	1.7	Silty CLAY	Hard silty clay of medium plasticity grading into extremely low strength shale. Unit 2 was observed in BH1 only. SPT refusal in Unit 2, and hand penetrometer readings on the SPT samples were >600kPa.
3	**Fluvial Soil**	2.5	7.3	6.5	Sandy / Silty CLAY	Firm to stiff sandy clay of low plasticity. At a depth of 3.4m, became stiff to very stiff silty clay of medium to high plasticity. Unit 3 was observed in BH2 only. SPT N values of 7 to 13, and hand penetrometer readings on the SPT samples were between 100 to 350kPa.
4a	**Extremely Low to Very Low Strength Shale**	2.2 and 9.0	7.5 and 0.8	2.1 and 2.8	SHALE	Extremely low to very low strength, extremely to distinctly weathered shale with iron indurated bands and clay.
4b	**Medium Strength Shale**	4.3 and 11.8	5.4 and -2.0	4.7 and 2.1 [3]	SHALE	Generally medium strength, slightly weathered to fresh shale. Defects in Unit 3c are generally moderately to widely spaced (200-2000mm), including sub-horizontal bedding partings, joints inclined up to 5°, and up to 2% decomposed and crushed seams.

Notes:
1 Approximate depth and level at the time of our assessment. Depths and levels may vary across the site.
2 For more detailed descriptions of the subsurface conditions, reference should be made to the borehole logs attached to **Appendix A.**
3 Observed up to termination depth in BH1M and BH2

3.2 GROUNDWATER OBSERVATIONS

No groundwater seepage was encountered in BH1M during auger drilling. Groundwater seepage was observed in BH2 at a depth of about 3.0m, or RL of about 6.8m AHD, during auger drilling. The water induced during the coring process of the boreholes precluded further observations of the groundwater levels.

However, following the completion of fieldwork, a monitoring well was installed in BH1M for further monitoring, and was bailed dry on the day of installation. The groundwater within the well was measured during fieldwork 5 hours following well installation. We note that the groundwater level may have not become stabilised during the limited time in site.

A summary of groundwater levels measured during fieldwork is presented in **Table 3-2** below.

Table 3-2 Summary of Groundwater Levels

Monitoring Well / Borehole ID	Date of Observation	Approximate Depth to Groundwater (m BEGL)	Approximate RL of Groundwater (m AHD) [1]
BH1M	16 May 2016 (5 hours following well development)	3.6	6.1

Notes:
1 Interpolated from spot levels shown on the supplied survey plan.

3.3 TEST RESULTS

Three soil samples, two rock chip samples, and one groundwater sample were selected for laboratory testing to assess the following:

- Atterberg Limits and Linear Shrinkage;
- Rock Moisture Content; and
- Soil and groundwater aggressivity (pH, Chloride and Sulfate content and electrical conductivity).

A summary of soil and groundwater test results is provided in **Table 3-3** below.

16 selected rock core samples were tested by Macquarie to estimate the Point Load Strength Index (Is_{50}) values to assist with rock strength assessment. The results of the testing are summarised on the attached borehole logs.

Laboratory test certificates are presented in **Appendix B**.

Table 3-3 Summary of Laboratory Test Results

Test/ Sample ID		BH1_3.0-3.1	BH1_3.8-4.0	BH2_7.5-7.95	BH1_1.5-1.75	BH2_3.0-3.4	BH1_GW1
Unit		4a	4a	3	2	3	-
	Material Description [1]	SHALE	SHALE	Silty CLAY	Silty CLAY	Sandy CLAY	GROUNDWATER
Atterberg Limits	Liquid Limit (%)	-	-	-	-	22	-
	Plastic Limit (%)	-	-	-	-	16	-
	Plasticity Index (%)	-	-	-	-	6	-
	Linear Shrinkage (%)	-	-	-	-	2.0	-
Aggressivity	pH	-	-	-	8.7	8.1	6.8
	Electrical Conductivity (µS/cm)	-	-	-	100	58	7500
	Sulfate SO_4 (mg/kg)	-	-	-	32	13	310
	Chloride Cl (mg/kg)	-	-	-	73	11	1900
	Moisture Content (%)	6.7	6.8	19.9	14.0	19.9	-

Notes:
More detailed descriptions of the subsurface conditions at each borehole location are available on the borehole logs presented in **Appendix A**.

The Atterberg Limits and Linear Shrinkage results on Unit 3 indicated these clays to be inorganic clays and slightly reactive with moisture change (Class S).

The point load strength index tests correlated reasonably well with our field assessments of rock strength. The approximate Unconfined Compressive Strength (UCS) of the rock core, estimated from correlations with the point load strength index test results, varied from <1 MPa to 20 MPa.

The assessment indicated low permeability soils were present above and below the groundwater table. In accordance with Tables 6.4.2(C) and 6.5.2(C) of AS 2159:2009 'Piling – Design and Installation', the results of the pH, chloride and sulfate content and electrical conductivity of the soils and groundwater, provided the following exposure classifications:

- 'Non-aggressive' for buried concrete structural elements; and
- 'Non-aggressive' for buried steel structural elements.

In accordance with Table 4.8.1 of AS3600-2009 'Concrete Structures' these soils would be classified as exposure classification 'A1' for concrete in sulfate soils.

4 RECOMMENDATIONS

4.1 GEOTECHNICAL ISSUES

Based on the results of the assessment, we consider the following to be the main geotechnical issues for the proposed development:

- Varying depth to rock and quality across the site;
- Presence of deep fill on site;
- Presence of compressible firm clay;
- Foundation design for building loads; and
- Sydney Trains Corridor is located within close vicinity of the site to the west.

4.2 CONSTRUCTION CONSIDERATIONS

Should the existing concrete retaining wall be retained, a structural engineer should assess its condition and ascertain its suitability for the proposed development. Should a new retaining wall be required, further advice can be provided on the design of the retaining wall.

4.3 SITE CLASSIFICATION

The fill observed in the boreholes is deep and variable in compaction and hence, considered to be uncontrolled. Because of this fill and the presence of the compressible firm clays, the site is considered to be Class 'P' in accordance with AS2870-2011. We advise that in strict sense AS2870 site classification does not apply to this development. As a guide, reference should also be made to AS2870 for design, construction, performance criteria and maintenance precautions on Class P sites. The fill is deemed unsuitable as a bearing stratum for, at least the footings and is considered a 'moderate risk' (of poor performance) as a supporting subgrade under the floor slab. Our recommendation is that the slab is suspended on piles bearing into the natural bedrock.

4.4 EARTHWORKS

The architectural drawings provided by Synergy indicate that as part of the proposed works filling (estimated to be up to 0.5m) will be required to achieve the proposed FFL of RL 10.3m AHD. The following are some general guidelines and recommendations regarding these proposed earthworks.

4.4.1 Excavation Materials and Methods

Prior to any excavation commencing, we recommend that reference be made to the WorkCover Excavation Work Code of Practice – July 2015.

EI assumes that local excavations for footings, service trenches and lifts overrun pits may be required.

Based on the borehole logs, any local excavations may encounter Units 1, 2, and/or 3 material.

Units 1, 2, and 3 materials should be readily achievable using conventional earthmoving equipment, such as hydraulic excavators.

4.4.2 Groundwater

Groundwater seepage does not appear to be a significant issue as levels were measured within the open boreholes after completion at depths of 4.3m BGL to 5.3m BGL which are well below the proposed development.

Groundwater run-off inflows into the excavation will occur following periods of rainfall. Such inflow of water is expected to be drained through the Unit 1 sandy fill layer

4.4.3 Subgrade Preparation and Engineered Fill

If the slab is to be fully suspended on footings then it would be unnecessary to complete any particular subgrade preparation other than stripping any top layer of root affected soil in Unit 1. Alternatively, if the slab is non-suspended then we recommend that the top 1m of the existing uncontrolled fill and be fully removed and replaced

with engineered fill as recommended below. Earthworks recommendations provided in this report should be complemented by reference to AS3798.

1. Strip the upper layer of fill that contains deleterious materials or organics, and stockpile this separately since these materials are not suitable for re-use as engineered fill.
2. The remaining existing fill should be excavated down to at least 1m BGL and replaced with engineered fill. The replacement should extend to at least 2m beyond the boundaries of the floor area. Such an excavation might have to be completed with battered sides of not steeper than 1 vertical to 2 horizontal. The earthworks contractor must ensure that during the backfilling earthworks that the engineered fill is well 'keyed' into the side batters of the excavation.
3. The exposed subgrade at the base of the excavation should be proof rolled with at least 10 passes of a heavy (at least 12 tonne) smooth drum roller used in static or non-vibratory mode of operation. Caution is required when proof rolling near the outhouse south of the site. The purpose of the proof rolling is to detect any soft or heaving areas.
4. The final pass should be undertaken in the presence of a geotechnician or a geotechnical engineer, to detect any unstable areas or soft subgrade areas and to allow for some further improvement in strength/compaction
5. Unstable subgrade detected during proof rolling should be locally excavated down to a sound base and replaced with engineered fill or further advice should be sought. Any fill placed to raise site levels should also be engineered fill.

4.4.3.1 Engineered Fill Specifications

Any fill used to backfill unstable subgrade areas, raise surface levels or backfill service trenches should be engineered fill. Materials preferred for use as engineered fill are well-graded granular materials, such as ripped or crushed sandstone, free of deleterious substances and having a maximum particle size not exceeding 75 mm. such fill should be compacted in layers not greater than 200 mm loose thickness, to a minimum density of 98% of Standard Maximum Dry Density (SMDD).

The existing sand fill and clays at the site are acceptable for re-use on conditions that the soils used are clean (i.e. free of organics and inclusions greater than 75mm size), and free of contaminants. These soils should be compacted in maximum 200mm loose layers to the required specifications. All clayey fill should preferably be used in the lower fill layers. Thus, the use of any existing clayey fill for engineered fill will entail more rigorous earthwork supervision and compaction control, time for drying out soils and thus, possibly a greater eventual cost for earthworks.

Density tests should be regularly carried out on the fill to confirm the above specifications are achieved. The frequency of density testing should be at least one test per material type per 2500 m^2 or three tests per lot or 1 test per 500 m^3 distributed reasonably evenly throughout full depth and area, whichever requires the most tests. We recommend that Level 1 control of fill compaction, as defined in AS3798-2007, be adhered to on this site. Preferably, the geotechnical testing authority (GTA) should be engaged directly on behalf of the client and not by the earthworks subcontractor.

During construction of the fill, platform runoff should be enhanced by providing suitable falls to reduce ponding of water on the surface of the fill. Ponding of water may lead to softening of the fill and subsequent delays in the earthworks program.

4.5 Earthquake Site Risk Classification

AS 1170.4:2007 indicates that the site is classified with an earthquake subsoil class of Class C_e (Shallow soil site). The hazard factor (z) for Sydney is 0.08.

4.6 FOUNDATIONS

Considering the presence of deep fill, firm clay which is susceptible to settlement and the expected medium to high column loads of the proposed development, it is recommended that all footings for the building and retaining walls (if any) be founded within Unit 4b shale bedrock of similar strength to provide uniform support and reduce the potential for differential settlements.

Footings founded within Unit 4b may be designed for an allowable bearing capacity of 3500kPa, based on serviceability. An allowable shaft adhesion of 10% (5% in uplift) of the allowable bearing capacity may be used. Piles will be required to reach the shale bedrock.

Bored piers are not recommended for this site due to potential difficulties resulting from collapse of the sandy fill and soft soils and the presence of the relatively shallow groundwater levels. However, the use of temporary/sacrificial liners together with tremmie methods may assist in overcoming such difficulties. If bored piers are adopted, we recommend that trial piers be drilled to assess their suitability. Our recommendation is the use of grout injected (CFA) piles.

For piles socketed into the shale bedrock, large capacity piling rigs (e.g. Soilmec SR-40 or larger) will be required. We note that the use of conventional uncased CFA rigs will have a risk of 'draw in' of soils whilst drilling rock sockets. Such 'draw in' of soils can lead to settlement adjacent to the pile which may damage adjacent structures. We recommend further advice be sought from piling contractors who should be provided with a copy of this report. Working platforms may also be required. The proposed pile locations should take into account the presence of buried services.

EI recommends the drilling of additional cored boreholes (at least three) to confirm the depth and quality of bedrock across the site, following demolition of the existing warehouse building.

Geotechnical inspections of foundations are recommended to determine that the required socket lengths have been achieved and founding material has been reached and determine any variations that may occur between the boreholes and inspected locations.

4.7 WALLAP PARAMETERS

Table 4-1 WALLAP Parameters

Unit	Material [1]	Bulk Unit Weight (kN/m^3)	Effective Cohesion, C' (kPa)	Angle of Internal Friction, Φ' (degrees)	Poisson's Ratio	Elastic Modulus E'(MPa)
1	**Fill / Topsoil**	18	0	25	0.3	5-8
2	**Residual Soil**	20	3	25	0.3	20
3	**Fluvial Soil**	19	0	25	0.3	15
4a	**Extremely Low to Very Low Strength Shale**	22	10	30	0.3	100
4b	**Medium Strength Shale**	24	80	40	0.2	800

Notes:
1 For more detailed descriptions of the subsurface conditions, reference should be made to the borehole logs attached to **Appendix A.**

5 RECOMMENDATIONS FOR FURTHER GEOTECHNICAL SERVICES

Below is a summary of the previously recommended additional work that needs to be carried out:

- Additional geotechnical investigation in the form of at least three cored boreholes to confirm the depth and quality of shale bedrock across the site;
- Design of working platforms (if required) for construction plant by an experienced and qualified geotechnical engineer;
- Classification of all excavated material transported off site; and
- Geotechnical inspections of foundations.

We recommend that a meeting be held after initial structural design has been completed to confirm that our recommendations have been correctly interpreted. We also recommend a meeting at the commencement of construction to discuss the primary geotechnical issues and inspection requirements.

6 STATEMENT OF LIMITATIONS

This report has been prepared for the exclusive use of Synergy Development Group Pty Ltd who is the only intended beneficiary of EI's work. The scope of the assessment carried out for the purpose of this report is limited to those agreed with Synergy Development Group Pty Ltd

No other party should rely on the document without the prior written consent of EI, and EI undertakes no duty, or accepts any responsibility or liability, to any third party who purports to rely upon this document without EI's approval.

EI has used a degree of care and skill ordinarily exercised in similar investigations by reputable members of the geotechnical industry in Australia as at the date of this document. No other warranty, expressed or implied, is made or intended. Each section of this report must be read in conjunction with the whole of this report, including its appendices and attachments.

The conclusions presented in this report are based on a limited assessment of conditions, with specific sampling and test locations chosen to be as representative as possible under the given circumstances.

EI's professional opinions are reasonable and based on its professional judgment, experience, training and results from analytical data. EI may also have relied upon information provided by the Client and other third parties to prepare this document, some of which may not have been verified by EI.

EI's professional opinions contained in this document are subject to modification if additional information is obtained through further investigation, observations, or validation testing and analysis during construction. In some cases, further testing and analysis may be required, which may result in a further report with different conclusions.

We draw your attention to the document "Important Information", which is included in **Appendix C** of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by EI, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

Should you have any queries regarding this report, please do not hesitate to contact EI.

7 REFERENCES

AS1170.4:2007, *Structural Design Actions, Part 4: Earthquake Actions in Australia*, Standards Australia.

AS1726:1993, *Geotechnical Site Investigations*, Standards Australia.

AS2159:2009, *Piling – Design and Installation*, Standards Australia.

AS3600:2009, *Concrete Structures,* Standards Australia

Excavation Work Code of Practice – July 2015 – WorkCover NSW,

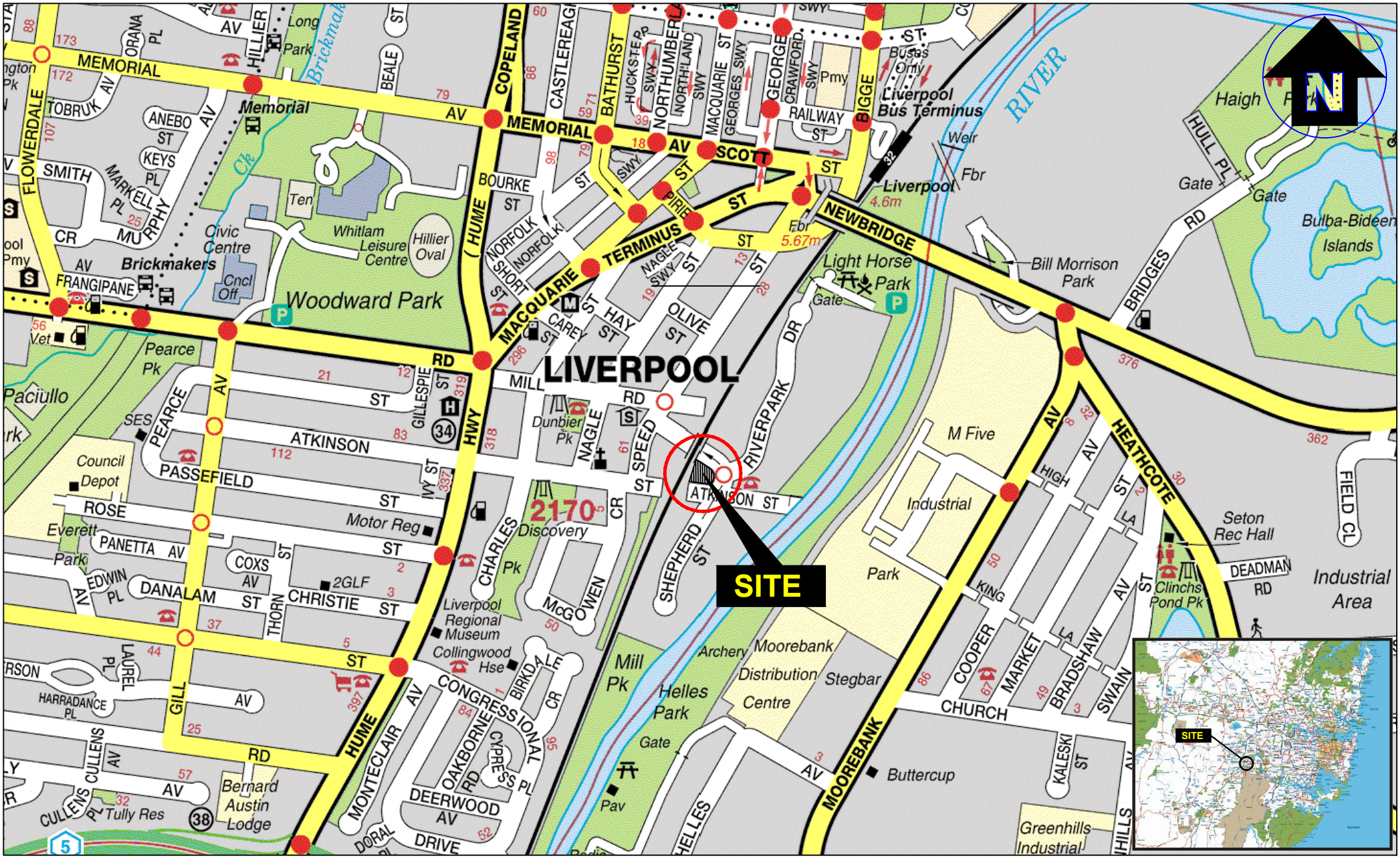
NSW Department of Finance and Service, Spatial Information Viewer, maps.six.nsw.gov.au.

NSW Department of Mineral Resources (1983) Sydney 1:100,000 Geological Series Sheet 9130 (Edition 1). Geological Survey of New South Wales, Department of Mineral Resources.

8 ABBREVIATIONS

AHD	Australian Height Datum
AS	Australian Standard
BEL	Bulk Excavation Level
BEGL	Below Existing Ground Level
BH	Borehole
DBYD	Dial Before You Dig
DP	Deposited Plan
EI	Environmental Investigations Australia Pty Ltd
GA	Geotechnical Assessment
NATA	National Association of Testing Authorities, Australia
RL	Reduced Level
SPT	Standard Penetration Testing
T-C	Tungsten-Carbide
UCS	Unconfined Compressive Strength

FIGURES



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Approx Scale:	N.T.S.

Synergy Development Group Pty Ltd

Geotechnical Assessment

21 Atkinson Street, Liverpool NSW

Site Locality Plan

Figure: 1

Project: E23001 GA_Rev0

LEGEND

- Approximate borehole location
- Approximate site boundary

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Synergy Development Group Pty Ltd
Geotechnical Assessment
21 Atkinson Street, Liverpool NSW

Borehole Location Plan

Figure: 2

Project: E23001 GA

APPENDIX A

BOREHOLE LOGS AND EXPLANATORY NOTES

BOREHOLE: BH1M

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Project	Proposed Mixed-Use Development	East	307979.3 m		
Location	21 Atkinson Street, Liverpool, NSW	North	6243520.9 m MGA94 Zone 56	Sheet	1 OF 2
Position	Refer to Figure 2	Surface RL	9.70 m AHD	Date Started	16/5/16
Job No.	E23001	Contractor	Rockwell Drilling Pty Ltd	Date Completed	16/5/16
Client	Synergy Development Group Pty Ltd	Drill Rig	Hanjin DB8	Logged BY	Date: 16/5/16
		Inclination	-90°	Checked SK	Date: 17/6/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
DT			0	0.12				-	CONCRETE; 120mm thick.	-	-	CONCRETE HARDSTAND
				9.58				-	FILL: Silty CLAY; medium to high plasticity, pale grey, brown with orange-brown to red-brown mottling, with fine to medium subangular gravel.	M (>PL)	-	FILL
				0.50								
AD/T	-	GWNE on completion of augering	1	9.20	SPT 0.50-0.95 m 6,10,14 N=24 BH1_0.5-0.95 PP =300 kPa			CI	Silty CLAY; medium plasticity, pale grey-brown with orange-brown to red-brown mottling, grading into extremely low strength shale.	M (>PL)	H	RESIDUAL SOIL
			2	2.20	SPT 1.50-1.75 m 13,20/100mm HB N>20 BH1_1.5-1.75 PP >600 kPa							
		16/05/16		7.50				-	SHALE; extremely weathered, extremely low strength, pale grey to grey with orange-red iron staining.	-	-	WEATHERED ROCK
			3		SPT 3.00-3.10 m 10/100mm HB N=SPT BH1_3.0-3.1							
			4	4.00	BH1_3.8-4.0 D 3.80-4.00 m				Continued as Cored Borehole			
			5									
			6									
			7									
			8									
			9									
			10									

This borehole log should be read in conjunction with Environmental Investigations Australia's accompanying standard notes.

BOREHOLE: BH1M

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Contamination | Remediation | Geotechnical

Project	Proposed Mixed-Use Development	East	307979.3 m		
Location	21 Atkinson Street, Liverpool, NSW	North	6243520.9 m MGA94 Zone 56	Sheet	2 OF 2
Position	Refer to Figure 2	Surface RL	9.70 m AHD	Date Started	16/5/16
Job No.	E23001	Contractor	Rockwell Drilling Pty Ltd	Date Completed	16/5/16
Client	Synergy Development Group Pty Ltd	Drill Rig	Hanjin DB8	Logged BY	Date: 16/5/16
		Inclination	-90°	Checked SK	Date: 17/6/16

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (Ei 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH 10)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) (10, 30, 100, 300, 1000, 3000)
				0							
				1							
				2							
				3							
				4	*4.00*		Continuation from non-cored borehole				
NMLC	90-95% RETURN	100	87 (81)	5	5.70		SHALE; orange-brown, interbedded with clay.	XW			
					4.32						
					5.38		SHALE; bedding dipping 0-5 degrees, <1-5mm thick, <1-10mm average spacing, grey to dark grey with pale-grey siltstone laminations.	SW - FR		4.41: JT 0° PR RF Fe SN 4.72-4.74: DS 20mm thick 4.83-5.40: BPx3 0° PR RF CN avg sp = 250mm 5.68-5.70: CS 20mm thick 6.70: BP 0° PR RF CN 7.09: JT 0° PR RF CN 7.10: BP 0° PR RF CN 7.63-7.65: DS 20mm thick 8.38: BP 0° PR RF CN 8.82-8.84: DS 20mm thick	
		100	99 (99)	6							
				7							
				8							
				9	*9.00*						
					0.70		Hole Terminated at 9.00 m Borehole converted to monitoring well.				
				10							

This borehole log should be read in conjunction with Environmental Investigations Australia's accompanying standard notes.

CORE PHOTOGRAPH OF BOREHOLE: BH1M

Project:	Proposed Mixed Use Development	East:	307979.3 m	Depth Range:	4.00 m to 9.00 m
Location:	21 Atkinson Street, Liverpool, NSW	North:	6243520.9 m MGA94 Zone 56	Contractor:	Rockwell Drilling Pty Ltd
Position:	Refer to Figure 2	Surface RL:	9.70 m AHD	Drill Rig:	Hanjin DB8
Job No. :	E23001	Inclination:	-90°	LOGGED: BY	DATE: 16/05/16
Client:	Synergy Development Group Pty Ltd	Box:	1 of 1	CHECKED: SK -	DATE: 17/06/16
		Hole Depth:	9.00 m		

BOREHOLE: BH2

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Project	Proposed Mixed-Use Development	East	308046.9 m		
Location	21 Atkinson Street, Liverpool, NSW	North	6243571.1 m MGA94 Zone 56	Sheet	1 OF 3
Position	Refer to Figure 2	Surface RL	9.80 m AHD	Date Started	16/5/16
Job No.	E23001	Contractor	Rockwell Drilling Pty Ltd	Date Completed	16/5/16
Client	Synergy Development Group Pty Ltd	Drill Rig	Hanjin DB8	Logged BY	Date: 16/5/16
		Inclination	-90°	Checked SK	Date: 17/6/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	-	▽	0	9.80				-	TOPSOIL: Silty SAND; fine grained, brown, with roots and root fibres, trace fine to medium subangular gravel.			TOPSOIL
				0.40								
				9.40	SPT 0.50-0.65 m 12 HB N=SPT BH2_0.5-0.65			-	FILL: Silty GRAVEL; dark grey/black slag.	D		FILL
			1	1.00								
				8.80				-	FILL: Gravelly Silty CLAY; low to medium plasticity, orange-brown to yellow-brown, with fine to medium gravel and trace of slag.		-	
					SPT 1.50-1.95 m 5,6,9 N=15 BH2_1.5-1.95 PP =400 kPa					M (>PL)		
			2	2.50								
				7.30				CL	Sandy CLAY; low plasticity, fine to medium grained, pale grey to yellow-brown.			ALLUVIUM
		▽	3		SPT 3.00-3.45 m 4,4,3 N=7 BH2_3.0-3.4 PP =100 kPa BH2_3.4-3.45 PP =200 kPa					M (<PL)	F - St	
				3.40								
				6.40				CI-CH	Silty CLAY; high plasticity, grey, yellow-grown with orage-brown mottling, with roots and root fibres.			
			4									
				4.50								
				5.30	SPT 4.50-4.95 m 3,6,7 N=13 BH2_4.5-4.95 PP =350 kPa				From 4.5m; medium plasticity, grey to yellow-brown			
			5									
				6.00								
				3.80	SPT 6.00-6.45 m 3,5,7 N=12 BH2_6.0-6.45				From 6.0m, high plasticity, grey to yellow-brown with orange-brown mottling.	M (>PL)	St - VSt	
			6									
			7									
					SPT 7.50-7.95 m 4,4,8 N=12 BH2_7.5-7.95							
			8									
				9.00								
			9	0.80				-	SHALE; grey to pale grey with red-brown ironstaining, extremely weathered, extremely low strength.			WEATHERED ROCK
					SPT 9.20-9.40 m 9,15/50mm HB N>15 BH2_9.2-9.4					-	-	
			10									

This borehole log should be read in conjunction with Environmental Investigations Australia's accompanying standard notes.

BOREHOLE: BH2

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Project	Proposed Mixed-Use Development	East	308046.9 m		
Location	21 Atkinson Street, Liverpool, NSW	North	6243571.1 m MGA94 Zone 56	Sheet	2 OF 3
Position	Refer to Figure 2	Surface RL	9.80 m AHD	Date Started	16/5/16
Job No.	E23001	Contractor	Rockwell Drilling Pty Ltd	Date Completed	16/5/16
Client	Synergy Development Group Pty Ltd	Drill Rig	Hanjin DB8	Logged BY	Date: 16/5/16
		Inclination	-90°	Checked SK	Date: 17/6/16

Drilling					Sampling		Field Material Description					
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T	-		10	*10.75*				-	SHALE; grey to pale grey with red-brown ironstaining, extremely weathered, extremely low strength.	-	-	WEATHERED ROCK
									Continued as Cored Borehole			
			11									
			12									
			13									
			14									
			15									
			16									
			17									
			18									
			19									
			20									

This borehole log should be read in conjunction with Environmental Investigations Australia's accompanying standard notes.

BOREHOLE: BH2

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Contamination | Remediation | Geotechnical

Project	Proposed Mixed-Use Development	East	308046.9 m		
Location	21 Atkinson Street, Liverpool, NSW	North	6243571.1 m MGA94 Zone 56	Sheet	3 OF 3
Position	Refer to Figure 2	Surface RL	9.80 m AHD	Date Started	16/5/16
Job No.	E23001	Contractor	Rockwell Drilling Pty Ltd	Date Completed	16/5/16
Client	Synergy Development Group Pty Ltd	Drill Rig	Hanjin DB8	Logged BY	Date: 16/5/16
		Inclination	-90°	Checked SK	Date: 17/6/16

Drilling						Field Material Description				Defect Information	
METHOD	WATER	TCR	RQD (SCR)	DEPTH (metres)	DEPTH RL	GRAPHIC LOG	ROCK / SOIL MATERIAL DESCRIPTION	WEATHERING	INFERRED STRENGTH $Is_{(50)}$ MPa (EL 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH)	DEFECT DESCRIPTION & Additional Observations	AVERAGE DEFECT SPACING (mm) (10, 30, 100, 300, 1000, 3000)
				10							
					10.75		Continuation from non-cored borehole				
NMLC	90-95% RETURN	100	59 (65)	11	-0.95		SHALE; brown to orange-red.	XW			
					11.81						
				12	-2.01		SHALE; bedding dipping 0-5 degrees, <1-6mm thick, <1-15mm average spacing, grey to dark grey with pale-grey siltstone laminations and orange iron-staining.	SW		12.04: JT 0 - 5° PR RF Fe SN closed 12.08: JT 0 - 5° PR RF Fe SN closed 12.20: JT 5° PR S Clay VNR 12.28-12.29: JT2 0 - 5° PR RF Fe SN closed 12.38-12.40: DS 20mm thick 12.50: JT 0° PR RF CN 12.61: JT 0° PR S Clay VNR 12.76-12.77: JT 0 - 5° IR RF CN 12.87: JT 0° PR RF CN	
					12.40						
					-2.60		From 12.4m, no iron staining.	FR			
				13	*13.89*						
				14	-4.09		Hole Terminated at 13.89 m Backfilled with drilling spoil.				
				15							
				16							
				17							
				18							
				19							
				20							

This borehole log should be read in conjunction with Environmental Investigations Australia's accompanying standard notes.

CORE PHOTOGRAPH OF BOREHOLE: BH2

Project:	Proposed Mixed Use Development	East:	308046.9 m	Depth Range:	10.75 m to 13.89 m
Location:	21 Atkinson Street, Liverpool, NSW	North:	6243571.1 m MGA94 Zone 56	Contractor:	Rockwell Drilling Pty Ltd
Position:	Refer to Figure 2	Surface RL:	9.80 m AHD	Drill Rig:	Hanjin DB8
Job No. :	E23001	Inclination:	-90°	LOGGED: BY	DATE: 16/05/16
Client:	Synergy Development Group Pty Ltd	Box:	1 of 1	CHECKED: SK -	DATE: 17/06/16
		Hole Depth:	13.89 m		

EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT LOGS

DRILLING/EXCAVATION METHOD

HA	Hand Auger	**RD**	Rotary blade or drag bit	**NQ**	Diamond Core - 47 mm
DTC	Diatube Coring	**RT**	Rotary Tricone bit	**NMLC**	Diamond Core - 52 mm
NDD	Non-destructive digging	**RAB**	Rotary Air Blast	**HQ**	Diamond Core - 63 mm
AS*	Auger Screwing	**RC**	Reverse Circulation	**HMLC**	Diamond Core - 63 mm
AD*	Auger Drilling	**PT**	Push Tube	**BH**	Tractor Mounted Backhoe
***V**	V-Bit	**CT**	Cable Tool Rig	**EX**	Tracked Hydraulic Excavator
***T**	TC-Bit, e.g. AD/T	**JET**	Jetting	**EE**	Existing Excavation
ADH	Hollow Auger	**WB**	Washbore or Bailer	**HAND**	Excavated by Hand Methods

PENETRATION RESISTANCE

L	**Low Resistance**	Rapid penetration/ excavation possible with little effort from equipment used.
M	**Medium Resistance**	Penetration/ excavation possible at an acceptable rate with moderate effort from equipment used.
H	**High Resistance**	Penetration/ excavation is possible but at a slow rate and requires significant effort from equipment used.
R	**Refusal/Practical Refusal**	No further progress possible without risk of damage or unacceptable wear to equipment used.

These assessments are subjective and are dependent on many factors, including equipment power and weight, condition of excavation or drilling tools and experience of the operator.

WATER

Water level at date shown

Partial water loss

Water inflow

Complete Water Loss

GWNE	GROUNDWATER NOT OBSERVED - Observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave-in of the borehole/ test pit.
GWNO	GROUNDWATER NOT ENCOUNTERED - Borehole/ test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/ test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11 N=18 seating	4,7,11 = Blows per 150mm. N = Blows per 300mm penetration following 150mm
30/80mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
Sampling	
DS	Disturbed Sample
BDS	Bulk disturbed Sample
GS	Gas Sample
WS	Water Sample
U63	Thin walled tube sample - number indicates nominal sample diameter in millimetres
Testing	
FP	Field Permeability test over section noted
FVS	Field Vane Shear test expressed as uncorrected shear strength (sv= peak value, sr= residual value)
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket Penetrometer test expressed as instrument reading in kPa
WPT	Water Pressure tests
DCP	Dynamic Cone Penetrometer test
CPT	Static Cone Penetration test
CPTu	Static Cone Penetration test with pore pressure (u) measurement

ROCK CORE RECOVERY

TCR=Total Core Recovery

$$= \frac{Length\ of\ core\ recovered}{Length\ of\ core\ run} \times 100$$

SCR=Solid Core Recovery (%)

$$= \frac{\sum Length\ of\ cylindrical\ core\ recovered}{Length\ of\ core\ run} \times 100$$

RQD = Rock Quality Designation (%)

$$= \frac{\sum Axial\ lengths\ of\ core > 100mm}{Length\ of\ core\ run} \times 100$$

MATERIAL BOUNDARIES

———— = Inferred Boundary

– – – – – – – – – = Probable Boundary

– ? – ? – ? – ? – ? – = Possible Boundary

METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT LOGS

	FILL		ORGANIC SOILS (OL, OH or Pt)		CLAY (CL, CI or CH)
	COUBLES or BOULDERS		SILT (ML or MH)		SAND (SP or SW)
	GRAVEL (GP or GW)	Combinations of these basic symbols may be used to indicate mixed materials such as sandy clay			

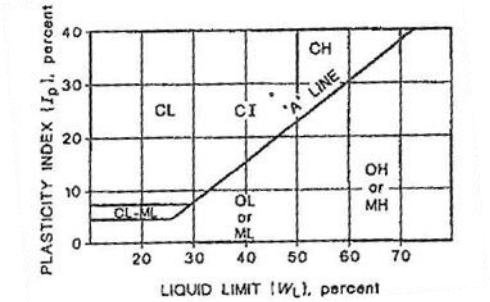
CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil is broadly classified and described in Borehole and Test Pit Logs using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. Material properties are assessed in the field by visual/tactile methods.

PARTICLE SIZE CHARACTERISTICS

Major Division	Sub Division	Particle Size
BOULDERS		>200 mm
COBBLES		63 to 200 mm
GRAVEL	Coarse	20 to 63 mm
	Medium	6 to 20 mm
	Fine	2 to 6 mm
SAND	Coarse	0.6 to 2 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2mm
SILT		0.002 to 0.075 mm
CLAY		<0.002 mm

PLASTICITY PROPERTIES



USCS SYMBOLS

Major Divisions		Symbol	Description
COARSE GRAINED SOILS More than 50% by dry mass less than 63mm is greater than 0.075mm	More than 50% of coarse grains are >2.mm	GW	Well graded gravel and gravel-sand mixtures, little or no fines.
		GP	Poorly graded gravel and gravel-sand mixtures, little or no fines.
		GM	Silty gravel, gravel-sand-silt mixtures.
		GC	Clayey gravel, gravel-sand-clay mixtures.
	More than 50% of coarse grains are <2 mm	SW	Well graded sand and gravelly sand, little or no fines.
		SP	Poorly graded sand and gravelly sand, little or no fines.
		SM	Silty sand, sand-silt mixtures.
		SC	Clayey sand, sandy-clay mixtures.
FINE GRAINED SOILS More than 50% by dry mass less than 63mm is less than 0.075mm	Liquid Limit less < 50%	ML	Inorganic silts of low plasticity, very fine sands, rock flour, silty or clayey fine sands.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
		OL	Organic silts and organic silty clays of low plasticity.
	Liquid Limit > than 50%	MH	Inorganic silts of high plasticity.
		CH	Inorganic clays of high plasticity.
		OH	Organic clays of medium to high plasticity.
		PT	Peat muck and other highly organic soils.

MOISTURE CONDITION

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

Moisture content of cohesive soils may also be described in relation to plastic limit (WP) or liquid limit (WL) [» much greater than, > greater than, < less than, « much less than].

CONSISTENCY

Symbol	Term	Undrained Shear Strength
VS	Very Soft	0. to 12 kPa
S	Soft	12 to 25 kPa
F	Firm	25 to 50 kPa
St	Stiff	50 to 100 kPa
VSt	Very Stiff	100 to 200 kPa
H	Hard	Above 200 kPa

DENSITY

Symbol	Term	Density Index %	SPT "N" #
VL	Very Loose	< 15	0 to 4
L	Loose	15 to 35	4 to 10
MD	Medium Density	35 to 65	10 to 30
D	Dense	65 to 85	30 to 50
VD	Very Dense	Above 85	Above 50

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.
SPT correlations are not stated in AS1726 – 1993, and may be subject to corrections for overburden pressure and equipment type.

MINOR COMPONENTS

Term	Assessment Guide	Proportion by Mass
Trace	Presence just detectable by feel or eye but soil properties little or no different to general properties of primary component	Coarse grained soils: ≤ 5% Fine grained soil: ≤15%
Some	Presence easily detectable by feel or eye but soil properties little or no different to general properties of primary component	Coarse grained soils: 5 - 12% Fine grained soil: 15 - 30%

TERMS FOR ROCK MATERIAL STRENGTH AND WEATHERING

CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil is broadly classified and described in Borehole and Test Pit Logs using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. Material properties are assessed in the field by visual/ tactile methods.

STRENGTH

Symbol	Term	Point Load Index, $Is_{(50)}$ (MPa) #	Field Guide
EL	Extremely Low	< 0.03	Easily remoulded by hand to a material with soil properties.
VL	Very Low	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm can be broken by finger pressure.
L	Low	0.1 to 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of 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.
M	Medium	0.3 to 1	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
H	High	1 to 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken with pick with a single firm blow; rock rings under hammer.
VH	Very High	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
EH	Extremely High	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

 # Rock Strength Test Results

▼ Point Load Strength Index, $Is_{(50)}$, Axial test (MPa)

● Point Load Strength Index, $Is_{(50)}$, Diametral test (MPa)

Relationship between rock strength test result ($Is_{(50)}$) and unconfined compressive strength (UCS) will vary with rock type and strength, and should be determined on a site-specific basis. UCS is typically 10 to 30 x $Is_{(50)}$, but can be as low as 5 MPa.

ROCK MATERIAL WEATHERING

Symbol		Term	Field Guide
RS		Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
EW		Extremely Weathered	Rock is weathered to such an extent that it has soil properties - i.e. it either disintegrates or can be remoulded, in water.
DW	HW	Distinctly Weathered	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. In some environments it is convenient to subdivide into Highly Weathered and Moderately Weathered, with the degree of alteration typically less for MW.
	MW		
SW		Slightly Weathered	Rock slightly discoloured but shows little or no change of strength relative to fresh rock.
FR		Fresh	Rock shows no sign of decomposition or staining.

ABBREVIATIONS AND DESCRIPTIONS FOR ROCK MATERIAL AND DEFECTS

CLASSIFICATION AND INFERRED STRATIGRAPHY

Rock is broadly classified and described in Borehole Logs using the preferred method given in AS1726 – 1993, (Amdt1 – 1994 and Amdt2 – 1994), Appendix A. Material properties are assessed in the field by visual/ tactile methods.

ROCK MATERIAL DESCRIPTION

Layering

Term	Description
Massive	No layering apparent
Poorly Developed	Layering just visible; little effect on properties
Well Developed	Layering (bedding, foliation, cleavage) distinct; rock breaks more easily parallel to layering

Structure

Term	Spacing (mm)
Thinly laminated	<6
Laminated	6 – 20
Very thinly bedded	20 – 60
Thinly bedded	60 – 200
Medium bedded	200 – 600
Thickly bedded	600 – 2,000
Very thickly bedded	> 2,000

ABBREVIATIONS AND DESCRIPTIONS FOR DEFECT TYPES

Defect Type	Abbr.	Description
Joint	JT	Surface of a fracture or parting, formed without displacement, across which the rock has little or no tensile strength. May be closed or filled by air, water or soil or rock substance, which acts as cement.
Bedding Parting	BP	Surface of fracture or parting, across which the rock has little or no tensile strength, parallel or sub-parallel to layering/ bedding. Bedding refers to the layering or stratification of a rock, indicating orientation during deposition, resulting in planar anisotropy in the rock material.
Foliation	FL	Repetitive planar structure parallel to the shear direction or perpendicular to the direction of higher pressure, especially in metamorphic rock, e.g. Schistosity (SH) and Gneissosity.
Contact	CO	The surface between two types or ages of rock.
Cleavage	CL	Cleavage planes appear as parallel, closely spaced and planar surfaces resulting from mechanical fracturing of rock through deformation or metamorphism, independent of bedding.
Sheared Seam/ Zone (Fault)	SS/SZ	Seam or zone with roughly parallel almost planar boundaries of rock substance cut by closely spaced (often <50 mm) parallel and usually smooth or slickensided joints or cleavage planes.
Crushed Seam/ Zone (Fault)	CS/CZ	Seam or zone composed of disoriented usually angular fragments of the host rock substance, with roughly parallel near-planar boundaries. The brecciated fragments may be of clay, silt, sand or gravel sizes or mixtures of these.
Decomposed Seam/ Zone	DS/DZ	Seam of soil substance, often with gradational boundaries, formed by weathering of the rock material in places.
Infilled Seam	IS	Seam of soil substance, usually clay or clayey, with very distinct roughly parallel boundaries, formed by soil migrating into joint or open cavity.
Schistocity	SH	The foliation in schist or other coarse grained crystalline rock due to the parallel arrangement of platy or prismatic mineral grains, such as mica.
Vein	VN	Distinct sheet-like body of minerals crystallised within rock through typically open-space filling or crack-seal growth.

ABBREVIATIONS AND DESCRIPTIONS FOR DEFECT SHAPE AND ROUGHNESS

Shape	Abbr.	Description	Roughness	Abbr.	Description
Planar	Pl	Consistent orientation	Polished	Pol	Shiny smooth surface
Curved	Cu	Gradual change in orientation	Slickensided	SL	Grooved or striated surface, usually polished
Undulating	Un	Wavy surface	Smooth	S	Smooth to touch. Few or no surface irregularities
Stepped	St	One or more well defined steps	Rough	RF	Many small surface irregularities (amplitude generally <1mm). Feels like fine to coarse sandpaper
Irregular	Ir	Many sharp changes in orientation	Very Rough	VR	Many large surface irregularities, amplitude generally >1mm. Feels like very coarse sandpaper

Orientation: **Vertical Boreholes –** The dip (inclination from horizontal) of the defect.
Inclined Boreholes – The inclination is measured as the acute angle to the core axis.

ABBREVIATIONS AND DESCRIPTIONS FOR DEFECT COATING

Coating	Abbr.	Description
Clean	CN	No visible coating or infilling
Stain	SN	No visible coating but surfaces are discoloured by staining, often limonite (orange-brown)
Veneer	VNR	A visible coating of soil or mineral substance, usually too thin to measure (< 1 mm); may be patchy

DEFECT APERTURE

Aperture	Abbr.	Description
Closed	CL	Closed.
Open	O	Without any infill material.
Infilled	-	Soil or rock i.e. clay, talc, pyrite, quartz, etc.

APPENDIX B

LABORATORY CERTIFICATES

MOISTURE CONTENT TEST REPORT

Client:	Environmental Investigations	**Job No:**	S16193
Address:	Suite 6.01, 55 Miller Street, Pyrmont, NSW 2009	**Report No:**	S11636-MC
Project:	21 Atkinson St, Liverpool (E23001)		

Test Procedure:

- ☑ AS 1289 2.1.1 Soil moisture content tests - Determination of the moisture content of a soil - Oven drying method (Standard method).
- ☐ AS4133 1.1.1 Rock moisture content tests - Determination of the moisture content of rock - Oven drying method (standard method)
- ☐ RMS T120 Moisture content of road construction materials (Standard method)
- ☐ RMS T262 Determination of moisture content of aggregates (Standard method)

Sampling:	Sampled by Client	**Date Sampled:**	Unknown
Preparation:	Prepared in accordance with the test method		

Sample No.	Source	Sample Description	Moisture Content %
S11636	BH1_3.0-3.1m	SHALE	**6.7**
S11637	BH1_3.8-4.0m	SHALE	**6.8**
S11639	BH2_7.5-7.95m	sandy CLAY	**19.9**

Notes:

NATA Accredited Laboratory Number: 14874

Authorised Signatory:

Chris Lloyd

31/05/2016

Date:

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Unit 8/10
Bradford Street
Alexandria NSW 2015

SOIL CLASSIFICATION REPORT

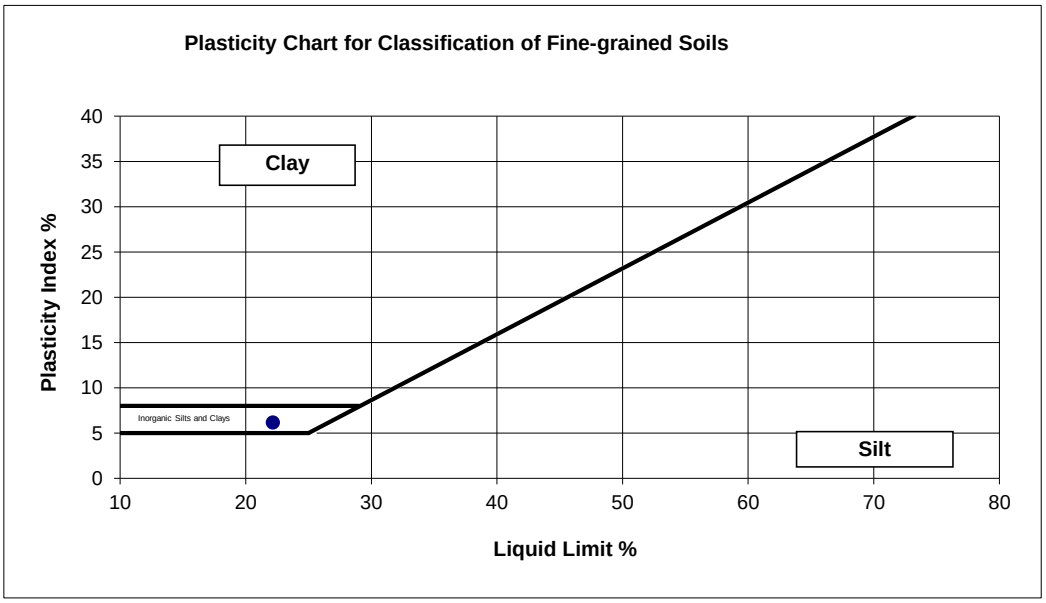
Client:	Environmental Investigations	**Source:**	BH2_3.0-3.4m
Address:	Suite 6.01, 55 Miller Street, Pyrmont, NSW 2009	**Sample Description:**	sandy CLAY
Project:	21 Atkinson St, Liverpool (E23001)	**Report No:**	S11638-PI
Job No:	S16193	**Lab No:**	S11638

Test Procedure:

- ☑ AS1289 2.1.1 Soil moisture content tests (Oven drying method)
- ☐ AS1289 3.1.1 Soil classification tests - Determination of the liquid limit of a soil - Four point casagrande method
- ☑ AS1289 3.1.2 Soil classification tests - Determination of the liquid limit if a soil - One point Casagrande method (subsidiary method)
- ☑ AS1289 3.2.1 Soil classification tests - Determination of the plastic limit of a soil - Standard method
- ☑ AS1289 3.3.1 Soil classification tests - Calculation of the plasticity Index of a soil
- ☑ AS1289 3.4.1 Soil classification tests - Determination of the linear shrinkage of a soil - Standard method

Sampling:	Sampled by Client	**Date Sampled:**	Unknown
Preparation:	Prepared in accordance with the test method		

Liquid Limit (%):	22	**Linear Shrinkage (%):**	2.0
Plastic Limit (%):	16	**Field Moisture Content (%):**	19.9
Plastic Index:	6		



Soil Preparation Method: Dry Sieved
Soil History: Air Dried
Soil Condition: Linear

NATA

The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced, except in full.

NATA Accredited Laboratory Number: 14874

Authorised Signatory:

Chris Lloyd

31/05/2016

Date:

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Alexandria NSW 2015

POINT LOAD STRENGTH INDEX REPORT

Client:	Environmental Investigations	**Moisture Content Condition:**	As Received
Address:	Suite 6.01, 55 Miller Street, Pyrmont, NSW 2009	**Storage History:**	Core Box
Project:	21 Atkinson St, Liverpool (E23001)	**Report No:**	S11640-PL
Job No:	S16193	**Date Tested:**	23.05.16

Test Procedure: ☑ AS4133 4.1 Rock strength tests - Determination of point load strength index

Sampling: Sampled by Client **Date Sampled:** Unknown

Preparation:

Sample Number	Sample Source	Sample Description	Test Type	Average Width (mm)	Platen Separation (mm)	Failure Load (kN)	Point Load Index Is (MPa)	Point Load Index $Is_{(50)}$ (MPa)	Notes
S11640	BH1 4.05m	Shale	Diametral	-	45.0	0.00	0.00	0.00	
			Axial	52.0	13.0	0.01	0.01	0.01	
S11641	BH1 4.60m	Shale	Diametral	-	50.0	0.38	0.15	0.15	
			Axial	52.0	31.0	0.71	0.35	0.33	
S11642	BH1 5.25m	Shale	Diametral	-	51.0	0.02	0.01	0.01	
			Axial	52.0	40.0	1.20	0.45	0.46	
S11643	BH1 5.75m	Shale	Diametral	-	51.0	0.04	0.02	0.02	
			Axial	52.0	39.0	0.74	0.29	0.29	
S11644	BH1 6.25m	Shale	Diametral	-	50.0	1.08	0.43	0.43	
			Axial	52.0	42.0	2.69	0.97	0.99	
S11645	BH1 6.75m	Shale	Diametral	-	50.0	0.45	0.18	0.18	
			Axial	52.0	45.0	1.60	0.54	0.56	
S11646	BH1 7.20 m	Shale	Diametral	-	50.0	0.39	0.16	0.16	
			Axial	52.0	39.0	1.06	0.41	0.41	
S11647	BH1 7.75m	Shale	Diametral	-	50.0	0.87	0.35	0.35	
			Axial	52.0	36.0	1.35	0.57	0.56	
S11648	BH1 8.25m	Shale	Diametral	-	51.0	0.60	0.23	0.23	
			Axial	52.0	36.0	2.30	0.96	0.95	
S11649	BH1 8.75m	Shale	Diametral	-	50.0	0.43	0.17	0.17	
			Axial	52.0	32.0	2.12	1.00	0.96	

Comments:

NATA Accredited Laboratory Number: 14874

Authorised Signatory:

Chris Lloyd

31/05/2016

Date:

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Alexandria NSW

POINT LOAD STRENGTH INDEX REPORT

Client:	Environmental Investigations	**Moisture Content Condition:**	As Received
Address:	Suite 6.01, 55 Miller Street, Pyrmont, NSW 2009	**Storage History:**	Core Box
Project:	21 Atkinson St, Liverpool (E23001)	**Report No:**	S11650-PL
Job No:	S16193	**Date Tested:**	23.05.16

Test Procedure: ☑ AS4133 4.1 Rock strength tests - Determination of point load strength index

Sampling: Sampled by Client **Date Sampled:** Unknown

Preparation:

Sample Number	Sample Source	Sample Description	Test Type	Average Width (mm)	Platen Separation (mm)	Failure Load (kN)	Point Load Index Is (MPa)	Point Load Index $Is_{(50)}$ (MPa)	Notes
S11650	BH2 11.45m	Shale	Diametral	-	47.0	0.00	0.00	0.00	
			Axial	52.0	19.0	0.02	0.02	0.01	
S11651	BH2 11.95m	Shale	Diametral	-	50.0	0.28	0.11	0.11	
			Axial	52.0	17.0	0.53	0.47	0.39	
S11652	BH2 12.45m	Shale	Diametral	-	50.0	0.58	0.23	0.23	
			Axial	52.0	38.0	1.54	0.61	0.61	
S11653	BH2 12.95m	Shale	Diametral	-	51.0	0.52	0.20	0.20	
			Axial	52.0	39.0	1.76	0.68	0.69	
S11654	BH2 13.40m	Shale	Diametral	-	51.0	0.58	0.22	0.22	
			Axial	52.0	45.0	1.83	0.61	0.64	
S11655	BH2 13.80m	Shale	Diametral	-	50.0	0.58	0.23	0.23	
			Axial	52.0	32.0	0.97	0.46	0.44	

Comments:

NATA Accredited Laboratory Number: 14874

Authorised Signatory:

Chris Lloyd

31/05/2016

Date:

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Alexandria NSW

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

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Project	**E23001 21 Atkinson St, Liverpool NSW**
Order Number	**E23001**
Samples	3

LABORATORY DETAILS

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SGS Reference	**SE152317 R0**
Date Received	18/5/2016
Date Reported	24/5/2016

COMMENTS

Accredited for compliance with ISO/IEC 17025. NATA accredited laboratory 2562(4354).

SIGNATORIES

Andy Sutton
Senior Organic Chemist

Dong Liang
Metals/Inorganics Team Leader

pH in soil (1:5) [AN101] Tested: 23/5/2016

PARAMETER	UOM	LOR	BH1_1.5-1.75 SOIL - 16/5/2016 SE152317.001	BH2_3.0-3.4 SOIL - 16/5/2016 SE152317.002
pH	pH Units	-	**8.7**	**8.1**

Conductivity and TDS by Calculation - Soil [AN106] Tested: 23/5/2016

PARAMETER	UOM	LOR	BH1_1.5-1.75 SOIL - 16/5/2016 SE152317.001	BH2_3.0-3.4 SOIL - 16/5/2016 SE152317.002
Conductivity of Extract (1:5 dry sample basis)	µS/cm	1	**100**	**58**

Soluble Anions (1:5) in Soil by Ion Chromatography [AN245] Tested: 19/5/2016

PARAMETER	UOM	LOR	BH1_1.5-1.75 SOIL - 16/5/2016 SE152317.001	BH2_3.0-3.4 SOIL - 16/5/2016 SE152317.002
Chloride	mg/kg	0.25	**73**	**11**
Sulphate	mg/kg	5	**32**	**13**

Moisture Content [AN002] Tested: 19/5/2016

PARAMETER	UOM	LOR	BH1_1.5-1.75 SOIL - 16/5/2016 SE152317.001	BH2_3.0-3.4 SOIL - 16/5/2016 SE152317.002
% Moisture	%w/w	0.5	**14**	**14**

pH in water [AN101] Tested: 20/5/2016

PARAMETER	UOM	LOR	BH1_GW1 WATER - 16/5/2016 SE152317.003
pH**	No unit	-	**6.8**

Conductivity and TDS by Calculation - Water [AN106] Tested: 20/5/2016

PARAMETER	UOM	LOR	BH1_GW1 WATER - 16/5/2016 SE152317.003
Conductivity @ 25 C	µS/cm	2	**7500**

Anions by Ion Chromatography in Water [AN245] Tested: 19/5/2016

PARAMETER	UOM	LOR	BH1_GW1 WATER - 16/5/2016 SE152317.003
Chloride	mg/L	0.05	**1900**
Sulphate, SO4	mg/L	1	**310**

METHOD	METHODOLOGY SUMMARY
AN002	The test is carried out by drying (at either 40°C or 105°C) a known mass of sample in a weighed evaporating basin. After fully dry the sample is re-weighed. Samples such as sludge and sediment having high percentages of moisture will take some time in a drying oven for complete removal of water.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode and is calibrated against 3 buffers purchased commercially. For soils, sediments and sludges, an extract with water (or 0.01M CaCl2) is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Salinity can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. Reference APHA 2510 B.
AN245	Anions by Ion Chromatography: A water sample is injected into an eluent stream that passes through the ion chromatographic system where the anions of interest ie Br, Cl, NO2, NO3 and SO4 are separated on their relative affinities for the active sites on the column packing material. Changes to the conductivity and the UV-visible absorbance of the eluent enable identification and quantitation of the anions based on their retention time and peak height or area. APHA 4110 B

FOOTNOTES

*	NATA accreditation does not cover the performance of this service.	-	Not analysed.	UOM	Unit of Measure.
		NVL	Not validated.	LOR	Limit of Reporting.
**	Indicative data, theoretical holding time exceeded.	IS	Insufficient sample for analysis.	↑↓	Raised/lowered Limit of Reporting.
		LNR	Sample listed, but not received.		

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calculated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical Documents/MP-AU-ENV-QU-022 QA QC Plan.pdf

APPENDIX C

IMPORTANT INFORMATION

Important Information

SCOPE OF SERVICES

The geotechnical report ("the report") has been prepared in accordance with the scope of services as set out in the contract, or as otherwise agreed, between the Client And Environmental Investigations Pty Ltd ("EI"). The scope of work may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

RELIANCE ON DATA

EI has relied on data provided by the Client and other individuals and organizations, to prepare the report. Such data may include surveys, analyses, designs, maps and plans. EI has not verified the accuracy or completeness of the data except as stated in the report. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations ("conclusions") are based in whole or part on the data, EI will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to EI.

GEOTECHNICAL ENGINEERING

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared for a specific client, for a specific project and to meet specific needs, and may not be adequate for other clients or other purposes (e.g. a report prepared for a consulting civil engineer may not be adequate for a construction contractor). The report should not be used for other than its intended purpose without seeking additional geotechnical advice. Also, unless further geotechnical advice is obtained, the report cannot be used where the nature and/or details of the proposed development are changed.

LIMITATIONS OF SITE INVESTIGATION

The investigation programme undertaken is a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions. The data derived from the site investigation programme and subsequent laboratory testing are extrapolated across the site to form an inferred geological model, and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation, the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies. The engineering logs are the subjective interpretation of subsurface conditions at a particular location and time, made by trained personnel. The actual interface between materials may be more gradual or abrupt than a report indicates.

SUBSURFACE CONDITIONS ARE TIME DEPENDENT

Subsurface conditions can be modified by changing natural forces or man-made influences. The report is based on conditions that existed at the time of subsurface exploration. Construction operations adjacent to the site, and natural events such as floods, or ground water fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. EI should be kept appraised of any such events, and should be consulted to determine if any additional tests are necessary.

VERIFICATION OF SITE CONDITIONS

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that EI be notified of any variations and be provided with an opportunity to review the recommendations of this report. Recognition of change of soil and rock conditions requires experience and it is recommended that a suitably experienced geotechnical engineer be engaged to visit the site with sufficient frequency to detect if conditions have changed significantly.

REPRODUCTION OF REPORTS

 Where information from the accompanying report is to be included in contract documents or engineering specification for the project, the entire report should be included in order to minimize the likelihood of misinterpretation from logs.

REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the Client and no other party. EI assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of EI or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own inquiries and obtain independent advice in relation to such matters.

OTHER LIMITATIONS

EI will not be liable to update or revise the report to take into account any events or emergent circumstances or fact occurring or becoming apparent after the date of the report.