Port of Newcastle Operations Pty Ltd

65 Denison Street Development - Carrington

Geotechnical and Mine Subsidence Report

April 2021

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

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1. Introduction

This report presents the results of geotechnical assessment by GHD for a proposed four storey development at 46 Fitzroy Street / 65 Denison Street, Carrington (Lot 33, DP 1078910).

The proposed development is shown on the concept design drawings (Rainsford Architecture and Design, 2020). It comprises a four-storey reinforced concrete framed commercial office building on the western portion of the lot (fronting Fitzroy Street) and areas of on-grade carpark with 12 spaces along Fitzroy Street and 139 spaces on the eastern portion of the site (Denison Street). Additional carparking is provided on ground level of the building. Two vehicular access points are provided off Fitzroy Street with a third off Denison Street.

No basement is proposed with the finished ground level to be at about 2.6 m AHD. A stormwater detention tank is understood to be proposed on the eastern portion of the site with an invert of about 0.9 m AHD.

The work was commissioned by Port of Newcastle Operation Pty Ltd in response to the following GHD proposals:

- GHD 2020a: *46 Fitzroy St Carrington – Development Options. Proposal for mine subsidence and contamination assessment – Rev 1*. 26 March 2020.
- GHD 2021a: *46 Fitzroy Street / 65 Denison Street, Carrington. Proposal for geotechnical assessment – Rev 1*. 2 February 2021.

This report firstly presents the investigation methodology and then the subsurface conditions encountered and various test results. Following that is an interpretation (model) of the subsurface conditions presented in terms of geotechnical units. Lastly, discussion and recommendations on pavement subgrade, building foundations, excavation conditions, acid sulfate soils and mine subsidence are provided. A separate report (GHD 2021b) has been prepared to address contamination and waste classification aspects. This includes findings from an additional 19 'push tube' boreholes to 2.1 m depth across the site.

With respect to mine subsidence, this report follows on from, and should be read in conjunction with, GHD report (GHD 2020b), a copy of which is included in Appendix G.

This report should also be read in conjunction with the General Notes provided in Appendix A.

1.1 Limitations

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2. Investigation methodology

2.1 Preliminaries

A Health, Safety and Environment (HSE) Plan, Job Safety and Environment Analysis (JSEA) and reviewed subcontractor Safe Work Method Statements (SWMS) were prepared and approved prior to conducting investigation fieldwork. All project site personnel were inducted in to the HSE Plan prior to commencing fieldwork by the GHD supervisor as well as completing the Port of Newcastle on-line inductions.

A ‘Dial Before You Dig’ services search was undertaken and reviewed prior to commencement of the fieldwork.

Proposed test locations were set out using a differential GPS by GHD. These locations were then checked for buried services by our sub-contracted service locator SureSearch. SureSearch reports were provided to Port of Newcastle.

2.2 Consultation with Subsidence Advisory NSW

A meeting with Subsidence Advisory NSW (SA NSW) was held on 4 May 2020 to discuss the project concept and subsidence matters. Also attending were representatives from Port of Newcastle, Monteath & Powys and GHD. Minutes of the meeting are included in Appendix H.

At that time the proposal being considered was two buildings, one three-storey office building and the other a two-storey industrial building. In order to provide advice on the need for subsurface site investigation, SA NSW advised they would need to review the desktop study report being prepared at that time. This is now GHD 2020b (included in Appendix G).

Following the meeting with SA NSW, the desktop study report (GHD 2020b) and preliminary cost estimates for the development were completed. The industrial building was not considered commercially viable and the proposal changed to the current four-storey commercial office building and on-grade carparking. Given the change to a four-storey building, Port of Newcastle decided to proceed with the subsurface geotechnical investigations presented herein.

2.3 Desktop studies

GHD 2020b presents the findings of a mine subsidence desktop study which includes information of relevance to geotechnical aspects such as bedrock geology and likely soil profile. This information was supplemented through review of the following:

- 1927 aerial photo obtained from Newcastle Regional Library on-line catalogue
- 1910 *Map of the Country around Newcastle N.S.W*. Lc Cpl A. Barrett (1910)
- *1983 -1995 History of Carrington*. Transcript. Coulin (undated)
- Acid sulfate soil risk map. Accessed through eSPADE

The findings of the geotechnical desktop study are presented in Section 3 with references provided in Section 9.

2.4 Fieldwork

Geotechnical investigation fieldwork was undertaken between the 22nd of February and the 4th of March 2021 and comprised drilling of four 2 m deep boreholes (GBH1, GBH2, GBH7 and GBH8), two 16 m deep boreholes (GBH3 and GBH4), two 60+ m mine subsidence boreholes (GBH5 and GBH6) and five piezocone penetrometer tests (CPT1 to CPT5).

CPTs were conducted on the 12th of February 2021 and were undertaken by NEWSYD with a truck mounted rig from the University of Newcastle with a 20 tonne piezocone.

The boreholes were conducted with a truck mounted geotechnical drilling rig. They were initially advanced through the soil profile using 100 mm diameter solid flight augers. At about 2.5 m depth, wash boring methods were used to advance the boreholes down to the top of rock. Each borehole was extended into rock using HQTT diamond rock coring techniques. Whilst the logs of the boreholes should be referred to for details, briefly:

- In GBH5: interbedded siltstone and sandstone was encountered at 50.5 m and extended to 63.5 m where a void was intercepted which extended to 65 m depth. Due to the presence of the void, the borehole was discontinued.
- In GBH6: interbedded siltstone and sandstone was encountered at 48.6 m and extended to 66.1 m where the Borehole Seam coal was encountered and extended for 5 m before hitting the underlying Waratah Sandstone at 71.1 m.

Standard Penetration Tests (SPTs) were conducted in GBH3 and GBH4 to assist with sub-surface characterisation and sampling. Tube samples, (U50s) were taken in GBH3, GBH4 and GBH6 at selected depths to target sampling of cohesive soil identified from review of CPT data.

GBH5 and GBH6 were logged with a wireline tool by GHD sub-contractor Groundsearch. The tool comprised Acoustic Televiewer (ATV), inclination, sonic calliper, deviation and natural gamma.

GBH5 and GBH6 were grouted to the surface. Given the void in GBH5 at 63.5 m depth, a “Van Ruth” plug was inserted in the borehole at 52 m depth prior to grouting above it.

Fieldwork was supervised on a full-time basis by GHD geotechnical team members and overseen by an experienced GHD Geotechnical Engineer. The GHD field supervisors were responsible for locating the CPTs, boreholes, boxing rock core, logging the encountered strata, directing in-situ testing and collecting representative samples for laboratory testing.

The CPT and borehole locations are shown on Figure 1 in Appendix B and listed with termination depths in Table 2-1. Ground surface levels at test locations were estimated using the site survey plan provided (Rainsford Architecture and Design, 2020).

Table 2-1 Test location summary

Test location	Coordinates (MGA2020)		Surface level (m AHD) ± 0.1 m	Termination depth (m)
	Easting (m)	Northing (m)		
GBH1	384,448.9	6,357,153.1	1.9	2.0
GBH2	384,483.1	6,357,094.9	2.1	2.0
GBH3	384,413.1	6,357,124.9	2.0	16.0
GBH4	384,424.9	6,357,090.0	2.1	16.4
GBH5	384,463.9	6,357,114.1	2.2	63.5
GBH6	384,414.9	6,357,104.9	2.1	74.0
GBH7	384,407.0	6,357,069.1	2.4	2.0
GBH8	384,387.0	6,357,132.0	2.1	2.0
CPT1	384,398.0	6,357,125.1	1.9	19.0
CPT2	384,428.0	6,357,135.9	2.1	9.4
CPT3	384,413.1	6,357,080.9	2.1	11.2
CPT4	384,443.1	6,357,091.1	1.9	9.7
CPT5	384,419.0	6,357,108.1	2.1	10.9

The borehole logs and core photograph are provided in Appendix C. The logs should be read in conjunction with the Standard Sheets provided in Appendix A, which explain the terms, abbreviations and symbols used together with the interpretations and limitations of the logging and testing procedures.

CPT reports are provided in Appendix D. Wireline logs are provided in Appendix E.

2.5 Laboratory testing

Selected soil samples were submitted to GHD's NATA registered laboratory for geotechnical testing and to a NATA accredited environmental laboratory for soil aggressivity and Acid Sulfate Soil (ASS) testing.

The soil aggressivity suite included pH, sulfate, electrical conductivity and chloride tested in a 1:5 soil to water ratio. The results allow consideration of durability requirements as required by Australian Standard AS2159-2009 *Piling – Design and installation*.

ASS testing comprised six field screening tests (undertaken by the environmental laboratory) and three Chromium Reducible Sulfur tests.

Point load strength index (rock) testing was undertaken at regular (typically 1.5 m) depth intervals on recovered rock core.

Geotechnical testing for soil classification and pavement design comprised the following:

- 4 field moisture content tests
- 4 particle Size Distribution tests
- 4 Standard Compaction tests
- 4 California Bearing Ratio tests

U50 tube samples were extruded in our Artarmon laboratory and each sample tested for undrained shear strength, photographed and described by a GHD laboratory geotechnician. The results of this work has been incorporated into the borehole logs.

The laboratory test results are summarised in Section 4. The laboratory report sheets are provided in Appendix F while the point load strength index tests are presented graphically on the borehole logs in Appendix C.

3. Site setting and desktop findings

3.1 Natural versus existing site setting

The natural (pre-development) landscape in this area comprised low lying tidal mangrove swamps (Coulin, undated). In this estuarine environment, fine grained clay and silt “muds” would have been deposited and would likely contain organics and shells. The surface elevation at this time would have been about 0 to 0.5 m relative to Australian Height Datum (AHD).

The existing surface elevation varies between about 1.8 m AHD in the northeast corner to about 2.7 m AHD in the southwest corner. As such, it is expected that at least about 1.3 m to 2.7 m of fill thickness exists across the site with this fill underlain by fine grained estuarine soils of low strength. The reclamation of the site and placement of fill took place prior to 1910 and comprised “Sandy soil” (Barrett, 1910). Subsequent filling associated with site development has occurred with the ground surface now notably covered with topsoil or gravel.

The site is currently vacant although the concrete slab from the previous building remains on the eastern portion of the site. Remnants of drains and buried services are present on the western site of the site.

3.2 Acid sulfate soils (ASS)

ASS risk mapping (eSPADE) shows the site is located in an “X4: Disturbed terrain” region. The area west of Throsby Creek is mapped as “H2: High probability 1 - 3 m below ground. Based on this, it is highly probably that the natural estuarine and marine soils underling the fill are ASS.

3.3 Geology

Geology maps and historical mining records indicate the site is underlain by alluvial soils.

Bedrock is expected to be interbedded sandstone and siltstone with minor tuffaceous beds and carbonaceous laminations of the Lambton Formation. This includes the Borehole Seam at about 65 m depth and below this the Waratah Sandstone unit, the base (oldest unit) of the Newcastle Coal Measures.

The mine plan, Record Tracing RT579, indicates a Borehole Seam dip of 1 in 40 (1.4°) to the southeast

RT579 and another mine plan (M12137) show a fault passing through the Borehole Seam beneath the site with RT579 indicating a 6 foot (~1.8 m) displacement with the downside on the east as indicated by convention with the direction of the arrow. However, underground survey spot levels of the mine roof shown on these plans indicate the difference in roof level across the fault is 0.73 m with the downside on the west (GHD 2020b – Section 2.2).

As discussed in Section 5, the subsurface conditions encountered by the investigation presented herein are broadly consistent with the above expectations with rock encountered at 44 m to 49 m depth and the top of the Borehole Seam at about 66 m depth (GBH6).

Displacement across the fault is also discussed in Section 5 with a 1.8 m difference, downside on the west being our interpretation based on the mining records and stratigraphic correlation between GBH5 and GBH6.

3.4 Coal mining

The site is undermined by abandoned mine workings in the Borehole Seam at about 64 to 66 m depth (this investigation). Mining occurred between 1884 to 1904 at the Wickham and Bullock Island Colliery (GHD 2020b).

The subject site and surrounding area is within a gazetted mine subsidence district administered by Subsidence Advisory NSW (SA NSW) under the Coal Mine Subsidence Compensation Act 2017. SA NSW is an approval authority for surface improvements.

Reference should be made to GHD 2020b in Appendix G for detail of the mine subsidence desktop study.

4. Laboratory test results

4.1 Geotechnical earthworks tests

Moisture content, Standard Compaction, California Bearing Ratio (CBR) and particle size distribution test results are summarised in the below tables with brief material descriptions provided for each. Reference to the borehole logs in Appendix C should be made for a detailed description of these samples. The laboratory report sheets are provided in Appendix F.

Table 4-1 Particle size distribution test results

Test location	Sample depth (m)	Material	Distribution by mass		
			Clay/Silt (%)[1]	Sand (%)	Gravel (%)
GBH1	0.85 – 1.5	FILL: SAND, fine to medium, dark grey	5	90	5
GBH2	0.4 – 2.0	FILL: SAND, medium, pale grey	2	88	10
GBH7	0.5 – 1.5	FILL: SAND, medium, brown	3	94	3
GBH8	0.6 – 1.2	FILL: SAND, fine to medium, dark brown	7	85	8

1. Testing of fines comprised conventional sieve or wash sieve test methods. The clay and silt proportions were not determined individually and are combined – i.e. percent passing 75 micron sieve.

The results of the particle size distribution testing indicate the tested alluvial marine samples were fine to medium grained sand with 7% or less fines (silt and clay).

Table 4-2 Moisture Content, Standard Compaction and CBR test results

Sample Location	Sample Depth (m)	Material description	FMC (%)	OMC (%)	MDD (t/m^3)	CBR (%)
GBH1	0.85 – 1.5	FILL: SAND, fine to medium, dark grey	9.5	11.5	1.79	16
GBH2	0.4 – 2.0	FILL: SAND, medium, pale grey	9.2	13.0	1.74	30
GBH7	0.5 – 1.5	FILL: SAND, medium, brown	9.0	13.0	1.67	11
GBH8	0.6 – 1.2	FILL: SAND, fine to medium, dark brown	5.5	10.5	1.83	14

FMC = Field Moisture Content   MDD = Standard Maximum Dry Density

CBR = California Bearing Ratio   OMC = Standard Optimum Moisture Content

The Standard Compaction tests indicate that the tested materials possessed field moisture contents well dry of optimum moisture content with standard maximum dry densities from 1.67 to 1.83 t/m^3.

CBR test results ranged from 11% to 30% but were typically 11% to 16%.

4.2 Soil aggressivity tests

Soil aggressivity test results are summarised in the following table. The laboratory report sheets are provided in Appendix F.

Table 4-3 Soil aggressivity test results

Test location	Sample depth (m)	Material	FMC (%)	EC (µS/cm)	pH	SO_4 (mg/kg)	Cl (mg/kg)
GBH1	0.45	FILL: SAND, fine to medium, brown	15.6	91	8.6	10	10
GBH2	1.4	CH: Sandy CLAY, dark brown	19.6	413	8.1	870	30
GBH3	1.5 - 1.95	CI: Sandy CLAY, grey to dark grey	42.6	196	8.0	190	50
GBH3	3.0 - 3.45	SP: SAND, medium, brown to grey	21.5	98	8.9	120	20
GBH4	1.5 - 1.95	CI: Gravelly CLAY, brown to grey	27.9	240	8.4	130	20
GBH7	1.6	CI: CLAY, dark grey	33.4	232	8.7	300	190

FMC = Field Moisture Content; SO_4 = Sulfate; Cl = Chloride; EC = Electrical conductivity; pH from 1:5 soil water ratio

Discussion relating to the soil aggressivity test results are provided in Section 6.1.

4.3 Acid sulfate soil test results

Acid sulfate soil (ASS) testing was undertaken on selected soil samples. Initially, screening tests were undertaken and following this, Chromium Reducible Sulfur test suites on selected samples. The laboratory report sheets are provided in Appendix F.

The screening results are summarised in Table 4-4.

Table 4-4 Acid sulfate soil field screening results (Ahern et al, 2004)

Test location	Sample depth (m)	Material	pH_F	pH_{Fox}	pH change	Reaction rate
GBH1	0.45	FILL: SAND, fine to medium, brown	8.9	6.1	**2.8**	2
GBH2	1.4	CH: Sandy CLAY, dark brown	8.0	5.7	**2.3**	2
GBH3	1.5 - 1.95	CI: Sandy CLAY, grey to dark grey	8.0	**1.9**	**6.1**	**3**
GBH3	3.0 - 3.45	SP: SAND, medium, brown to grey	8.0	4.6	**3.4**	1
GBH4	1.5 - 1.95	CI: Gravelly CLAY, brown to grey	8.7	5.5	**3.2**	2
GBH7	1.6	CI: CLAY, dark grey	8.8	**2.2**	**6.6**	**4**

Where: pH_F = Field pH measurement (undertaken by laboratory) – 1:5 soil water ratio

pH_{Fox} = Field pH measurement after peroxide oxidation (undertaken by laboratory)

Oxidation reaction rate: 1 – slight, 2 – moderate, 3 – strong, 4 – extreme.

Bold values indicate potential acid sulfate soil

Based on the above ASS screening test results and considering the locations and depths of soils expected to be disturbed by the proposed development, the three samples listed in Table 4-5 were selected for Chromium Reducible Sulfur testing.

Table 4-5 ASS Chromium Reducible Sulfur (Scr) suite test results

Test location	Sample depth (m)	Material	Potential Acidity (as S) (mol H^+/t)	Actual Acidity (mol H^+/t)	Net Acidity (mol H^+/t)
GBH1	0.45	FILL: SAND, fine to medium, brown	15	< 2	< 10
GBH3	1.5 - 1.95	CI: Sandy CLAY, grey to dark grey	537	< 2	**283**
GBH7	1.6	CI: CLAY, dark grey	814	< 2	**470**

Where: Scr = Chromium Reducible Sulfur. Liming rate based on laboratory calculation

Bold values indicate exceedance of action criteria (18 mol H^+/t) (National Acid Sulfate Soils Guidance, National acid sulfate soils identification and laboratory methods manual, Australian Government, 2018)

5. Sub-surface conditions

5.1 Soil and general bedrock

Reference should be made to the borehole logs in Appendix C for a more detailed description of the subsurface conditions encountered in the boreholes as well as the CPT plots in Appendix D and wireline logs in Appendix E.

In general terms the encountered conditions comprised uncontrolled fill to between 1.2 to 1.6 m depth (to 0.4 to 1.0 m AHD) underlain by estuarine clay/silt and marine sand layers to about -1.8 to -3.3 m AHD. A 10 to 13 m thick, dense to very dense sand unit was encountered beneath this with density generally increasing with depth. Lenses of clay / clayey sand within this sand layer resulted in distinct drops in density / consistency as shown on the CPT plots.

At about -12.8 to -13.8 m AHD beneath the proposed building, the above sand layer abruptly transitioned to stiffer estuarine clay that is likely of Lower Holocene or possibly Pleistocene age. This thick clay layer extends to residual clay soils and/or weathered bedrock.

Groundwater was encountered between 0.23 to 0.55 m AHD (1.6 to 1.7 m depth) in the CPT holes and between 0.58 and 1.1 m AHD (1.0 to 1.6 m depth) in the boreholes. The higher groundwater levels in the boreholes are likely due to higher recent rainfall and so may be higher than normal. However, even higher groundwater levels should be anticipated during prolonged and heavy rainfall.

For descriptive purposes, the encountered strata have been grouped into the following geotechnical units:

- Unit 1 – Fill
- Unit 2a – Holocene Estuarine Clay
- Unit 2b – Holocene Marine Sand - upper
- Unit 2c – Holocene Estuarine Clay
- Unit 3 – Holocene Marine sand - lower
- Unit 4 – Lower Holocene? Clay
- Unit 5 – Permian - Interbedded siltstone / sandstone with coal seams

The distribution of the above units as encountered is summarised in Table 5-1.

Table 5-1 Distribution of units encountered

Test location	Unit base level AHD and (thickness)						
	Unit 1	Unit 2a	Unit 2b	Unit 2c	Unit 3	Unit 4	Unit 5
GBH1	0.38 (1.5)	0.13 (0.25)	ne	ne	ne	ne	ne
GBH2	0.85 (1.3)	0.65 (0.20)	ne	ne	ne	ne	ne
GBH3	0.55 (1.5)	0.20 (0.35)	-1.35 (1.55)	-2.3 (0.9)	-13.5 (11.3)	ne	ne
GBH4	0.55 (1.6)	0.20 (0.35)	-1.25 (1.45)	-2.1 (0.85)	-13.8 (11.7)	ne	ne
GBH5	0.98 (1.2)	0.88 (0.1)	-1.0 (1.90)	?	-14.2 (?)	-46.9 (32.8)	loi
GBH6	0.69 (1.4)	0.29 (0.4)	-1.1 (1.4)	-2.3 (1.2)	-13.6 (10.4)	-41.7 (28.1)	loi
GBH7	0.59 (1.8)	ne	ne	ne	ne	ne	ne
GBH8	0.36 (1.7)	ne	ne	ne	ne	ne	ne
CPT1	0.43 (1.5)	0.3 (0.1)	-0.57 (0.9)	-1.8 (1.2)	-12.8 (11.0)	ne	ne
CPT2	0.65 (1.5)	0.5 (0.2)	-0.45 (0.9)	-2.0 (1.5)	ne	ne	ne
CPT3	0.65 (1.5)	0.1 (0.6)	-0.75 (0.8)	-2.3 (1.5)	ne	ne	ne
CPT4	0.75 (1.2)	0.5 (0.3)	-0.55 (1.0)	-1.8 (1.2)	ne	ne	ne
CPT5	0.66 (1.4)	0.3 (0.4)	-0.84 (1.1)	-2.3 (1.5)	ne	ne	ne
ne = not encountered; loi = limit of investigation							

The pertinent aspects of the geotechnical units are described below.

Unit 1 – Fill

Typically SAND, fine to medium grained and often with shells and shell fragments and some gravel / gravelly layers. Variable surface layers, with gravel and topsoil typically less than 0.2 m thick.

CPT results indicate the sand is typically dense to very dense but variability is expected. That is: the characteristics and strength of uncontrolled fill will be variable.

Unit 2a – Holocene Estuarine Clay

This thin layer appears to be the natural ground surface. Typically it is a firm, high plasticity Sandy Clay and contains shell fragments and organic matter.

This unit has been confirmed through laboratory testing to be an Acid Sulfate Soil.

Unit 2b – Holocene Marine Sand – upper

Typically SAND, medium to coarse grained with shell fragments and trace of whole shells, Typically dense.

Unit 2c – Holocene Estuarine Clay

An interbedded unit of Sandy Clay, Silty Sand and Clayey Sand layers of firm consistency or medium density respectively.

Potentially Acid Sulfate Soil but not confirmed.

Unit 3 – Holocene Marine sand – lower

Typically SAND, medium to coarse grained with shell fragments. Increasing in density from medium dense to dense and then very dense to about -7 m AHD and remaining very dense.

With the exception of CPT1, all CPTs refused in this layer at between about -7 and -9 m AHD.

The base of Unit 3 appears to be relatively abrupt based on the CPT1 data.

Unit 4 – Lower Holocene Clay

This appears to be a relatively uniform stiff to hard (typically very stiff), high plasticity clay. From previous investigations in the Newcastle harbour area, it is known to be fissured.

Unit 5 – Permian siltstone / sandstone (Lambton Formation and Waratah Sandstone)

The interbedded siltstone and sandstone Lambton Formation is typically of medium to high strength and contains abundant carbonaceous laminations and frequent tuffaceous claystone bands. Several coal seams are known to exist but only the Borehole Seam was encountered.

The Borehole Seam is the lowest (oldest) seam in the Newcastle Coal Measures and is underlain by the Waratah Sandstone which was only encountered in GBH6.

5.2 Fault, survey traverse and mine roof convergence

5.2.1 Fault interpretation

As shown on Figure 2 and Figure 3 in Appendix B, mine plans RT579 and M12137 both show a fault passing beneath the site at mine level. RT579 shows the fault to have a displacement of 6 feet (~1.8 m) with the arrow pointing east, which is assumed to indicate the down throw side by convention. That is, the strata is lower on the eastern side of the fault. It would appear that this 1.8 m is probably the true fault displacement (on dip) rather than the vertical fault throw. For 1.8 m displacement and dip of 60°, the throw would be about 1.5 m for example.

The type of fault (normal or reverse) is not indicated on the plans. However, given its similar orientation (strike) to normal faults in the area shown on geology maps, short length on a regional scale and relatively minor disruption to the mine layout, it is judged to be a normal fault, dipping toward the northeast at 60° to 90°. At dip of 70° is shown on Figure 4 in Appendix B.

The faulted zone encountered in GBH5 between about 59.3 m to 60.5 m depth discussed in Section 5.3 is interpreted to be associated with the fault shown on the mine plans but not the same fault plane. It is likely to be a minor parallel normal fault and is also shown on Figure 4 with an assumed dip of 70°.

5.2.2 Survey roof levels and roof convergence

A comparison of spot levels from RT579 and M12137 where they are shown on the mine plans (red text on mine plans) at locations surrounding the site is reproduced below from GHD 2020b.

Table 5-2 Mine roof spot levels (below high water mark)

<table>
<tr><th>Spot level label on plans</th><th>Location</th><th>RT579</th><th>M12137</th><th>Difference</th></tr>
<tr><td>2a</td><td rowspan="2">western of site along the “Engine Road” – west of fault</td><td>221.84 feet (67.6 m)</td><td>221.8 feet (67.6 m)</td><td>No difference</td></tr>
<tr><td>483</td><td>225.60 feet (68.8 m)</td><td>224.86 feet (68.5 m)</td><td>RT579 roof is 0.23 m lower</td></tr>
<tr><td>483a</td><td>south of site along “first left hand heading” – west of fault</td><td>227.05 feet (69.2 m)</td><td>-</td><td rowspan="2">RT579 roof west of fault at 483a is 0.73 m lower than M12137 roof east of fault at 495 despite being only about 20 m away</td></tr>
<tr><td>495</td><td>south of site along “first left hand heading” – east of fault</td><td>-</td><td>224.64 feet (68.5 m)</td></tr>
<tr><td>Between 495 and 496</td><td rowspan="2">southeast of site along “first left hand heading” – east of fault</td><td>227.80 feet (69.4 m)</td><td>-</td><td>0.23 m lower than at 483a on RT579</td></tr>
<tr><td>496</td><td></td><td>231.32 feet (70.5 m)</td><td>1.1 m lower than at between 495 and 496 on RT579</td></tr>
</table>

The above roof levels agree generally with a seam dip of 1 in 40 (1.4°) to the southeast between the winding shaft and fan shaft as indicated on RT579.

The roof level west of the fault would be expected to be 0.9 m to 1.8 m higher than the east side on account of the fault. However, there are also differences between RT579 and M12137 with RT579 indicating roof levels about 0.7 m lower (survey station 483a) on the west side of the fault. This is interpreted to be due to roof convergence that occurred between when the M12137 transverse and when the RT579 surveys were undertaken. Comparison to the top of seam level encountered in GBH6 to the levels shown on RT579 and M12137 has not been attempted as the available levels are too far from GBH6 to allow such a comparison reliably.

Plan M12137 shows a mine survey traverse, survey stations and an area of dashed pillars as reproduced in Figure 5-1. These features are discussed below.

5.2.3 Dashed pillars and roof convergence

The existence of a ‘creep’ (area of crushed pillars resulting in roof convergence) is indicated on M12137 by dashed pillars as shown on Figure 5-1. Similar areas of dashed pillars in other parts of the mine are shown on M12137 with survey traverse lines going around them also. Presumably because they were deemed unsafe to enter or were not accessible. This relevance of this is discussed further in Section 8.

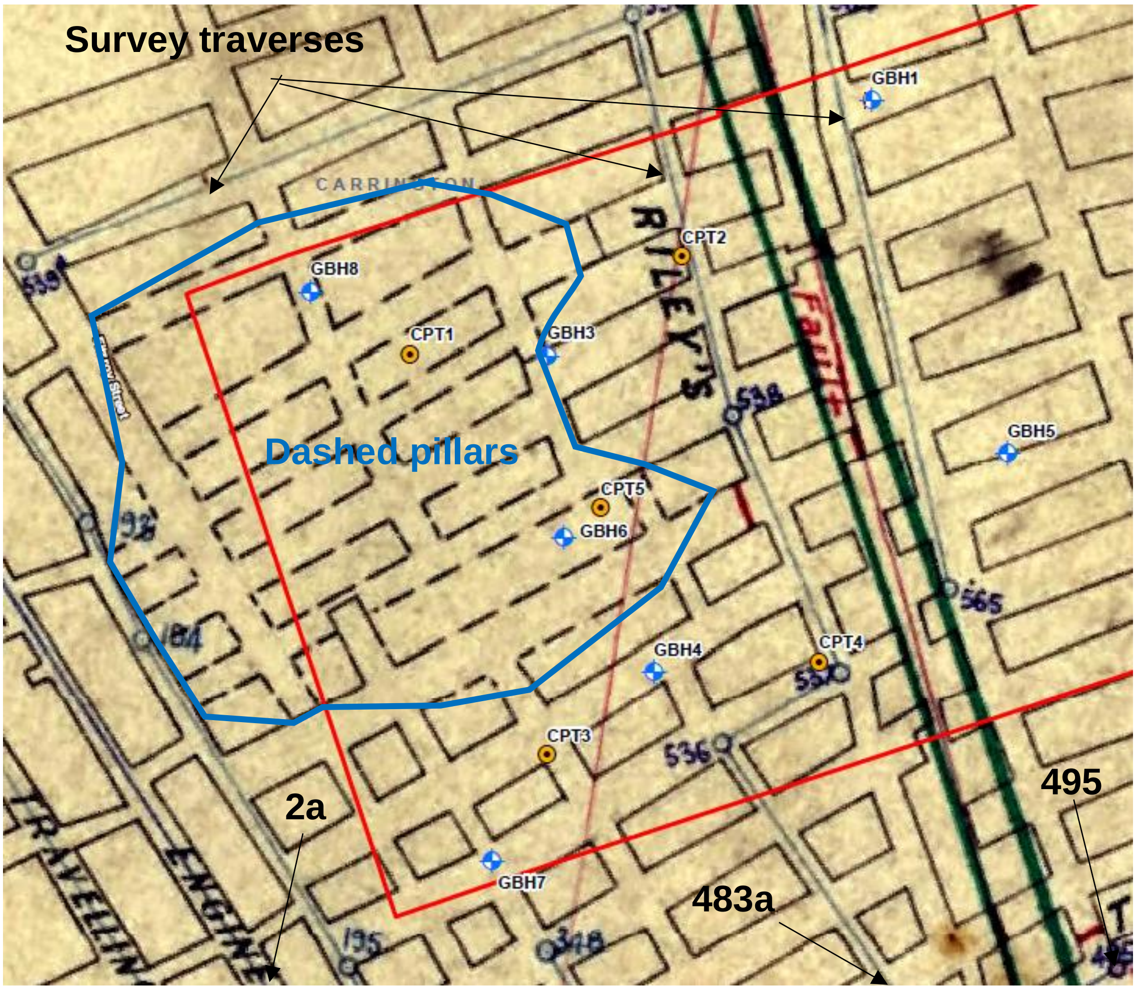

Figure 5-1 Extract from Figure 2 showing survey traverse and dashed pillars

5.2.4 Summary of Borehole Seam levels

In summary, west of the fault the top of the Borehole Seam was naturally about 1.5 to 1.8 m higher (depending on inferred fault dip) than east of the fault. During mining, the coal pillars became over stressed and began to crush resulting in the mine roof and hence top of the Borehole Seam to converge by about 0.7 m west of the fault. Later, probably post mine closure, it is inferred that pillar crushing and roof convergence east of the fault likely lowered the overburden strata in that area also.

The top of void in GBH5 is at -61.5 m AHD (from the geophysics calliper log) and the top of the Borehole Seam at GBH6 is at -64.2 m AHD (from the geophysics gamma log). Taking into account the estimated 1.5 to 1.8 m difference in levels due to the fault and apparent stratigraphic dip, the void encountered in GBH5 is expected to be about 5 m above the top of the Borehole Seam as shown in Figure 4 in Appendix B.

5.3 Stratigraphic correlation between GBH5 and GBH6

To further assess the potential for subsidence east side of the fault, correlation of stratigraphic markers in the core has been made as shown in the photo comparisons included in Appendix C and Figure 4 in Appendix B.

GBH6 is interpreted to not be intersected by a fault while GBH5 is interpreted to be faulted between about 59.3 m to 60.5 m depth. The fault in GBH5 makes correlation to GBH6 difficult through and below this faulted zone and no reliable correlations were achieved.

The correlation exercise indicates a difference in level between stratigraphic markers of about 2.6 m increasing with depth to around 3.4 m (GBH6 higher). About 1 m difference is attributed to stratigraphic dip, leaving up to about 1.9 m difference due to the fault, variability in strata thickness, local variation in stratigraphic dip, logging error, displacement at other faults and/or roof convergence. It is not possible to reliably attribute how much of these various factors contribute to the additional difference in levels beyond the 1.5 to 1.8 m attributed to the fault.

5.4 Subsidence fracturing and void in GBH5

Evidence of subsidence induced fracturing was observed in both borehole cores. The subsidence fractures generally presented as high angled clean fractures, many of which are visible in the core photographs and have been noted on the borehole logs. Additionally, the presence of subsidence induced fractures was observed through difficult drilling conditions (short core runs and core loss) in both the overburden rock and crushed coal in GBH6.

The following observations are made:

- Subsidence induced fractures are present throughout the cored sections of both GBH5 and GBH6
- There is a greater concentration of fractures in the 2 to 4 m above the Borehole seam/void
- In GBH5, the fractures dip to the north east, east and south east
- In GBH6, the fracture dip was not generally observable from the acoustic televiewer log. The fracture at 65.4 m depth dips toward the south-south-west, another at 65.25 m depth dips toward the south-east.

The observed fractures are attributed to roof convergence and mine subsidence that has propagated through the overburden rock and to the ground surface. The direction of fracture dips generally toward the east suggests roof convergence propagated from west to east, similar to the pattern of cracking from longwall mining as shown in the figure below.

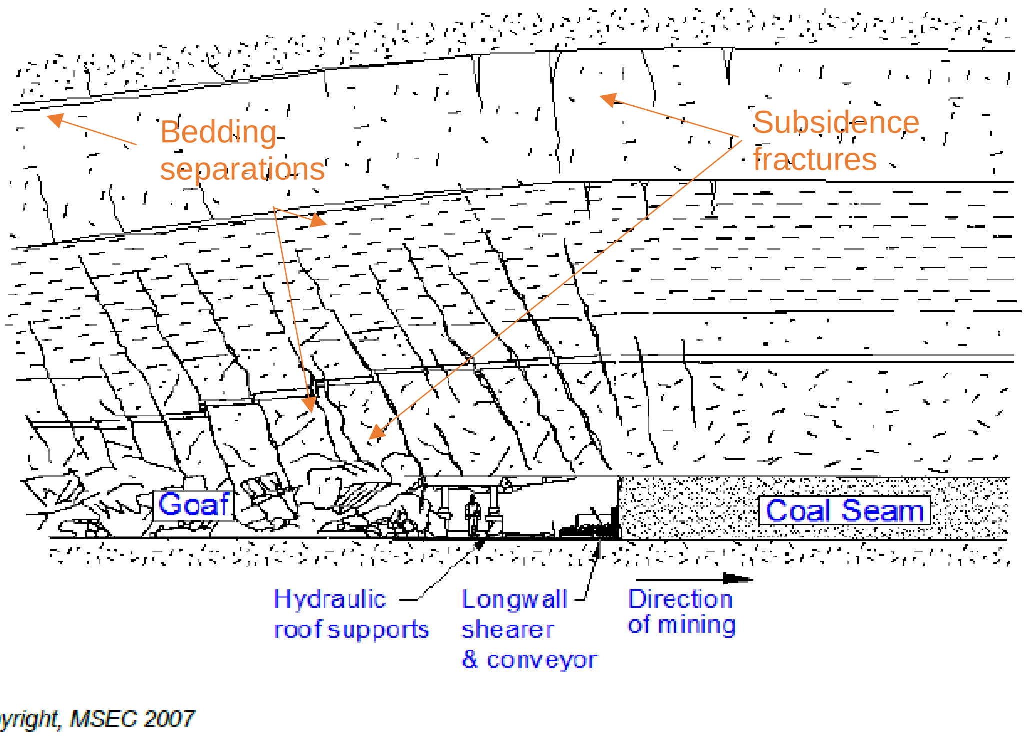

Figure 5-2 Typical fracture pattern from longwall caving (orange annotation by GHD)

The void encountered in GBH5 was logged by drilling observation to be 1.45 m high with the top of void at 63.55 m depth. However, the geophysical calliper measured the top of void at 63.7 m. The latter is more accurate and with the void depth of 65 m gives a void height of 1.3 m.

With the top of the void interpreted to be about 5 m above the Borehole Seam as discussed in Section 5.2 and Section 5.3, and the prevalence of subsidence induced fractures observed, the void is likely to be the crown of a caved section of roof that fell into the mine workings. Such a roof fall would be not surprising given the inferred minor fault intersecting GBH5.

On falling, the rock would have increased in volume (bulked). Typically, this is by 1.2 to 1.4 times but can be above and below this range. A 5 m thickness of rock would be expected to bulk to 6 to 7 m thickness leaving a crown void 4 to 5 m high. The much lesser void height of 1.3 m is attributed to roof convergence post roof fall which would have compressed the overburden strata.

An alternative explanation for the void is a large open subsidence fracture or bedding separation such as those labelled in Figure 5-2.

6. Pile foundation discussion and recommendations

6.1 Preliminary design parameters for pile foundations

Preliminary geotechnical design parameters have been assessed for the soil units presented in Section 5 using the data obtained from the ground investigations. The parameters can be adopted in design approaches using the relevant design standards and appropriate strength reduction and load factors for limit state design.

Table 6-1 Preliminary geotechnical design parameters

Unit	Soil consistency / density	Unit weight (kN/m^3)	Measured values	Adopted undrained shear strength, S_u (kPa)	Adopted effective cohesion, c' (kPa)	Adopted effective friction angle, ϕ'	Adopted drained Young's Modulus, E' (kPa)
1 - Fill	-	19		-	-	34	15
2a - Holocene Estuarine Clay	Soft to Firm	17	qc ~ 0.37 – 0.43 MPa	20	0	26	6
2b - Holocene Marine Sand - upper	Medium dense to dense	19	qc ~ 8 – 16 MPa	-	0	37	35
2c - Holocene Estuarine Clay	Soft to Firm	17	qc ~ 0.25 – 0.55 MPa	17	0	26	5
3 - Holocene Marine sand – lower (upper 1.5 m)	Medium dense to dense	20	SPT N ~ 12 – 14 qc ~ 10 – 1 MPa	-	0	38	40
3 - Holocene Marine sand – lower (below upper 1.5 m)	Very dense	21	SPT N ~ 42– refusal qc > 25 MPa	-	0	42	100
4 – Lower Holocene Clay	Stiff to Very Stiff	20	qc ~ 1.6 – 2.2 MPa	100	6	28	30
Note – Unit 3 has been divided into two units to reflect the increase in density with depth in the upper 1.5 m of Unit 3.							

6.2 Pile foundations types

The type of pile foundation system will depend on the imposed load and performance criteria of the proposed structure. Helical steel screw piles, driven piles or Continuous Fight Auger (CFA) piles are options. These are discussed under the below sub-headings.

In all cases, founding within Unit 3 is recommended.

6.2.1 Helical steel screw piles

Potential advantages and limitations

Table 6-2 provides some of the potential advantages and limitations of helical steel screw piles.

Table 6-2 Potential advantages and limitations of helical screw piles

Advantages	Limitations
Rapid installation – Screw piles are installed using conventional construction equipment such as a track excavator with an appropriately sized low speed high torque hydraulic motor. Installation is less dependent on weather conditions. Shallow groundwater conditions generally have little impact on the installation as there is no requirement for excavation.	***Limiting soil conditions*** – Screw piles are generally limited to installation in soils that have a maximum grain size less than about 60% of the pitch of the helices. For a typical pitch of 75 mm, this means a maximum grain size of about 40 to 45 mm or medium gravel. Screw-piles and helical anchors will generally not advance correctly in gravel and cobble deposits. Screw pile advancement through very dense sand (Unit 3) may not be possible and could limit the pile termination depth and hence capacities.
Immediate load carrying capacity – Screw piles can be loaded immediately after installation. There is no need to wait for concrete or grout to harden.	***Equipment limitation*** - Proper installation of screw piles is essential to performance. The equipment used by the contractor should be selected to meet the expected soil conditions.
Minimal site disturbance – Screw piles cause less disturbance to the site compared to driven piles and bored piles. The installation typically produces no soil cuttings.	***Structural limitations*** - There is a limit to the amount of torque that should be applied to the screw pile before the structural integrity is compromised. During installation, this limit should not be exceeded even though perhaps the equipment being used for installation has a higher torque capability.
Installation monitoring – The load capacity of the pile can be inferred during installation by using empirical relationship between installation torque and load capacity, although this does not properly account for potential punching failure into underlying weaker strata.	***Durability*** – Due to their slender steel shafts and relatively thin helical bearing plates, corrosion protection measures must provide support for the design life of the structure.

Bearing capacity

The shaft frictional resistance (f_s) and the end bearing (f_b) of the helical steel screw piles should be derived from those of the founding Unit 3 layer only. The f_s and f_b of the overlying Holocene soils (including Units 2a, 2b and 2c) as well as the upper fill material (i.e. Unit 1) should not be considered for design purposes.

There are two methods for determining bearing capacity based on theoretical soil mechanics: *individual bearing* and *cylindrical shear*. If the spacing between helical bearing plates is very large, as in Figure 6-1(a), then each helix will act independently. The ultimate bearing capacity (P_u) of the helical pile in this case is the sum of the individual capacities of all the helical bearing plates plus adhesion along the shaft. This is called the "individual bearing" method and its P_u value can be calculated by:

$$P_u = \underbrace{f_{b1} \times A_1 + f_{b2} \times A_2 + \ldots\ldots + f_{bn} \times A_n}_{\text{Sum of individual bearing capacities of all helical plates}} \; + \underbrace{f_s \times H \times \pi d}_{\text{Shaft resistance of pile shaft above top helical plate}}$$

Where:

A_n is the area of the nth helical bearing plate;
H is the length of the helical pile shaft within Unit 3 above the top helix; and
d is diameter of the shaft.

If the spacing between helical bearing plates is small, as in Figure 6-1(b), the plates will act as a group. The bearing capacity of the pile in this case is the combination of the bearing of the bottom plate and the side shear along the cylinder of soil encased between the helical plates. This is called the “”cylindrical shear” method and its P_u value can be computed based on:

$$P_u = \underbrace{f_{b1} \times A_1}_{\text{End bearing of the helical plate}} + \underbrace{f_s \times (n\text{-}1) \times s \times \pi D_{AVG}}_{\text{Side shear of the soil cylinder encapsulated between helical plates}} + \underbrace{f_s \times H \times \pi d}_{\text{Shaft resistance of pile shaft above top helical plate}}$$

Where:

A_1 is the area of the bottom helix;

H is the length of shaft within Unit 3 above the top helix;

d is diameter of the pile shaft;

D_{AVG} is average helix diameter; and

$(n\text{-}1) \times s$ is the length of soil between the helices.

The closeness of helical bearing plates is a relative term that depends on the geometry of the pile and surrounding soil conditions. It is not generally known in advance whether the helical bearing plates are close together or far apart. Therefore, it is recommended that the pile capacity should be determined using both methods and the least value adopted for design.

Recommended design parameters for helical pile

The recommended geotechnical design parameters recommended for helical pile are presented in Table 6-3. The helical plates should be installed into Unit 3 stratum with at least 5 times the helical plate diameter below the top of Unit 3 in order to mobilise the full end bearing capacity. However, the end bearing capacity could be reduced as the founding level approaches the underlying Unit 4. Figure 6-2 presents the recommended end bearing capacity profile within the Unit 3 layer for design.

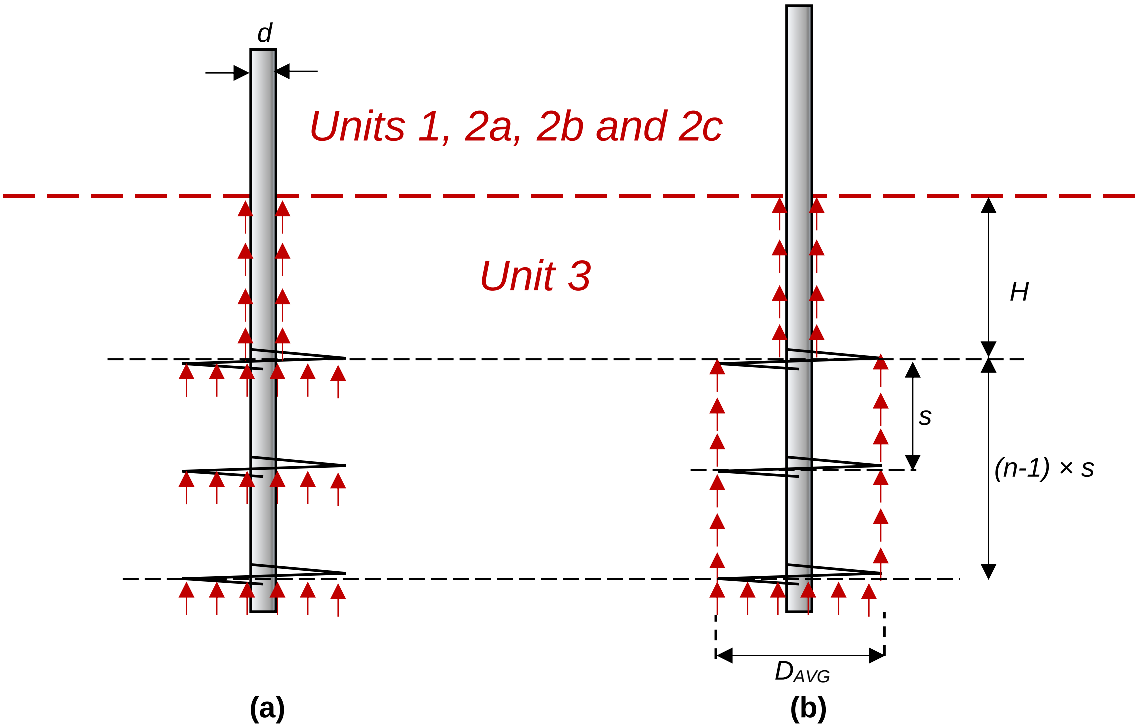

Figure 6-1 (a) Individual bearing method and (b) Cylindrical shear methods

Table 6-3 Design parameters for helical piles

Unit	Soil Consistency	Ultimate shaft friction, f_s (kPa)(1) (4)	Ultimate end bearing, f_b (MPa) (1)	Ultimate lateral yield pressure, p_y (MPa)	Young's modulus for vertical loading, E_v, (MPa)	Young's modulus for horizontal loading, E_H, (MPa)
1 - Fill	-	-	-	0 – 0.2 MPa in the upper 1.0 m, and 0.2 MPa thereafter	15	11
2a - Holocene Estuarine Clay	Soft to firm	-	-	0.15	6	4.5
2b - Holocene Marine Sand - upper	Medium dense to dense	-	-	0.4	35	26
2c - Holocene Estuarine Clay	Soft to firm	-	-	0.15	5	4
3 - Holocene Marine sand – lower (upper 1.5 m)	Medium dense to dense	55 (2)	Based on effective stress method and Nq value of 85. See Figure 6-2	0.7	40	30
3 - Holocene Marine sand – lower (below upper 1.5 m)	Very dense	105 (3)	Based on effective stress method and Nq value of 150. See Figure 6-2	1.3	100	75
4 - Lower Holocene Clay	Stiff to very stiff	50	450	0.9	30	22

Note –
(1) Ultimate shaft friction and end bearing values are not provided for Units 1, 2a, 2b & 2c since pile design should not rely on the skin friction above Unit 3.
(2) Based on $K_s\tan\delta = 1.0$; $f_s = K_s\tan\delta \times \sigma'_v$, where σ'_v is the vertical effective stress.
(3) Based on $K_s\tan\delta = 1.5$; $f_s = K_s\tan\delta \times \sigma'_v$, where σ'_v is the vertical effective stress.
(4) For piles in tension, ultimate shaft friction can be taken as 0.8 x f_s. Cone pull out failure should also be considered and the lesser capacity adopted.

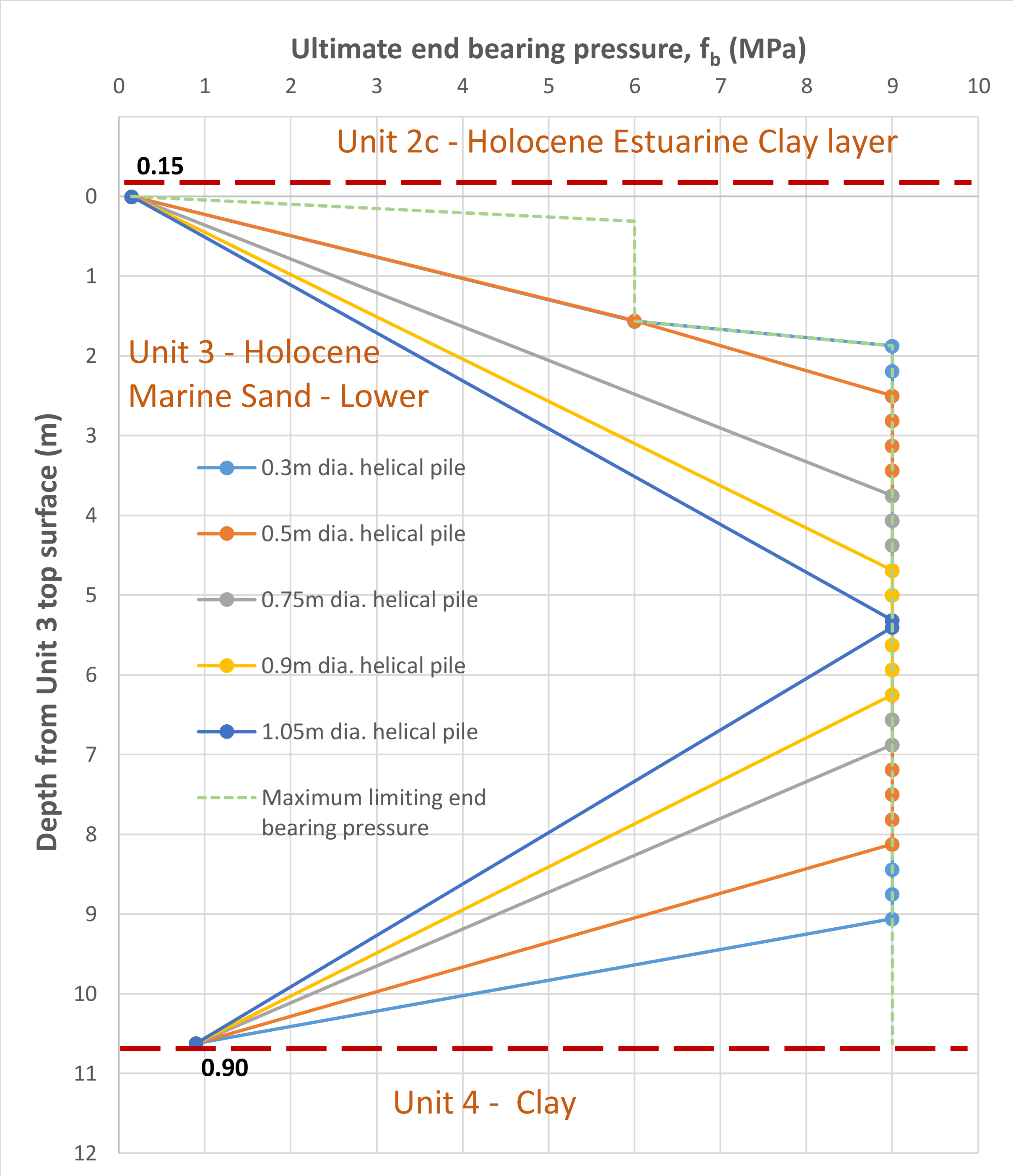

Figure 6-2 Ultimate End Bearing pressure (fb) for helical screw pile in Unit 3

Durability

Acid Sulfate Soils and aggressivity are discussed in Section 4.3, 6.3 and 0.

The upper 2 to 2.5 m section of helical piles is considered to be the most susceptible to corrosion resulting from exposure of acid sulfate soils. Corrosion protection measures should be considered in helical pile design as per AS2159.

Pile design and construction

All piles should be designed and constructed in accordance with AS2159.

Screw pile advancement through very dense sand (Unit 3) may not be possible and could limit the pile termination depth and hence capacities.

6.2.2 Pre-cast Driven Piles

Potential advantages and limitations

Pre-cast driven pile can be square, octagonal or cylindrical in shape. Table 6-4 outlines some advantages and limitations of pre-cast driven piles.

Table 6-4 Potential advantages and limitations of pre-cast driven piles

Advantages	Limitations
Piles are pre-fabricated off-site which allows for efficient installation once on site.	Advance planning is required for handling and driving, as well as the heavy equipment on site.
Driven piles displace and compact the soil which increases the geotechnical capacity of the pile. Whereas, other deep foundations such as bored piles tend to require the removal of soil which can lead to settlement and other structural problems.	Pre-stressed concrete piles must be adequately reinforced in order to withstand dynamic stress during driving. Pile advancement through very dense sand (Unit 3) may not be possible (driving refusal) and could limit pile termination depth and hence capacities.
They generally have superior structural strength to other forms of foundation. Their high lateral and bending resistance can result in the need for fewer piles on site.	It may not be possible to determine the exact length required and so splicing or cut-off techniques may be required which has time and cost implications.
Installation usually produces little spoil for removal and disposal.	Driven piles may not be suitable for compact sites, where sensitive structures / receivers in close proximity may be affected by the vibrations and noise caused by installation.

General design considerations for pre-cast driven piles

The load capacity of pre-cast driven piles is predominately derived from soil adhesion rather than end bearing. The capacity of a pile is estimated based on wave equation analyses. Piles should be driven with appropriate equipment to the required load capacity. It should be noted that during pile installation, the surrounding ground is displaced and noise and vibration occurs. In general, driven piles are not recommended in areas where sensitive structures are nearby.

The assessment of geotechnical capacity should be performed in two steps: an initial static analysis which is followed by a driveability analysis using wave equations. The above are subject to field verification with Pile Driving Analysis (PDA) during driving and Dynamic Load Testing.

Static analysis is performed based on the assessed shaft resistance and end bearing for a particular pile penetration depth. Depending on the quality of the available soil strength data and the variability of the soil properties, the reliability of the results obtained from such analysis will vary. Therefore, the calculated capacities are indirect estimates based on soil parameters estimated from the foundation investigation, and not based on the additional information provided by the installation process. Because of this inherent limitation, the pile founding level assessed from the static analysis should be considered as a nominal level only. Dynamic analysis is preferable as it provides a more direct verification of actual achieved capacity for each individual pile.

In essence, the static analysis provides indication on the founding stratum that would provide sufficient end bearing capacity to the pre-cast driven pile to meet the design load. The dynamic analysis (or driveability analysis) is then carried out to assess the required combination of driving set and hammer energy for construction. During construction and after achieving the minimum penetration depth as specified, the piles are driven further to achieve the required resistance.

All piles should be designed and constructed in accordance with AS2159.

Recommended design parameters for pre-cast driven pile (static analysis)

The recommended geotechnical design parameters for pre-cast driven piles and end bearing capacity profile within the Unit 3 layer are comparable to the values presented for helical piles. The design parameters presented in Table 6-3 and Figure 6-2 are applicable to static analyses for pre-cast driven piles.

Preliminary design parameters for driveability analysis

Driveability analysis using the wave equation approach should be undertaken as part of the design process to assess expected driving energy requirements and the associated tensile and compressive stresses generated in the pile during driving, which are to be provided to the Structural Engineer for structural capacity assessment. The driveability assessment can be undertaken using the commercially available computer program GRLWEAP (Wave Equation Analysis of Pile Driving).

The pile stresses generated during driving are related to the Static Resistance to Driving (SRD) that is actually present during driving. The actual SRD can be significantly different from the static soil resistance based on in-situ strength parameters. Notably, pore water pressure changes in the ground during pile installation tend to change the effective stress regime and therefore the resistance acting on the pile. Although empirical values are available for the selection of the gain-loss or capacity reduction factors, there is uncertainty in estimating the SRD. This affects both the energy to achieve penetration and driving stresses induced in the pile. For this reason continuous Pile Driving Monitoring (PDM) should be nominated.

The static resistance should be modified to consider potential loss of shaft resistance during driving, that is, the full loss of set-up during driving. The setup relates to soil and pore pressure response under dynamic loading, which are primarily evident within cohesive soils. Typical ranges of setup factors for initial assessment range from 1 for clean sands to 2 for clays. Actual setup factors in clay can exceed 10. With respect to the deeper gravel layers, it has been noted that driving records and dynamic testing for tubes driven through gravels has indicated that the fines content in these gravels (of inferred similar depositional history) is typically sufficient to develop a degree of setup. The following setup factors can be used for preliminary design:

- Unit 2a and 2c - Holocene alluvium clayey soils: Setup = 2.0
- Unit 2b - Holocene alluvial sand (upper): Setup =1.2
- Unit 3 - Holocene Marine sand (lower): Setup = 1.2

Preliminary values for other driveability design parameters, including quake and damping, are given below:

- Unit 2a and 2c - Holocene alluvium clayey soils: quake = 2.5 mm; damping =0.65 s/m
- Unit 2b - Holocene alluvial sands (upper): quake = 2.5 mm; damping =0.3 s/m
- Unit 3 - Holocene Marine sand (lower): quake = 2.5 mm; damping =0.3 s/m

6.2.3 Continuous Flight Auger (CFA) piles

Potential advantages and limitations

CFA piles are suitable to urban areas where noise and vibrations are a concern. They are constructed by drilling a continuous flight hollow stem auger into the ground to a specific depth. Once the pile toe level is achieved, concrete is pumped through the hollow stem to fill the cavity as the auger is extracted. A reinforcing cage, if specified, is then inserted into the fresh concrete by vibrating it into place after the auger has been withdrawn. Table 6-5 outlines some advantages and disadvantages of CFA piles.

Table 6-5 Potential advantages and disadvantages of CFA piles

Advantages	Limitations
Minimal levels of vibration	Typical pile length limit of about 12 m. Beyond that, there will be difficulty for lowering the reinforcing cage although depths of over 40 m have been achieved.
Lower noise levels generated by piling rig	Removal and disposal of spoil material generated from the pile.
Faster installation	Unlike bored piles where the drilled hole can be inspected and logged, it is not possible to verify visually the material encountered along the length of CFA pile during installation.
Self-supporting, generally without the need for casing for installation in sandy soils and below ground water	Strict quality control and thorough supervision is needed during installation.

General design considerations for CFA piles

The installation of CFA piles requires skilled operators to check stratification of the soil. Depending on the load and the dimension of the pile, an appropriate founding toe level needs to be defined to avoid punching failure since the recommended Unit 3 founding is underlain by Unit 4 clay.

The geotechnical design parameters recommended for CFA piles are presented in Table 6-6. Pile founding level should be at least 5 times pile diameter into Unit 3 to mobilise the full end bearing capacity and the capacity reduced linearly to the bottom of Unit 3 across the depth of 5 times pile diameter. The end bearing capacity profile in Unit 3 is presented in Figure 6-3.

All piles should be designed and constructed in accordance with AS2159.

Table 6-6 Design parameters for CFA piles

Unit	Soil Consistency	Ultimate shaft friction, f_s (kPa) [(1) (4)]	Ultimate end bearing, f_b (MPa) [(1)]	Ultimate lateral yield pressure, p_y (MPa)	Young's modulus for vertical loading, E_v, (MPa)	Young's modulus for horizontal loading, E_H, (MPa)
1 - Fill	-	-	-	0 – 0.2 MPa in the upper 1.0 m, and 0.2 MPa thereafter	15	11
2a - Holocene Estuarine Clay	Soft to firm	-	-	0.15	6	4.5
2b - Holocene Marine Sand - upper	Medium dense to dense	-	-	0.4	35	26
2c - Holocene Estuarine Clay	Soft to firm	-	-	0.15	5	4
3 - Holocene Marine sand – lower (upper 1.5 m)	Medium dense to dense	25 [(2)]	Based on effective stress method and Nq value of 50. See Figure 6-3	0.7	40	30
3 - Holocene Marine sand – lower (below upper 1.5 m)	Very dense	60 [(3)]	Based on effective stress method and Nq value of 60. See Figure 6-3	1.3	100	75
4 – Lower Holocene Clay	Stiff to very stiff	50	0.9	0.9	30	22

Note –

[(1)] Ultimate shaft friction and end bearing values are not provided for Units 1, 2a, 2b & 2c since pile design should not rely on skin friction above Unit 3.

[(2)] Based on $K_s \tan\delta = 0.5$;. $f_s = K_s \tan\delta \times \sigma'_v$, where σ'_v is the vertical effective stress.

[(3)] Based on $K_s \tan\delta = 0.8$; $f_s = K_s \tan\delta \times \sigma'_v$, where σ'_v is the vertical effective stress.

[(4)] For piles in tension, ultimate shaft friction can be taken as 0.8 x f_s

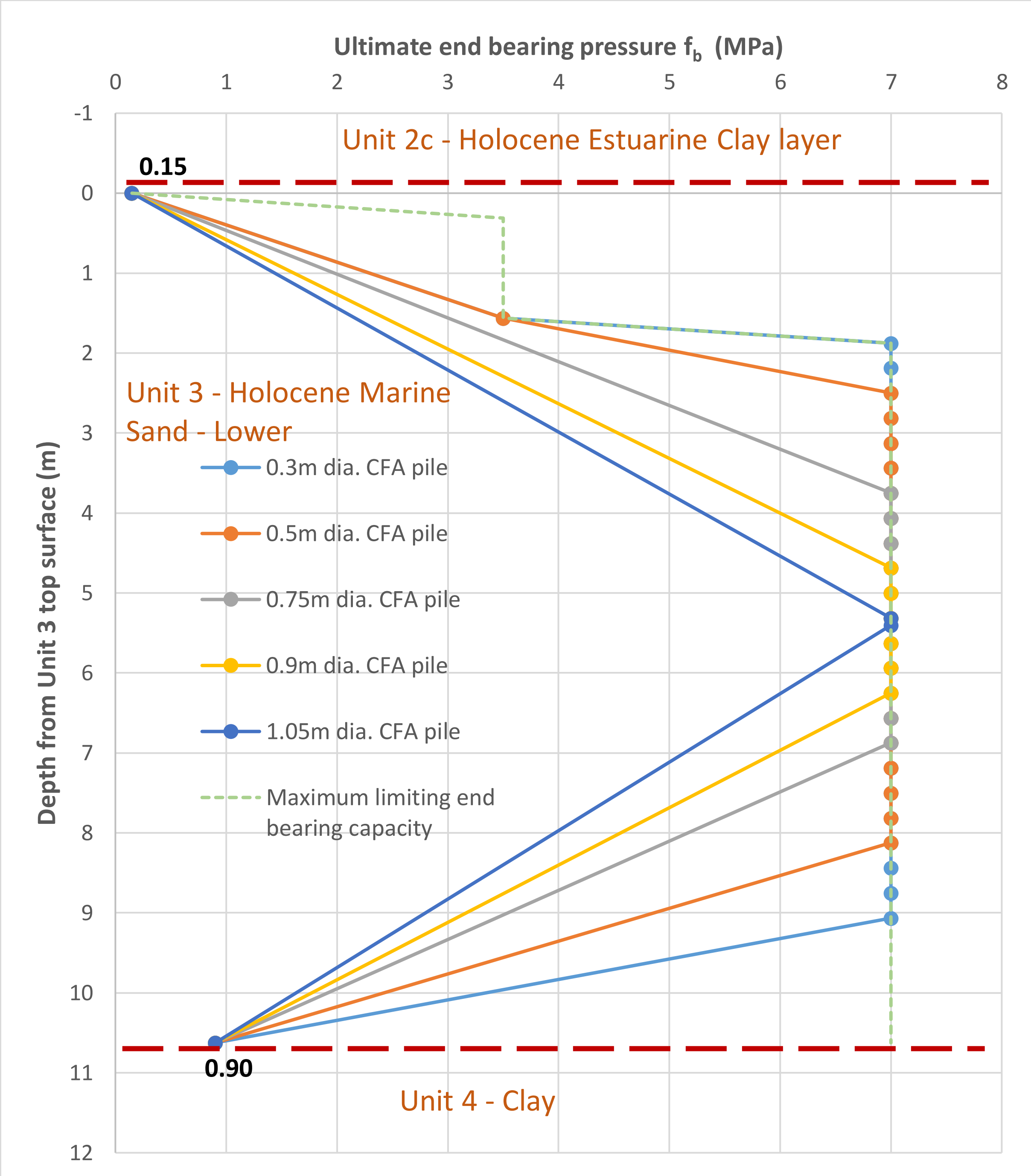

Figure 6-3 Ultimate end bearing pressure (fb) for CFA pile in Unit 3

6.2.4 Geotechnical strength reduction factors

Basic geotechnical strength reduction factor Φ_{gb}

The basic geotechnical strength reduction factor Φ_{gb} was assessed using an average risk rating (ARR) of 2.4 calculated using w_i and IRR_i values as outlined in Clause 4.3.2 of AS2159 for a medium redundancy system, Φ_{gb} = 0.60.

In accordance with Clause 8.2.4 (c)(i) of AS2159, dynamic or static pile load testing is not mandatory where Φ_{gb} of greater than 0.4 is adopted and ARR is < 2.5. However, pile shafts integrity testing in accordance with Clauses 8.2.4 (c)(ii), 8.2.4 (c)(iii) and Table 8.2.4(B) of AS2159 is mandatory.

Geotechnical strength reduction factor Φ_g for piles without dynamic pile load testing

For pile foundations where pile load testing has not been undertaken, the adopted geotechnical reduction factor, Φ_g, is equal to the basic geotechnical strength reduction factor, Φ_{gb}. Thus:

$\Phi_g = \Phi_{gb} = 0.60$ (no pile load testing assumed)

Geotechnical strength reduction factor Φ_g for piles with dynamic pile load testing

A Φ_g greater than the Φ_{gb} can be adopted if pile load testing (either by dynamic or static) is performed on production piles. Figure 6-4 shows Φ_g versus percentage of dynamically load tested piles in accordance with AS2159.

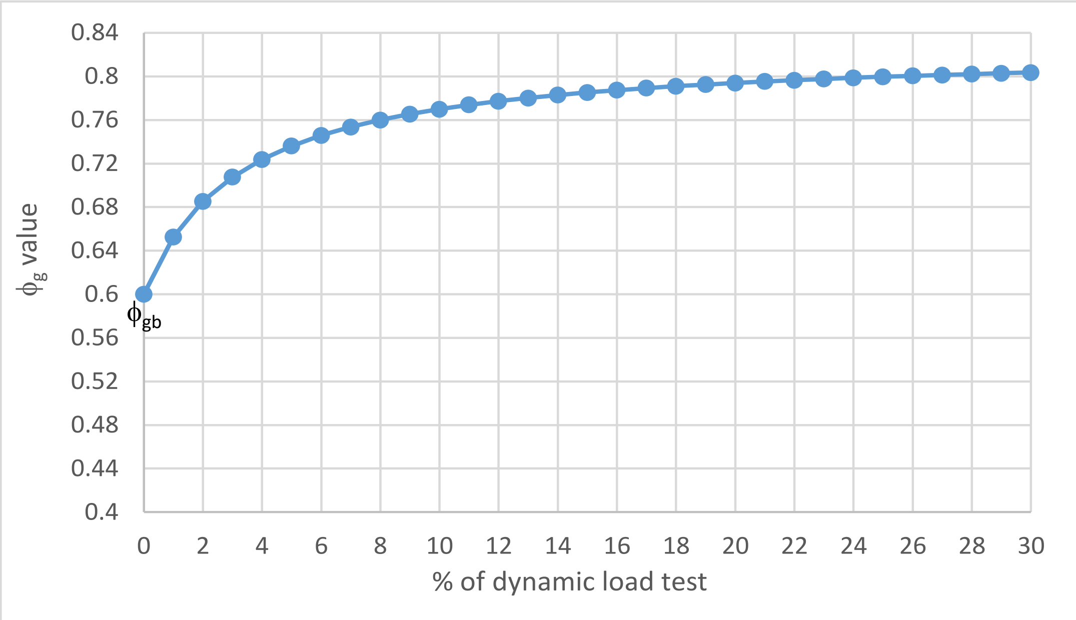

Figure 6-4 Φg for percentage of dynamic load testing in accordance with AS2159

6.3 Exposure classification for buried concrete and steel

Exposure classifications for buried steel and concrete elements based on the test results were assessed in accordance with AS2159, *Piling – Design and Installation*. The laboratory test results correspond to the following exposure classifications for buried steel and concrete elements buried in sandy and gravel soils.

- Concrete (Ref. AS2159-2009 Table 6.4.2(C)):
  - Mild from aggressivity test results
- Steel (Ref. AS2159-2009 Table 6.5.2(C)):
  - Non-aggressive from aggressivity test results

As discussed in AS2159, Acid Sulfate Soils (ASS) should be considered in pile durability design. Based on the investigation results, potential ASS are present. Exposing them through excavation or dewatering would result in their oxidation and acidic ground conditions. However, as no significant excavation or permanent dewatering is proposed, it is likely the ASS will not be exposed to a significant extent.

7. Pavements and earthworks

7.1 Filling and pavement subgrade

Subgrade preparation and filling

Internal roads and carparks are expected to be constructed above the existing ground surface with a finished level of about 2.6 m AHD.

Preparation for site filling should comprise stripping to remove vegetation, topsoil, root affected or other potentially deleterious material. The thickness of organics encountered at various borehole locations are summarised in the below table.

Table 7-1 Thickness of organics encountered

Borehole location	Thickness (mm)	Push tube location	Thickness (mm) (1)
GBH1	100	BH01 to BH09	Concrete
GBH2	30	BH10	~ 150
GBH3	150	BH11	No photo
GBH4	120	BH12	~ 30
GBH5	Concrete	BH13	~ 30
GBH6	100	BH14	~ 30
GBH7	100	BH15	No photo
GBH8	50	BH16	0
		BH17	0
		BH18	~ 20
		BH19	~ 30

(1) Estimated from push tube photograph

Prior to filling, the stripped ground surface should be assessed by a geotechnical testing authority as defined in AS3798. Assessment should include test rolling under a 40 to 50 kg/cm static smooth drum load or approved equivalent. If over-wet subgrades exist, excessive deflection or deleterious materials are encountered, these materials should be over-excavated and replaced with granular select material with a CBR of 10% or greater, and compacted to 100% Standard Compaction (AS1289 5.1.1-2003). Test rolling of these areas should then be repeated. Should further excessive deflection under test rolling occur, a Geotechnical Engineer should be consulted and the cause of deflection investigated.

Compaction and test rolling with vibration should be avoided or the number of passes limited to avoid generation of excess pore pressures in the underlying Unit 2a clay. Such increase in pore pressures within this unit will temporarily reduce its strength and could result in bearing capacity failures under wheel or track loading. Such failed subgrade areas would likely require remediation by excavation and replacement.

The presence of abandoned services (e.g. water, sewer, stormwater pits and pipes) should also be considered in subgrade preparation as such subsurface voids may collapse during or following subgrade preparation and require remediation. Abandoned pits and pipes should be either excavated or filled with high mobility (flowable) cementitious grout or concrete.

Engineered Fill should be placed and compacted in accordance with AS 3798 in layers not exceeding 300 mm loose thickness and compacted to a minimum density ratio of 98% Standard Compaction, in accordance with AS1289 5.1.1 or equivalent. Clay fill should be placed and maintained at -3% to +1% of standard optimum moisture content (SOMC).

The top 300 mm of subgrade (placed or in-situ) should be compacted to a minimum dry density ratio of 100% Standard Compaction (AS1289 5.1.1-2003) at a moisture content in the range of -3% to +1% of the SOMC.

Earthworks and compaction testing should be carried out in accordance with AS3798. It is recommended that 'Level 1' inspection and testing be undertaken during construction by a geotechnical testing authority. 'Level 1' is defined in AS3798 and requires full time supervision during material placement and compaction.

Subgrade design CBR

Pavements should be designed for a suitable subgrade CBR which takes into account the thickness and CBR of the various subgrade layers to a depth of 1 m below the underside of the sub-base as well as the anticipated variability of the subgrade materials.

For subgrade prepared as described above, a design subgrade CBR of 10 % is recommended, taking into consideration the possible variability of Unit 1 and avoiding overstressing the sand subgrade (resulting in its failure) by provide an adequate thickness of granular pavement over it.

It should be noted that the boreholes and CPTs across the site provide an indication of the likely subsurface materials. However, the characteristics of subgrade between these locations is unknown. The exposed subgrade should be inspected by a geotechnical testing authority to confirm the uniformity of the subgrade as discussed in the above section.

Pavement drainage

Pavement designs typically assume that adequate surface and subsurface drainage is provided. Guidance on subsurface drainage design is provided in Austroads 2009, *Guide to Pavement Technology – Part 10: Subsurface Drainage.*

7.2 Management of acid sulfate soils

Based on the ASS Chromium Reducible Sulfur testing, Unit 2a soils are ASS and disturbance would require an ASS management plan. Should this material be reused on site, further testing will be required. A preliminary lime dosing rate of 35 kg $CaCO_3$/t is recommended based on the available ASS test results.

Excavation of Unit 2a soils, or lowering of groundwater to expose Unit 2a soils, is likely to disturb ASS. Further investigation and assessment would be required to assess the need for an ASS management plan.

7.3 Excavation conditions and groundwater levels

Based on the conditions encountered and with the exception of the existing concrete slab and any other remnant footings, it is anticipated that excavation will be achievable using conventional earthmoving machinery such as backhoes and tracked excavators.

Groundwater was encountered between 0.23 to 0.55 m AHD (1.6 to 1.7 m depth) in the CPT holes and between 0.58 and 1.1 m AHD (1.0 to 1.6 m depth) in the boreholes. The higher groundwater levels in the boreholes are likely due to recent rainfall and so may be higher than normal. However, even higher groundwater levels again should be anticipated during prolonged and heavy rainfall.

Depending on the depth of trenching required, groundwater inflow may occur and require management. The extent of inflow and inflow rates will be dependent on the groundwater levels during excavation, permeability of the surrounding ground as well as the width and depth of excavation.

Due to the destabilising effects of groundwater flowing into an excavation through sandy soils, a spearpoint dewatering system is recommended for excavation below groundwater to temporarily lower the water table such that groundwater does not flow into excavations. Such a dewatering system should take into consideration the potential exposure of acid sulfate soils in Unit 2a.

7.4 Temporary excavation support

Temporary excavations should satisfy the requirements of relevant workplace health and safety legislation, including the Safe Work Australia, Excavation Work – Code of Practice, October 2013 or latest version. We recommend that no personnel should enter any excavation deeper than 1.0 m that is unsupported.

Excavation shoring should be designed by a qualified geotechnical and/or structural engineer or, in the case of pre-fabricated shoring boxes, be designed, manufactured and installed in accordance with the relevant Australian Standards and manufactures recommendations. The condition of shoring should be inspected as part of daily pre-work inspections as a minimum frequency and risks assessed and mitigated accordingly.

Trench support may be designed on the basis of a bulk soil unit weight of 19 kN/m^3 (non-submerged) and should take into consideration potential hydrostatic forces. Appropriate design earth pressures should be derived from the anticipated ground conditions, surcharge loading, proposed retention system, and allowable wall deflection.

The “stand-up” time of trenches with inflow of water may be too short to allow time to install shoring boxes with trench collapse potentially occurring within less than a minute. Where a spearpoint dewatering system is used to prevent water inflow into excavations or where no water inflow occurs, stand-up time is expected to be adequate for shoring box installation but excavation collapse may still occur with little warning. Appropriate measures should be put in place to protect structures and infrastructure within 2 m horizontally of an excavation crest, assuming excavations are no deeper than 2 m.

The potential for dewatering induced settlement should also be considered in the design of a dewatering system.

7.5 Working platforms for piling rigs and cranes

The adequacy of the site to support the proposed construction plant / vehicles, such as piling rigs and cranes should be assessed and managed by the Principal Contractor and should include consideration of:

- Loading conditions (i.e. track pressure distributions, outrigger loads / eccentricity and outrigger pad transfer of load to the ground) for various load cases.
- Ground conditions beneath the proposed working platforms / plant operation areas, including potential changes in groundwater level or reduction in subgrade strength resulting from potential over compaction and associated elevation of pore water pressures and bearing capacity failures.
- Presence of existing or past excavations, slopes, buried services or voids that could reduce bearing capacity.

The data presented in this report can be used by the Principal Contractor to assist in the assessment of ground conditions and bearing capacity. Given the possible variability of Unit 1, the Principal Contractor should supplement this data in areas such as outrigger pad locations and piling rig working platforms with additional subsurface investigations and geotechnical engineering assessment. The use of hand augers and dynamic cone penetrometer testing could be considered as a means of supplementing subsurface investigation data.

8. Mine subsidence

8.1 Desktop study report (GHD 2020b) and update

GHD 2020b, included in Appendix G, provides the findings of a desktop study and includes a summary of mining history, terminology and anticipated mining conditions based on historical documents as referenced. The report also provides an estimate of subsidence parameters (strain, tilt and curvature) for the case of an assumed 0.6 m ground surface maximum subsidence and discussion on four development options with respect to Subsidence Advisory NSW (SA NSW) Merit Assessment Policy.

Broadly, the ground conditions anticipated from the desktop study are consistent with the encountered ground conditions as discussed in Section 3.3 and Section 5 of this report. The notable difference being that the ground beneath the site is now interpreted to have subsided as a result of Borehole Seam coal pillar crushing.

Table 8-1 provides a comparison of mine subsidence related expectations included in the desktop study report to encountered and interpreted conditions as a result of boreholes GBH5 and GBH6 presented herein.

Table 8-1 Comparison of anticipated mining conditions to encountered

Anticipated as reported in GHD 2020b	Encountered and interpreted following GBH5 and GBH6
15 m of sand overlying 30 m of clay to bedrock at 45 depth.	16 m of sand and clay overlying 30 m of Unit 4 clay to bedrock at 44 to 49 m depth.
24 m thicknesses of overburden interbedded siltstone and sandstone.	20 to 22 m thicknesses of overburden interbedded siltstone and sandstone.
Top of Borehole Seam at 69 m depth	Top of Borehole Seam at ~ 66 to 69 m depth
Borehole Seam thickness about 6 m with the bottoms comprising about 1.8 m and the tops 4.2 m	No change: GBH5 and GBH6 do not provide any additional data in this regard except that the seam thickness is greater than 5 m from GBH6.
Mine working height (tops and bottoms) 6 m	No change: GBH5 and GBH6 do not provide any additional data in this regard.
Mining layout: bord and pillar	No change: GBH6 confirmed a crushed pillar
Fault displacement: • ~1.8 m with downside on the east from RT579 • 0.73 m with downside on the west from survey station 483a and 495 level difference	Fault displacement ~1.8 m with downside on the east
Subsidence: not expected to have occurred	Subsidence: pillar crush and subsidence, initially west of fault then extending east of the fault as interpreted from RT579 survey traverse path and boreholes as discussed in Section 5.
Pillar stability: • Case 1a (full seam, intact, flooded) FoS 1.7 to 2.1 • Case 3b “worst case during mining” (full seam, dewatered, reduced pillar width) FoS 0.8 to 1.0	Pillar stability: • Case 1a not applicable as pillars failed

8.2 Estimated subsidence

8.2.1 Comparison to documented subsidence events

As discussed in GHD 2020b, Section 2.3.2; descriptions of nearby subsidence events indicate up to about 0.6 m (two feet) of ground surface subsidence occurred at Darvall Street, south west of the site where tops and bottoms were taken in every bord. About 930 m north at Hargreave Street, three feet nine inches (~1.1 m) of subsidence was reported to have occurred in 1901/1902. This area is shown on RT579 and is also where tops and bottoms were taken in every bord. Geotechnical assessments by Coffey Geotechnics at Cottage Creek in 2009 about 650 m to the south, concluded that mine roof convergences of between 0.1 m and 1.65 m had occurred. These 'crushes' would have translated to surface subsidence of lesser magnitude as a function of the overburden characteristics.

The behaviour of the overburden in response to mine roof convergence dictates the profile of the surface subsidence. That is, the ground strains and curvature of the trough. For soil overburden materials, the profile shape can be estimated using soil mechanics theory employed in estimating surface subsidence profiles resulting from volume loss in tunnels.

Beneath the proposed building, there is about 22 m of rock overlying the mine workings and above this about 46 m thickness of alluvial clays and sands (GBH6). This is likely to be similar to conditions at Darvall Street. The fault passing beneath the site may locally increase roof convergence although the effects would not be directly reflected on the ground surface due to the ameliorating 'smoothing' effect of the overlying soils - in particular, the 30 m thick clay (Unit 4).

Estimates of maximum subsidence parameters are reported in GHD 2020b for the 'un-subsided' case where 0.6 m of maximum subsidence (S_{max}) is assumed to occur at ground surface based on the documented subsidence at Darvall Street.

8.2.2 Residual subsidence case

From review of the engineering logs and geophysics logs of GBH5 and GBH6 as discussed in Section 5, the remnant coal mine pillars beneath the proposed building are interpreted to be crushed. That is, roof convergence and the associated trough subsidence has already occurred west and east of the fault.

Despite the occurrence of roof convergence and hence trough subsidence, there is a possibility of future residual subsidence. That is, some much smaller amount of subsidence resulting from a change in stress conditions or reduction in coal pillar stiffness. Such residual subsidence often occurs in the months or years following longwall mining, triggered by changes in overburden stress caused by adjacent mining, alteration (usually lowering) of groundwater pressures or perhaps earthquake loading. While residual subsidence is a known phenomenon, the mechanism by which it would occur at the subject site is not established and as such, only estimates of the residual roof convergence can be used to calculate a resulting trough subsidence profile at the ground surface. For this purpose, we have considered two cases as follows:

- Residual mine roof convergence (Δ) of 0.1 m occurring anywhere beneath the site.
- Residual mine roof convergence (Δ) of 0.2 m occurring along the fault.

Where "Δ" represents the mine roof convergence as shown in Figure 8-1. The assumed subsidence profile is illustrated on Figure 8-1 as being two-dimensional. That is, the convergence Δ is assumed to have infinite length (into and out of the page).

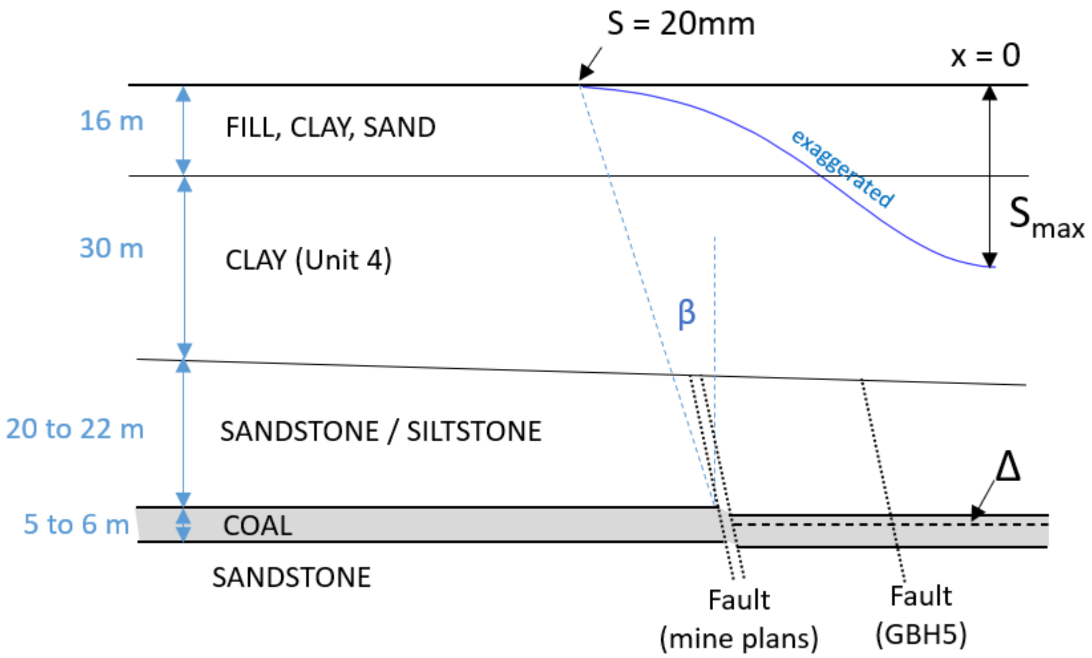

Figure 8-1 Modelled residual subsidence case (schematic not to scale)

The effects of convergence are translated through the overlying fractured rock and soils based on soil mechanics theory as per the method of Mair *et al* (1993). While the concept is the same as 'angle of draw' (β) in mine subsidence with a subsidence limit of 20 mm adopted, the behaviour of soil is different to the rock that the commonly adopted 26.5° (1H:2V) angle of draw is based upon. A key input parameter for the subsidence profile calculation in Mair *et al* (1993) is the parameter 'K' which changes the maximum extent of the trough and so affects strain, tilt and curvature. The larger the K value, the wider the trough and hence the lesser the strain, tilt and curvatures. K is based on soil mechanics and is a function of soil type and depth (derived originally through semi-empirical methods). K values for clays are typically between 0.4 and 0.7 and for sand about 0.3. For this analysis we have used K of 0.1 for fractured rock (20 m thickness), 0.3 for sand (16 m thickness) and 0.6 for clay (30 m thickness) for a weighted average of 0.38.

The resulting ground surface profiles and associated strains, curvatures and tilts are shown under the below sub-headings for each case.

Stepped residual mine roof convergence (Δ) of 0.1 m occurring anywhere beneath the site

For this case, the maximum values of subsidence, strains, tilts and curvatures are relevant as the location of the convergence is not defined.

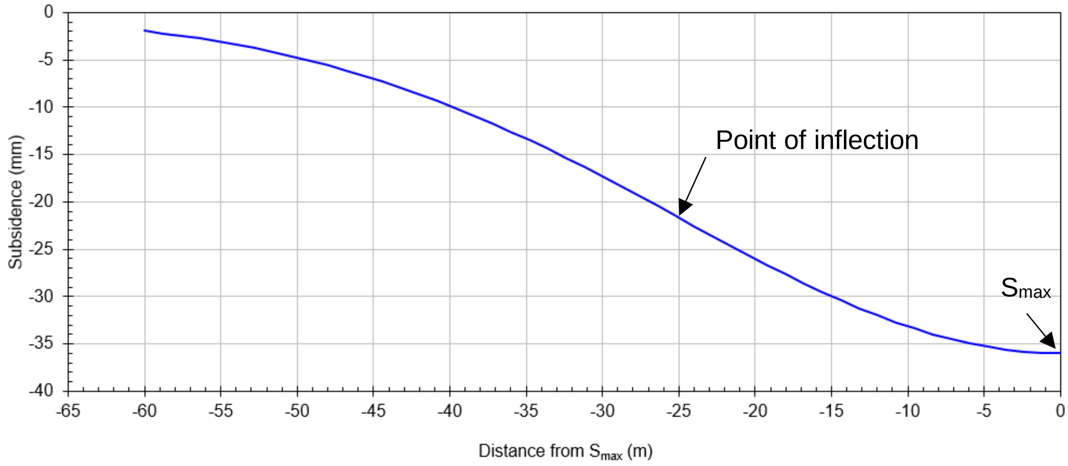

Figure 8-2 Resultant surface subsidence profile (Δ of 0.1 m)

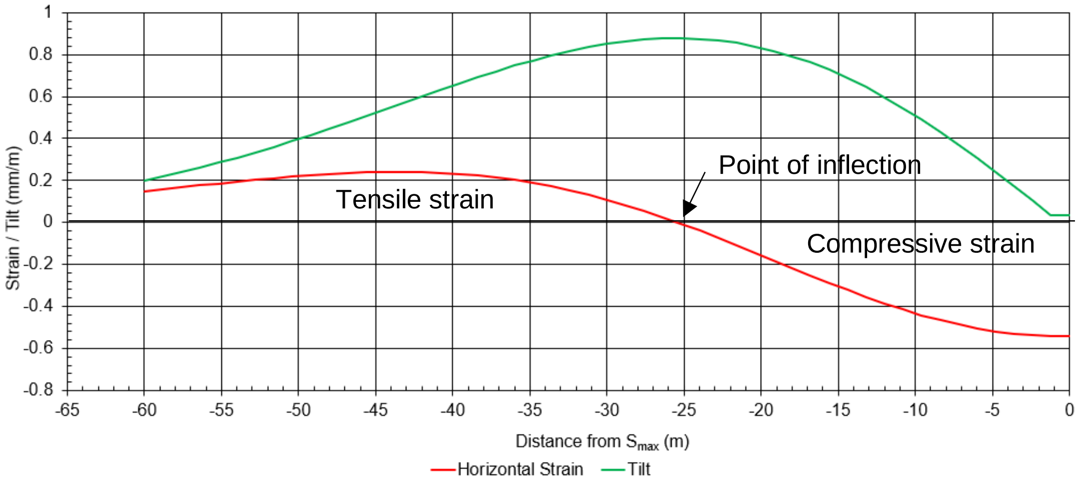

Figure 8-3 Resultant strain and tilt profile (Δ of 0.1 m)

S_{max} is defined at x = 0 m in the above figures. The point of inflection is at x = - 25 m and is where horizontal strain is zero and tilt is maximum.

The maximum subsidence parameters from the above analysis are:

- Maximum subsidence S_{max} : ‘s’ 36 mm
- Maximum tensile strain E+ = 0.24 mm/m
- Maximum compressive strain E- = 0.54 mm/m
- Maximum tilt T = 0.88 mm/m
- Minimum radius of curvature = 4.8 km

Stepped residual mine roof convergence (Δ) of 0.2 m occurring along the fault in the workings

For this case, the convergence is assumed to occur east of the fault which is a horizontal distance of about 13 m from the eastern edge of the proposed building at its closest point. Maximum values of subsidence, strains, tilts and curvatures within the proposed building footprint are relevant.

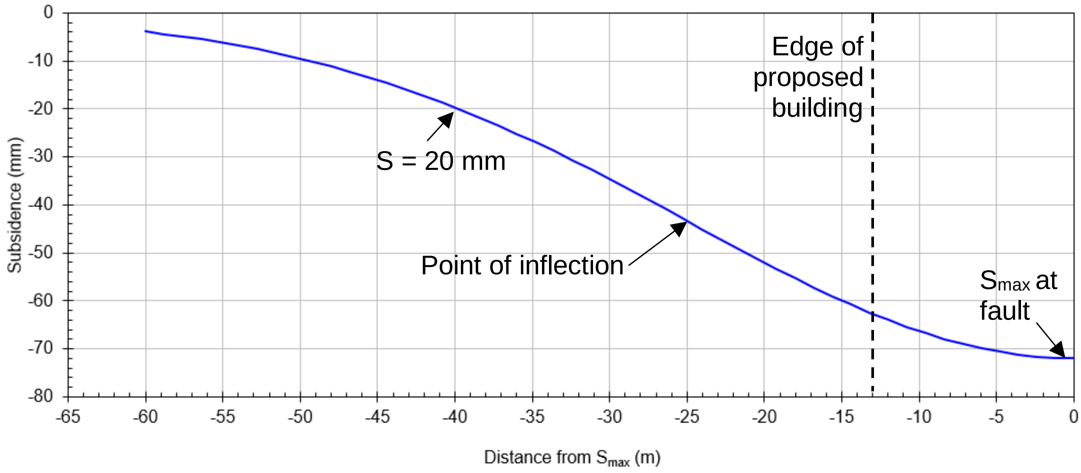

Figure 8-4 Resultant surface subsidence profile (Δ of 0.2 m along fault)

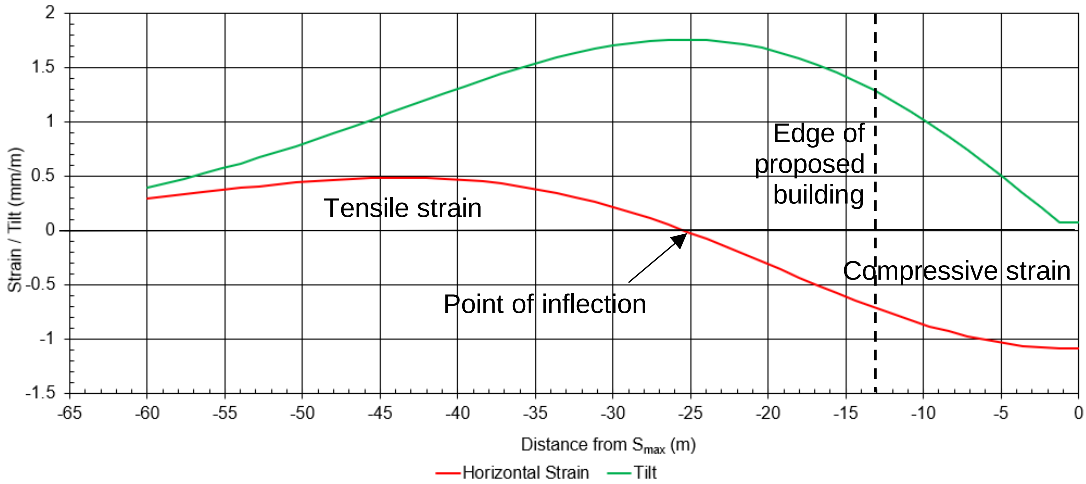

Figure 8-5 Resultant strain and tilt profile (Δ of 0.2 m along fault)

S_{max} is defined at x = 0 m in the above figures coinciding with the fault. The point of inflection is at x = - 25 m and is where horizontal strain is zero and tilt is maximum.

The maximum subsidence parameters from the above analysis within the proposed building footprint are:

- Maximum subsidence S_{max} : 's' 63 mm
- Maximum tensile strain E+ = 0.5 mm/m
- Maximum compressive strain E- = 0.6 mm/m
- Maximum tilt T = 1.7 mm/m
- Minimum radius of curvature = 2.7 km

8.3 SA NSW Merit Assessment Policy and development options

For non-residential development such as that proposed, SA NSW assessment will be based on their Development Application – Merit Assessment Policy (SA NSW. 2018). We understand this document is currently under review by SA NSW.

The Merit Assessment Policy classifies proposed building developments into three categories, shown in the below Table 8-2. The proposed development could fall within the B2 category if construction cost is less than five million or the B3 categories, if greater than five million.

Table 8-2 SA NSW Building Categories

SA NSW category	General Classification of Building type
B1	• Up to and including 3 storeys (including rooftop access) • < 50 m maximum plan footprint dimension • No basement • No load bearing masonry construction • Up to and equal to $3 M construction cost
B2	• Up to and including 4 storeys (including basements and rooftop access); or • Between $3 M to $5 M construction cost; or • > 50 m in maximum plan footprint dimension
B3	• Greater than 4 storeys (including basements and rooftop access); or • > 100 m maximum plan footprint dimension • Greater than $5 M construction cost; or • Use - Hospital Wards, Operating theatres, critical public infrastructure, Public Buildings with high trafficability (i.e. school halls etc.)

The SA NSW assessment requirements for each building category are a function of the perceived level of geotechnical uncertainty as either low, medium or high, based on the level of confidence and understanding of the following weighted factors.

- Geological environment (R1) - weighting 2
- Level of geotechnical investigation (R2) - weighting 2
- Type of coal mine plans and records (R3) - weighting 3
- Method used to assess stability and impact (R4) - weighting 3

An uncertainty factor (UF) is then calculated by summing the products of R weightings and their uncertainty value (U) and finally subtracting 10 as follows:

Uncertainty Factor (UF) = (R1 x U + R2 x U + R3 x U x R4 x U) – 10

Where: Low uncertainty, U = 1; Moderate uncertainty, U = 2; High uncertainty, U = 3.

Table C2 of the policy provides the reference descriptions for uncertainty categories.

For the subject site, our assessment of the SA NSW uncertainty factor (UF) is 12 as shown in the table below.

Table 8-3 SA NSW Uncertainty Factor calculation

Factor	Weighting	Uncertainty	Product	Comment
R1	2	3	6	Fault present
R2	2	2	4	Two boreholes, pillar dimensions not confirmed
R3	3	3	9	Hand working, irregular
R4	3	1	3	Pillar failure has occurred
		uncertainty factor (UF)	**12**	Product sum less 10

An uncertainty factor greater than 10 is “High Uncertainty”.

Table C3 of the Merit Assessment Policy sets out SA NSW's "Estimated Conditions of Approval for Trough Subsidence Risk". Different conditions are given depending on whether the assessed pillar (panel) factor of safety (FoS) and pillar width to height ratio is less than or greater than nominated criteria. The conditions are based on assessed pillar factors of safety (FoS) and the assumption that the pillars have not yet failed but may do so in the future.

However, as the investigation has concluded that the pillars have already failed and subsidence occurred, it is reasonable to assume that Table C3 is not directly applicable.

8.4 Mine subsidence recommendations

From our current understanding, mine convergence (crush) and trough subsidence has already occurred beneath the site. Residual subsidence to a much lesser degree is plausible, although a mechanism to trigger its occurrence has not been identified in this study.

Given the location of the proposed building on the western side of the site, thick sand and clay overburden units and indications that subsidence has already occurred, we recommend the proposed building be designed for residual subsidence effects.

Upper-bound estimates of likely adverse subsidence events have been considered for the potential mechanics of residual subsidence remaining beneath the site along the fault and elsewhere over the site. Estimates of residual subsidence effects (strain, tilt and curvature) resulting from mine roof convergence of 0.2 m along the fault or 0.1 m anywhere have been made and the following worst of these two cases could be used as subsidence design parameters:

- Maximum subsidence S_{max} : 's' 63 mm
- Maximum tensile strain E+ = 0.5 mm/m
- Maximum compressive strain E- = 0.6 mm/m
- Maximum tilt T = 1.7 mm/m
- Minimum radius of curvature = 2.7 km

SA NSW must provide approval conditions. The following is recommended based on extracts from Table C3 for a Category B3 building and must be confirmed by SA NSW.

Structure must be designed to be "safe, serviceable and readily repairable" under the predicted subsidence impact parameters". (This being the above residual subsidence parameters).

Submit plans prior to construction with a letter from a qualified structural engineer that the improvement will remain "safe, serviceable and any damage from mine subsidence shall be limited to 'very slight' in accordance with AS2870 (Damage Classification), and readily repairable". The subsidence impact parameters should be clearly stated.

Demonstrate that the improvement can be designed to remain "safe, serviceable and any damage from mine subsidence shall be limited to 'very slight' damage in accordance with AS2870 (Damage Classification), and readily repairable".

Submit an "Engineering Impact Statement" prior to commencement of detailed design for acceptance by SANSW, which shall identify the:

- *a. Mine subsidence parameters used for the design.*
- *b. Main building elements and materials.*
- *c. Risk of damage due to mine subsidence*
- *d. Design measures proposed to control the risks*
- *e. Comment on the likely building damage in the event of mine subsidence and sensitivity of the design to greater levels of mine subsidence.*

Submit detailed design drawings prior to commencement construction with the design measures proposed to control the mine subsidence risk clearly highlighted and the design subsidence parameters clearly marked on the plan.

A number of permanent survey marks to AHD will be required so that building movement can be monitored should mine subsidence occur. Survey marks need to be initially surveyed and all details are to be forwarded to Subsidence Advisory NSW.

Following construction, sign-off from qualified engineer that improvements have been constructed in accordance with plans submitted to SANSW and in accordance with all relevant codes and standards.

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Appendices

Appendix A – General Notes and standard sheets

GENERAL NOTES

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

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

TEST HOLE LOGGING

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

GROUNDWATER

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

INTERPRETATION OF RESULTS

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

CHANGE IN CONDITIONS

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

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

GEOTECHNICAL VERIFICATION

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

FOUNDATIONS

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

REPRODUCTION OF REPORTS

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

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

Ref: DS5.5.1 Issue 0 Date: 05/10/2018

SOIL DESCRIPTION AND CLASSIFICATION

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Soil is described in general accordance with Australian Standard AS 1726-2017 (Geotechnical Site Investigations) in terms of visual and tactile properties, with potential refinement by laboratory testing. AS 1726 defines soil as particulate materials that occur in the ground and can be disaggregated or remoulded by hand in air or water without prior soaking. Classification of the soil is undertaken following description.

SOIL DESCRIPTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Moisture - Coarse Grained Soils		
Term		**Tactile Properties**
Dry	*('D')*	Non-cohesive, free running
Moist	*('M')*	Feels cool, darkened colour, tends to stick together
Wet	*('W')*	Feels cool, darkened colour, tends to stick together, free water forms when handling

Moisture - Fine Grained Soils		
Term		**Tactile Properties**
Moist, dry of plastic limit	*('$w < PL$')*	Hard and friable or powdery
Moist, near plastic limit	*('$w \approx PL$')*	Can be moulded
Moist, wet of plastic limit	*('$w > PL$')*	Weakened, free water forms on hands with handling
Wet, near liquid limit	*('$w \approx LL$')*	Highly weakened, tends to flow when tapped
Wet, wet of liquid limit	*('$w > LL$')*	Liquid consistency, soil flows

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

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

Relative Density (Non-Cohesive Soils)		
Term and (Symbol)		**Density Index (%)**
Very Loose	*(VL)*	≤ 15
Loose	*(L)*	> 15 and ≤ 35
Medium Dense	*(MD)*	> 35 and ≤ 65
Dense	*(D)*	> 65 and ≤ 85
Very Dense	*(VD)*	> 85

Consistency assessment can be influenced by moisture variation.

Consistency (Cohesive Soils)			
Term and (Symbol)		**Tactile Properties**	**Undrained Shear Strength**
Very Soft	*(VS)*	Extrudes between fingers when squeezed	< 12 kPa
Soft	*(S)*	Can be moulded by light finger pressure	12 - 25 kPa
Firm	*(F)*	Can be moulded by strong finger pressure	25 - 50 kPa
Stiff	*(St)*	Cannot be moulded by fingers	50 - 100 kPa
Very Stiff	*(VSt)*	Can be indented by thumb nail	100 - 200 kPa
Hard	*(H)*	Can be indented with difficulty by thumb nail	> 200 kPa
Friable	*(Fr)*	Easily crumbled or broken into small pieces by hand	-

c) Structure (zoning, defects, cementing)

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

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

'lens' (a discontinuous layer with lenticular shape)

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

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

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

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

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

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

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

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

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

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

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

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

'weakly cemented'	easily disaggregated by hand in air or water
'moderately cemented'	effort required to disaggregate the soil by hand in air or water

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

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d) Origin

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

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

e) Additional Observations

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

SOIL CLASSIFICATION

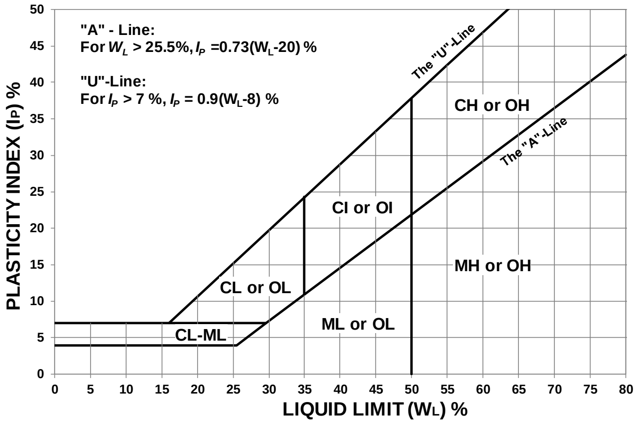
Classification allocates the material within distinct soil groups assigned a two character Group Symbol:

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

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

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

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



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

ROCK DESCRIPTION AND CLASSIFICATION

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

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

<table>
<tr><th rowspan="3">Grain Size (mm)</th><th colspan="6">Sedimentary</th><th colspan="2">Metamorphic</th><th colspan="3">Igneous</th></tr>
<tr><th colspan="2" rowspan="2">Clastic or Detrital</th><th colspan="2">Carbonate</th><th rowspan="2">Pyroclastic</th><th rowspan="2">Foliated</th><th rowspan="2">Non-Foliated</th><th rowspan="2">Felsic</th><th rowspan="2">↔</th><th rowspan="2">Mafic</th></tr>
<tr><th>Low Porosity</th><th>Porous</th></tr>
<tr><td>>2.0</td><td colspan="2">CONGLOMERATE (rounded grains in a finer matrix)
BRECCIA (angular or irregular fragments in a finer matrix)</td><td rowspan="4">LIMESTONE (Predominantly $CaCO_3$)
or
DOLOMITE (Predominantly $CaMgCO_3$)</td><td>CALCIRUDITE</td><td>AGGLOMERATE (rounded grains in a finer matrix)
VOLCANIC BRECCIA (angular fragments in a finer matrix)</td><td>GNEISS</td><td>MARBLE (carbonate)
QUARTZITE</td><td>GRANITE</td><td>DIORITE</td><td>GABBRO</td></tr>
<tr><td>2.0-0.06</td><td colspan="2">SANDSTONE</td><td>CALCARENITE</td><td>TUFF</td><td>SCHIST</td><td>SERPENTINITE</td><td>MICRO-GRANITE</td><td>MICRO-DIORITE</td><td>DOLERITE</td></tr>
<tr><td>0.06-0.002</td><td rowspan="2">MUDSTONE (silt and clay)</td><td>SILTSTONE (mostly silt)</td><td>CALCISILTITE</td><td rowspan="2">Fine grained TUFF</td><td rowspan="2">PHYLLITE or SLATE</td><td rowspan="2">HORNFELS</td><td rowspan="2">RHYOLITE</td><td rowspan="2">ANDESITE</td><td rowspan="2">BASALT</td></tr>
<tr><td><0.002</td><td>CLAYSTONE (mostly clay)</td><td>CALCILUTITE</td></tr>
</table>

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

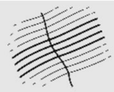
c) Description of defects (defect type, orientation, roughness and shape, coatings and composition of seams, spacing, length, openness and thickness, block shape)

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

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

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

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

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

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

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

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

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

Shape and (Symbol)		Description
Planar	(Pln	The defect does not vary in orientation.
Curved	(Cu)	The defect has a gradual change in orientation.
Undulating	(Un)	The defect has a wavy surface.
Stepped	(St)	The defect has one or more well defined steps.
Irregular	(Ir)	The defect has many sharp changes of orientation.

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

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

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

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

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

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

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

Persistence and Spacing of defects is described directly in millimetres and metres. If the measurement of defect persistence is limited by the extent of the exposure, the end conditions are noted (i.e. 0, 1 or 2 defect ends observed). The spacing between defects of similar orientation (i.e. within a specific defect set) is recorded when possible.

The frequency of defects within rock core can be measured as either: the spacing between successive defects; or the “Fracture Index”, which is the number of defects per metre of core.

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

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

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

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

Ref: DS6.5.2.1 Issue 2.0 Date: 01/08/2019

d) Interpreted stratigraphic unit

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

e) Geological structure

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

PARAMETERS RELATED TO CORE DRILLING

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

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

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

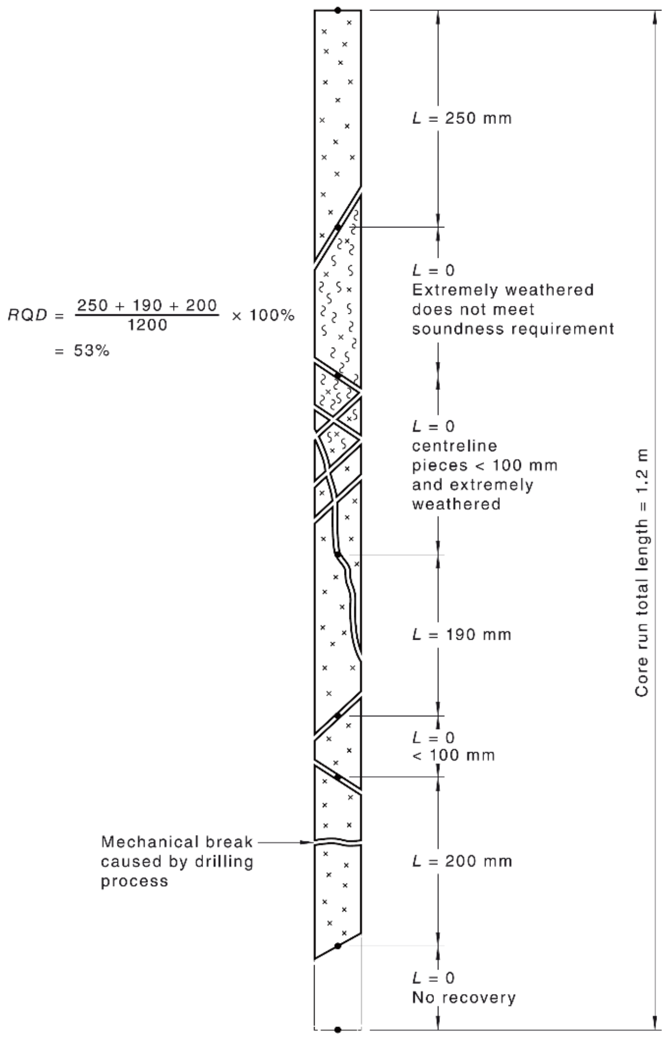
For certain projects, such as tunnelling or underground mining investigations, rock mass ratings or classifications can be required as part of the design process. The RQD forms a component of these rock mass ratings and provides a quantitative estimate of rock mass quality from rock core logs.

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

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

RQD is expressed as:

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



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

ROCK MASS CLASSIFICATION

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

References

STANDARDS AUSTRALIA (2017). AS 1726-2017. GEOTECHNICAL SITE INVESTIGATIONS.
BARTON, N. AND CHOUBEY, V. (1977). THE SHEAR STRENGTH OF ROCK JOINTS IN THEORY AND PRACTICE. ROCK MECHANICS 10, 1-54. SPRINGER.
DEERE, D.U. AND DEERE, D.W. (1989). ROCK QUALITY DESIGNATION (RQD) AFTER TWENTY YEARS. CONTRACT REPORT GL-89-1. ARMY CORPS OF ENGINEERS. WASHINGTON DC, 1989.

GLOSSARY OF SYMBOLS

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www.ghd.com/Geotechnical

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

GENERAL

Symbol	Description	Symbol	Description
D	Disturbed Sample	**R**	Rising Head Permeability Test
B	Bulk Sample	**F**	Falling Head Permeability Test
U(50)	Undisturbed Sampled (suffixed by sample size or tube diameter in mm if applicable)	**PBT**	Plate Bearing Test
CS	Core Sample (suffixed by diameter in mm)		Water Inflow (make)
ES	Soil sample for environmental sampling		Water Outflow (loss)
PID	Photoionisation Detector		Temporary Water Level
SPT	Standard Penetration Test (with blows per 0.15m)		Final Water Level
N	SPT Value		Point Load Test (axial)
HB/HW	SPT Hammer Bouncing/Hammer Weight		Point Load Test (diametric)
PP/HP	Pocket/Hand Penetrometer (suffixed by value kPa)	**PL**	Point Load (kPa)
PK	Packer Test (kPa)	**IMP**	Impression Device Test
PZ	Piezometer Installation	**PM**	Pressuremeter Test
SV/VS	Shear Vane Test (suffixed by value in kPa)		

SOIL SYMBOLS

Main Components		Minor Components	
SAND	FILL	sandy	vegetation, roots
GRAVEL	SILT	gravelly	silty
CLAY	TOPSOIL	clayey	*Note: Natural soils are generally a combination of constituents, e.g. sandy CLAY*

ROCK SYMBOLS

Sedimentary			Igneous	
SANDSTONE	SILTSTONE	CONGLOMERATE	GRANITIC ROCK	IGNEOUS DYKE
CLAYSTONE	SHALE	COAL	BASALTIC ROCK	

Note: Additional rock symbols may be allocated for a particular project

NATURAL DEFECTS *(Coding)*

Defect Type		Orientation					
Jt	Joint	For vertical non-oriented core ... "Dip" angle (eg. 5°) measured relative to horizontal.					
Pt	Parting	For inclined non-oriented core ... "Angle" measured relative to core axis.					
SS	Sheared Surface	For inclined oriented core ... "Dip" angle and "Dip Direction" angle (eg. 45°/225° mag.).					
WSm	Weathered Seam	**Orientation (con't)**		**Roughness**		**Coating**	
SSm	Sheared Seam	**VT**	Vertical	**Pol**	Polished	**Cn**	Clean
CSm	Crushed Seam	**HZ or 0°**	Horizontal	**So**	Smooth	**Sn**	Stained
ISm	Infilled Seam	**d / °**	Degrees	**Rf**	Rough	**Ve**	Veneer
SZ	Sheared Zone			**VR**	Very Rough	**Co**	Coating
VN	Vein			**Slk**	Slickensided		
Shape				**Infilling / Common Materials**			
Pln	Planar	**St**	Stepped	**CLAY**	Clay	**Mi**	Micaceous
Cu	Curved	**Ir**	Irregular	**Ca**	Calcite	**Mn**	Manganese
Un	Undulating	**Dis**	Discontinuous	**X**	Carbonaceous	**Py**	Pyrite
Others				**Kt**	Chlorite	**Qz**	Quartz
OP Open	**CL** Closed	**Ti**	Tight	**Fe**	Iron Oxide	**MU**	Unidentified Mineral

Ref: DS6.5.3 Rev 1 Date : 25/09/2019

LABORATORY TESTING

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GENERAL

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

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

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

TESTING

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

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

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

LABORATORIES

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

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

Ref: DS5.5.2 Issue 0 Date: 05/10/2018

CONE PENETRATION (CPT/CPTU) TESTING

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SCOPE

The Cone Penetration Test (CPT) comprises the measurement of soil resistance in response to a steel cone pushed into the ground at a constant rate. The CPTU (or piezo cone) test involves sophisticated equipment yet is simple in operation and provides rapid, almost continuous traces of soil response, with good repeatability.

The CPT/CPTU test is commonly employed as a means of extrapolation of discrete borehole data for a particular site. The interpretation of CPT and CPTU results without appropriate borehole data correlation must be considered for guide purposes only and should not be used in isolation for detailed design.

EQUIPMENT AND METHOD

The steel cone consists of a 37 mm diameter, 60° cone, hydraulically pushed vertically down into the soil profile. The piezo probe includes the measurement of cone resistance (q_c), friction sleeve (f_s), inclinometer and pore pressure (u) whilst the friction cone used for CPT testing includes cone resistance and friction sleeve readings only. The porous element of the piezo cone is situated on the cylindrical shaft immediately behind the cone. The rate of penetration for both cones is approximately 20 mm/sec with readings taken usually at 20 mm intervals throughout the profile.

The CPTU test is typically initiated by inserting the pre-saturated probe into a pre-drilled hole below the ground water table. The probe is then permitted to achieve temperature stabilisation prior to conducting the penetration test.

The CPT/CPTU readings are measured using load cells and strain gauges set in the probe. The signals from these gauges are transmitted to an analogue/digital converter. The digitised data is then recorded and stored on a lap-top computer for later analysis. In particular, data reduction includes processing of the q_c results recorded with the piezo cone to total resistance (q_t) values using the corresponding pore pressure value in accordance with published procedures.

The piezo cone can also be used to perform pore pressure dissipation measurements at selected test levels to determine the localised lateral drainage characteristics of the subsoil. Depending on the rate of dissipation, the excess pore pressure is recorded during the dissipation test until a nominated degree of dissipation is achieved.

The cone penetration test is terminated once the probe reaches refusal, when the rods behind the probe cannot be advanced further due to resistance developed along the rods or when the force required to advance the rods exceeds the capacity of the testing vehicle or frame. The probe is then withdrawn from the ground and the readings corrected to take into account effects of the temperature variation at depth.

INTERPRETATION

The CPT and CPTU results can be used to assess the soil profile at specific test locations and to estimate soil strength and consolidation characteristics. As mentioned previously, such interpretations are generally performed in association with discrete borehole data.

In particular, the interpretations must take account of the soil type (and consequent drainage conditions), soil strength, sensitivity and stress history (i.e. normally or over-consolidated). Details of these are beyond the scope of this explanation sheet.

Ref: 5.4.4 Issue 0 Date: 05/10/2018

Appendix B – Figures

Legend

- Site Boundary
- Borehole location
- CPT location

Paper Size ISO A3

0 6.5 13 19.5 26

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Port of Newcastle Operations Pty Ltd
65 Denison St / 46 Fitzroy St Carrington
Geotechnical and Mine Subsidence Assessment

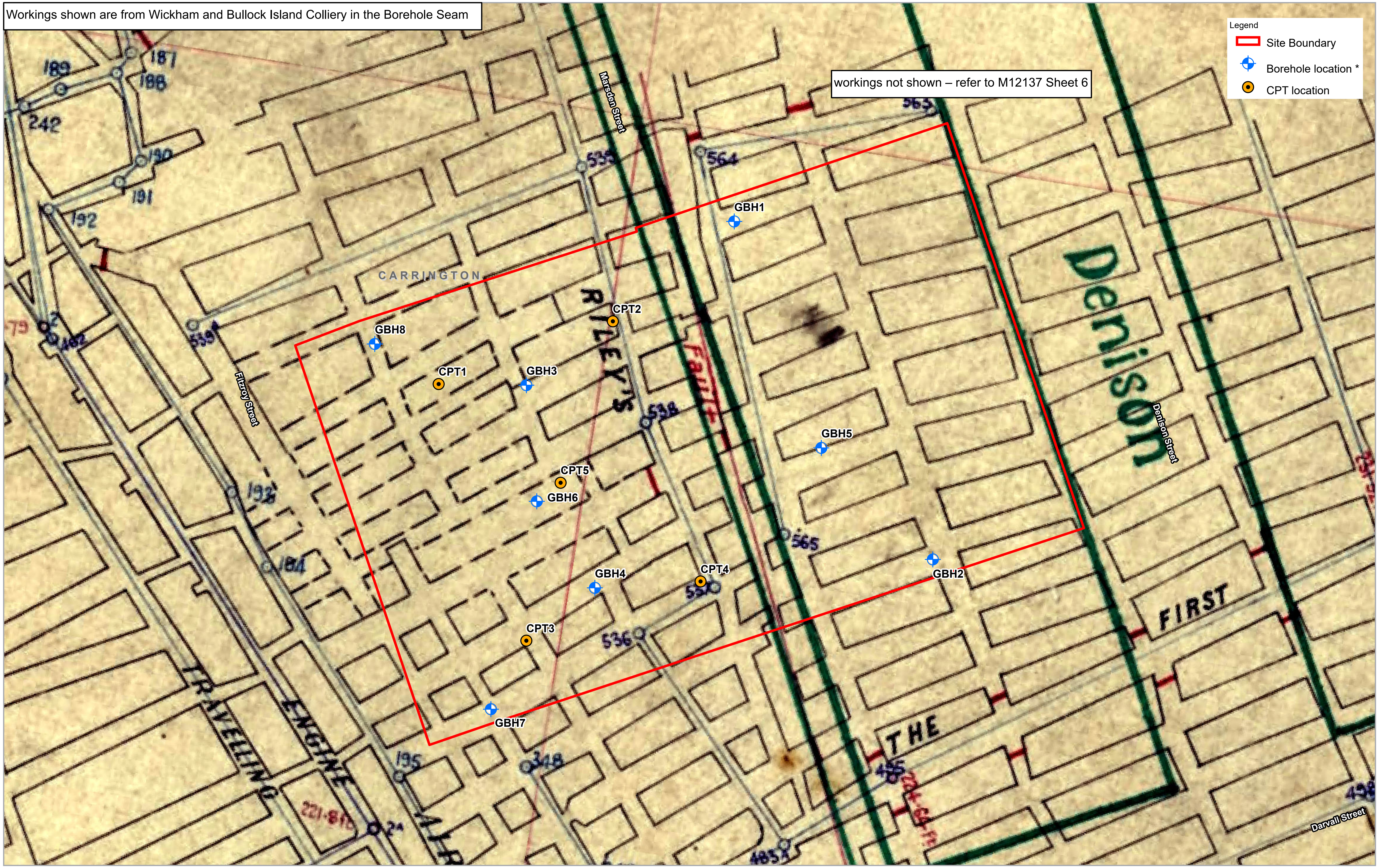
Borehole and CPT location plan

Project No. 12545790
Revision No. 0
Date 22/03/2021

FIGURE 1

G:\22\12527619\GIS\Maps\12527619_FitzroyStMineSubsidenceAndContamination\12545790_Geotech_0.aprx\12545790_G001_Geotech_0
Print date: 22 Mar 2021 - 08:34

Data source: LPI: DCDB/DTDB, 2017. public_NSW_Imagery: © Department of Customer Service 2020. Created by: fmackay



Note
* GBH5 location at seam level is 0.3m toward 160^0 bearing.
* GBH6 location at seam level is 0.9m toward 194^0 bearing.

Disclaimer

Any excerpts of original mine survey plans or record tracings and any data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitation) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning is not responsible or liable to any person for any loss or liability arising out of or in connection with use of any such excerpts or derived data.

Paper Size ISO A3

0 6 12 18 24

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Port of Newcastle Operations Pty Ltd
65 Denison St / 46 Fitzroy St Carrington
Geotechnical and Mine Subsidence Assessment

M12137 Sheet 4 Delta Colliery plan extract

Project No. 12545790
Revision No. 0
Date 22/03/2021

FIGURE 2

G:\22\12527619\GIS\Maps\12527619_FitzroyStMineSubsidenceAndContamination\12545790_Geotech_0.aprx\12545790_G002_MineWorkings_M12137_0
Print date: 22 Mar 2021 - 08:34

Data source: LPI: DCDB/DTDB, 2017. De Witt Consulting: RT0579.R10000566.Plan of workings- sheet 1 (pt 1) of 4. 1ch1inch.jpg/RT0579.R10000566.Plan of workings- sheet 2 (pt 1) of 4. 1ch1inch.jpg.. Created by: fmackay

Note
* GBH5 location at seam level is 0.3m toward 160⁰ bearing.
* GBH6 location at seam level is 0.9m toward 194⁰ bearing.

Disclaimer

Any excerpts of original mine survey plans or record tracings and any data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitation) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning is not responsible or liable to any person for any loss or liability arising out of or in connection with use of any such excerpts or derived data.

Paper Size ISO A3
0 6 12 18 24
Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Port of Newcastle Operations Pty Ltd
65 Denison St / 46 Fitzroy St Carrington
Geotechnical and Mine Subsidence Assessment

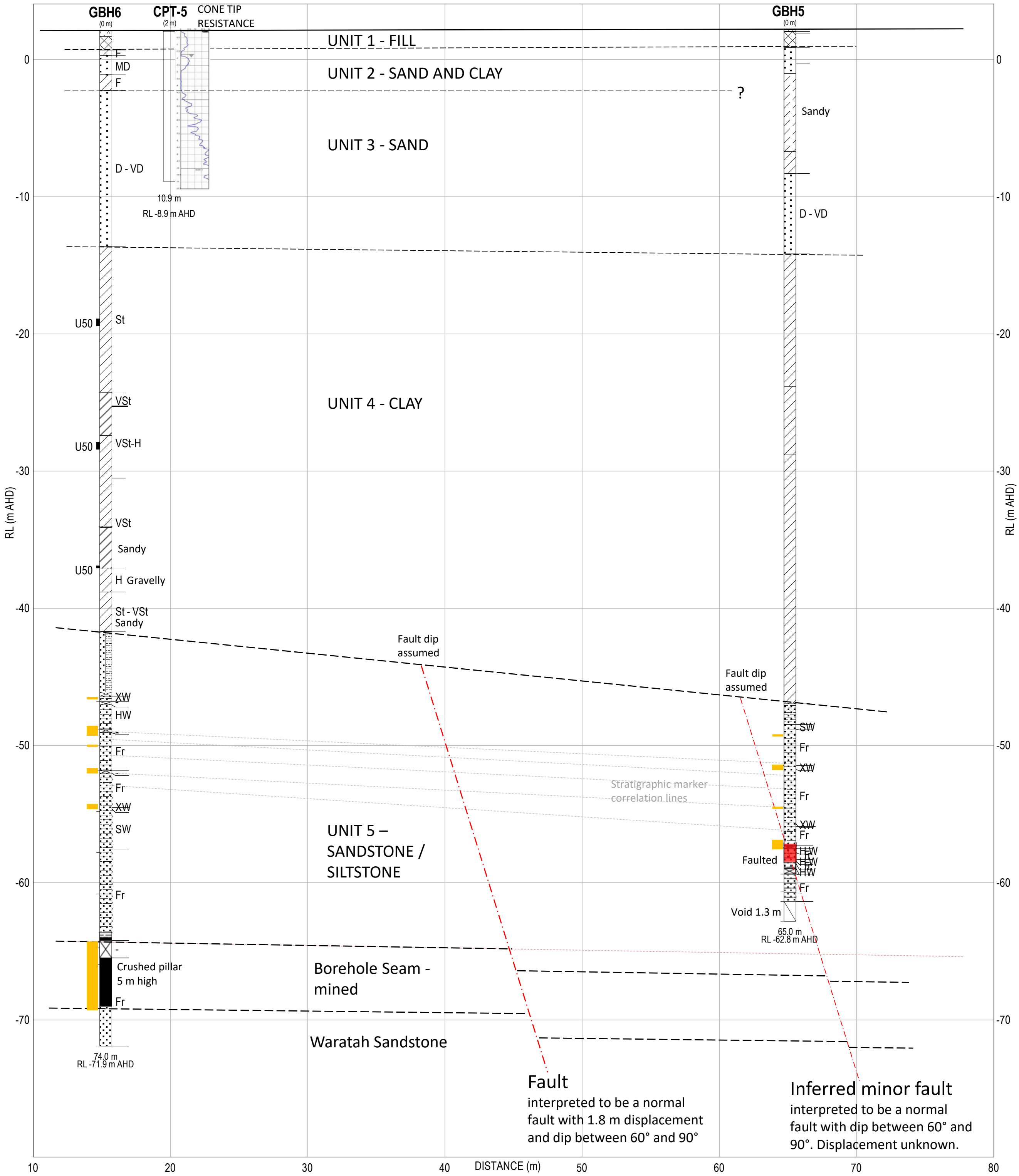
Project No. 12545790
Revision No. 0
Date 22/03/2021

Record Tracing RT579 extract

FIGURE 3

G:\22\12527619\GIS\Maps\12527619_FitzroyStMineSubsidenceAndContamination\12545790_Geotech_0.aprx\12545790_G003_MineWorkings_RT0579_0
Print date: 22 Mar 2021 - 08:34

Data source: LPI: DCDB/DTDB, 2017. De Witt Consulting: RT0579.R10000566.Plan of workings- sheet 1 (pt 1) of 4. 1ch1inch.jpg/RT0579.R10000566.Plan of workings- sheet 2 (pt 1) of 4. 1ch1inch.jpg.. Created by: fmackay



LEGEND

- CLAY
- CLAYEY SAND
- GEOPHYSICS CALIPER LOG INDICATES BOREHOLE WALL CAVING / SPALLING
- FILL
- SAND
- CORE LOSS
- COAL
- SANDSTONE
- SILTSTONE
- INTERBEDDED SILTSTONE & SANDSTONE

NOTES

1. THE INFERRED GEOTECHNICAL SECTIONS ARE AN IDEALISATION OF GEOLOGICAL INTERPOLATION AND EXTRAPOLATION OF DISCRETE BOREHOLE DATA. THE INTERPRETATION SHOWN DOES NOT NECESSARILY IMPLY THE ACTUAL CONTACT BETWEEN THE GEOLOGICAL UNITS.
2. REFER TO BOREHOLE LOGS FOR DETAILS. LOGS AND HISTOGRAMS OF ESTIMATED STRENGTH AND FRACTURE SPACING ARE SHOWN HERE FOR GENERAL GUIDANCE ONLY.
3. REFER TO BOREHOLE LOG SHEET AND CORE LOG SHEETS FOR SPECIFIC INFORMATION. (IN THE EVENT OF DISCREPENCIES BETWEEN LOGS ON THIS DRAWING AND THE CORE LOG SHEETS, THE LATTER HAVE PRECEDENCE).
4. REFER TO STANDARD SHEETS FOR SYMBOLS AND ABBREVIATIONS.
5. REFER TO TEXT OF THE REPORT FOR DESCRIPTION OF UNITS.
6. RL OF BOREHOLE COLLAR HEIGHTS ESTIMATED FROM SURVEY PLANS SUPPLIED.

0 2.5 5.0 10m
SCALE 1:300 AT ORIGINAL SIZE

Port of Newcastle
Proposed Commercial Development
46 Fitzroy Street/ 65 Denison Street Carrington NSW

Geotechnical Investigation
Cross Section A-A

12545790
A
April 2021

FIGURE 4

Levels 2 & 3 GHD Tower, 24 Honeysuckle Drive Newcastle NSW 2300 Australia T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com

Plot Date: 1 April 2021 - 10:14 AM Plotted by: Helen Warr Cad File No: \\ghdnet\ghd\AU\Newcastle\Projects\22\12545790\CADD\Drawings\Geotech\12545790-FIG004.dwg

Appendix C – Borehole logs and core photographs

GEO_BOREHOLE_AS1726 2017 12545790 DENISON ST CARRINGTON.GPJ GHD_GEO_TEMPLATE 2.00.GDT 31/3/21

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH1

SHEET 1 OF 1

Position : 384448.9 E 6357153.1 N MGA2020/ 56 | **Surface RL:** 1.88m AHD | **Angle from Horiz. :** 90° | **Processed :** SBO
Rig Type : Scout | **Mounting:** Truck | **Contractor :** Total Drilling Pty Ltd | **Driller :** Glen Gearside | **Checked :** SJM
Date Started : 22/2/2021 | **Date Completed :** 22/2/2021 | **Logged by :** Nick Leaver | **Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Auger	Nil			0.10			[TOPSOIL/FILL]: Sandy SILT: brown to dark grey, fine to medium sand, rootlets up to 100mm.	M		
				ASS	0.85			[FILL]: SAND: fine to medium grained, brown.	M		
1			22/2/21	B	1.40			[FILL]: SAND: fine to medium, grey/brown, organic matter present, trace fines and gravel.	M W		
					1.75		CH	Sandy CLAY: high plasticity, dark brown, fine grained sand (estuarine).	M	F	
2					2.00		SP	SAND: medium grained, white to grey, trace shell fragments (marine).	W	D-VD	
								End of borehole at 2.00 metres. Target Depth			
3											
4											
5											

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH2

SHEET 1 OF 1

Position : 384483.1 E 6357094.9 N MGA2020/ 56	**Surface RL:** 2.15m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver		**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Auger	Nil			0.20			[TOPSOIL/FILL]: Silty SAND: brown, rootlets to 30mm.	M		
					0.40			[FILL]: Gravelly SAND: medium grained, brown to grey, gravel up to 100mm.	M		
1				B	1.30			[FILL]: SAND: medium grained, pale grey, trace shell and shell fragments.	M		
				ASS	1.50		CI	CLAY: medium plasticity, dark brown to dark grey (estuarine).	M	F	
2			▽ 23/2/21	B	2.00		SP	SAND: medium grained, brown, trace of shell fragments.	W	D	
3								End of borehole at 2.00 metres. Target Depth			
4											
5											

See standard sheets for details of abbreviations & basis of descriptions

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BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH3

SHEET 1 OF 4

Position : 384413.1 E 6357124.9 N MGA2020/ 56	**Surface RL:** 2.05m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 22/2/2021	**Date Completed :** 22/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING: SCALE (m) | Drilling Method | Hole Support \ Casing | Water | Samples & Tests

MATERIAL: Depth metres | Graphic Log | USC Symbol | Description | Moisture Condition | Consistency / Density Index

Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects

Depth metres	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
0.15		[TOPSOIL/FILL]: Silty SAND: medium to coarse grained, brown to dark grey, rootlets up to 150mm.	M		
1.23		[FILL]: SAND: medium to coarse, brown, trace fine gravel and shell fragments.	M		
1.55		[FILL]: SAND: fine to medium grained, brown to grey, with silt.	W		
1.85	CI	Sandy CLAY: medium plasticity, grey to dark grey, fine to medium grained sand (estuarine).	W	F	ASS confirmed
3.40	SP	SAND: medium grained, brown to grey, trace shells and shell fragments, organic matter (marine).	W	D	
4.30	CI	Sandy CLAY: medium plasticity, grey to dark grey, fine grained sand (estuarine). 4.0m, becoming dark grey.	W	F	
	SP	SAND: medium grained, dark grey, trace shell fragments (marine).	W	D	

Drilling Method: Auger (0 to approx. 3.5m); Washbore (below approx. 3.5m)

Hole Support \ Casing: Nil (0 to approx. 3.5m); HWT casing (below approx. 3.5m)

Water: ∇ 22/2/21 (at approx. 1.25m)

Samples & Tests:

Samples & Tests
SPT ?/?/? N=15
ASS+SPT 7/7/7 N=14
ASS+SPT 2/3/3 N=6
SPT 1/6/8 N=14

SCALE (m): 1, 2, 3, 4, 5

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

BOREHOLE LOG SHEET

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH3

Position : 384413.1 E 6357124.9 N MGA2020/ 56	**Surface RL:** 2.05m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 22/2/2021	**Date Completed :** 22/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
							SP	SAND: as previous.	W	D	
6											
7	Washbore	HWT casing		SPT 14/14/28 N=42	7.30		SP	SAND: medium grained, grey, with shells up to 50mm and shell fragments (marine).	W	VD	
8											
9					9.00		SP	SAND: medium to coarse grained, grey, with shells and shell fragments (marine).	W	MD	
10					10.00						

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH3

Position : 384413.1 E 6357124.9 N MGA2020/ 56	**Surface RL:** 2.05m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 22/2/2021	**Date Completed :** 22/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore	HWT casing		SPT 10/31/19 N=ref			SP	SAND: as previous.	W	VD	
					10.58		SP	SAND: medium to coarse grained, grey, with shell fragments (marine).	W	VD	
11											
12											
13				SPT 13/24/26 N=ref							
14											
15											

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH3

Position : 384413.1 E 6357124.9 N MGA2020/ 56	**Surface RL:** 2.05m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 22/2/2021	**Date Completed :** 22/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					SP	SAND: as previous.	W	VD	
				U50	15.55		CI	Sandy CLAY: medium plasticity, grey to dark grey, medium grained sand, with shell fragments up to 1mm (estuarine).	M	VSt	Vs=113kPa Peak
16					16.00			End of borehole at 16.00 metres. Target Depth			
17											
18											
19											
20											

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH4

Position : 384424.9 E 6357090.0 N MGA2020/ 56	**Surface RL:** 2.10m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING / **MATERIAL**

Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Auger	Nil			0.12			[TOPSOIL/FILL]: Silty SAND: fine to medium grained, brown, rootlets down to 120mm.	M		
				SPT 5/4/6 N=10				[FILL]: SAND: medium grained, brown to pale grey, trace shell fragments and fine gravel.	M		
1			23/2/21		1.20						
					1.55			[FILL]: Sandy CLAY: low plasticity, brown to dark grey, fine grained gravel up to 7mm, trace organic matter.	W		
				ASS+SPT 1/1/6 N=7	1.90		CI	Gravelly CLAY: medium plasticity, brown to dark grey, shell and gravel up to 7mm, trace organic matter (estuarine?).	W	F	
2							SP	SAND: medium to coarse grained, pale grey, with shell fragments (marine). 2.35m, becoming grey.	W	D	
3				SPT 2/1/2 N=3	3.35					MD	
	Washbore	HWT casing			3.80		CI	Clayey SAND/Sandy CLAY: medium plasticity, dark grey, fine to medium grained sand, trace shell fragments (estuarine).	W	S-F	
4					4.20		SC	Clayey SAND: fine to medium grained, dark grey (estuarine).	W	MD	
				SPT 4/6/6 N=12	4.60		SP	SAND: medium grained, pale grey, trace shell fragments (marine).	W	MD-D	
5							SP	SAND: medium grained, dark grey, trace shell fragments of gravel size and clay (marine).	W	MD	

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

BOREHOLE LOG SHEET

HOLE No. GBH4

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW
Position :	384424.9 E 6357090.0 N MGA2020/ 56
Surface RL:	2.10m AHD
Angle from Horiz. :	90°
Rig Type :	Scout
Mounting:	Truck
Contractor :	Total Drilling Pty Ltd
Driller :	Glen Gearside
Date Started :	23/2/2021
Date Completed :	23/2/2021
Logged by :	Nick Leaver
Processed :	SBO
Checked :	SJM
Date:	03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING — Drilling Method: Washbore; Hole Support \ Casing: HWT casing

MATERIAL — Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					SP	SAND: as previous.	W	MD	
					5.20		SP	SAND: medium to coarse grained, grey, with shells and shell fragments (marine).	W	D	
6											
7				SPT 16/21/20 N=41							
8					8.05		CH	Clayey SAND/Sandy CLAY: high plasticity, dark grey, fine grained sand, with small shell fragments (estuarine).	W	F/D	
					8.40		SP	SAND: medium grained, grey, with small shell fragments present (marine).	W	D	
9					8.95		SC	Clayey SAND: fine grained, grey/dark grey (marine).	W		
10											

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BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH4**
Project : Proposed Commercial Development		
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 3 OF 4**

Position : 384424.9 E 6357090.0 N MGA2020/ 56	**Surface RL:** 2.10m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver		**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					SC	Clayey SAND: as previous.	W		
					10.15		SP	SAND: medium to coarse grained, grey, with shell fragments (marine).	W	VD	
				SPT 8/23/27 N=ref				From 10.59-10.64m, layer of shell fragments (shell hash). At 10.64m, becoming pale grey.			
11											
12											
13											
				SPT 12/26/24 N=ref							
14											
15											

BOREHOLE LOG SHEET

HOLE No. GBH4

Client : Port of Newcastle			
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW			
Position : 384424.9 E 6357090.0 N MGA2020/ 56	**Surface RL:** 2.10m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

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SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing			15.85		SP	SAND: as previous.	W	VD	
16				U50	16.40		CI	CLAY: medium plasticity, grey.	M		Vs=116kPa Peak
17								End of borehole at 16.40 metres. Target Depth			
18											
19											
20											

See standard sheets for details of abbreviations & basis of descriptions

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HOLE No. GBH5

Client : Port of Newcastle			
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW			
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING | **MATERIAL**

Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
	CC (0–0.12)	Nil (0–0.12)			0.12		-	CONCRETE: grey to pale grey, mixed aggregates up to 30mm, rebar at 60mm, 7mm diameter.	-	-	
	Auger (0.12–2.40)	HWT casing (0.12–2.40)			0.16		-	NO CORE: Void at 0.04m.	-	-	
					0.26		-	[FILL]: SAND: medium grained, dark grey, with fine to medium gravel, lightly cemented.	-	-	
					1.20		-	[FILL]: SAND: medium grained, brown, with fine gravel, traces of shells and shell fragments. 1.0m, becoming dark grey.	M	?	
1					1.30		CI	Sandy CLAY: medium plasticity, dark grey (estuarine).	M	-	
			3/1/21 (~1.6)		2.50		SP	SAND: fine to medium grained, grey/brown, trace shell/shell fragments (marine).	M / W	-	
2	Washbore (2.40–5.0)				3.20		SP	SAND: medium grained, pale grey, with fines, traces of organic matter (marine).	W		
3							SC	Clayey SAND: fine to medium grained, dark grey, trace of fine grained gravel, trace of shell fragments (marine/estuarine?).	W		
4											
5											

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BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH5**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 2 OF 14**	
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore						SC	Clayey SAND: as previous.	W		
6											
7											
8											
					8.90		CI	CLAY: medium plasticity, dark grey, with medium grained sand (estuarine).	M		
9											
10											

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH5**
Project : Proposed Commercial Development		
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 3 OF 14**
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD **Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021 **Logged by :** Nick Leaver	**Date:** 11/03/2021

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DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore						CI	CLAY: as previous.	M		
11					10.50		SP	SAND: fine to medium grained, dark grey, with shell fragments, trace fine gravel (marine).	W	D-VD	
12											
13											
14											
15											

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH5**
Project : Proposed Commercial Development		
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 4 OF 14**
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD **Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021 **Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore						SP	SAND: as previous.	W	D-VD	
16					16.35		CH	CLAY: high plasticity, dark grey, with fine to medium grained sand (estuarine).	M		
17					17.90		CH	CLAY: high plasticity, dark grey (estuarine).	M		
18											
19								19.0m, becoming pale grey. 19.2-19.27m, becoming harder.			
20											

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver		**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore						CH	CLAY: as previous.	M		
					20.40		CH	CLAY: high plasticity, dark grey, traces of fine to medium gravel up to 50mm, traces of shell fragments (estuarine).	M		
21											
22											
23											
24											
25											

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW
HOLE No.	**GBH5**
SHEET	6 OF 14
Position :	384463.9 E 6357114.1 N MGA2020/ 56
Surface RL:	2.18m AHD
Angle from Horiz. :	90°
Processed :	SBO
Rig Type :	Scout
Mounting:	Truck
Contractor :	Total Drilling Pty Ltd
Driller :	Glen Gearside
Checked :	SJM
Date Started :	1/3/2021
Date Completed :	3/3/2021
Logged by :	Nick Leaver
Date:	11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore						CH	CLAY: as previous.	M		
26					26.00		CL	CLAY: low plasticity, dark grey, with fine grained sand (estuarine).	M		
27											
28											
29											
30											

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore						CL	CLAY: as previous.	M		
31					31.00		CI	CLAY: medium plasticity, dark grey, traces of fine grained sand (estuarine).	M		
32											
33											
34											
35											

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH5**
Project : Proposed Commercial Development		
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 8 OF 14**
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD **Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021 **Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore						CI	CLAY: as previous.	M		
36											
					36.40		CI	CLAY: medium plasticity, dark grey, with medium grained sand (estuarine).	M		
37											
38											
39											
40											

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

Client : Port of Newcastle	**HOLE No. GBH5**
Project : Proposed Commercial Development	
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW	**SHEET 9 OF 14**
Position : 384463.9 E 6357114.1 N MGA2020/ 56 **Surface RL:** 2.18m AHD **Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021 **Date Completed :** 3/3/2021 **Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
41 42 43 44 45	Washbore						CI	CLAY: as previous.	M		

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore						CI	CLAY: as previous.	M		
46											
47					46.90		CI	CLAY: medium plasticity, dark grey, with fine to medium grained gravel, traces of fine to medium grained sand (estuarine?/possible residual?).	M		
48											
49					49.10		-	SILTSTONE AND SANDSTONE: fine grained sandstone, dark grey, extremely weathered.	-	-	
50											

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH5**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 11 OF 14**	
Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 1/3/2021	**Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore				50.65		-	SILTSTONE AND SANDSTONE: as previous.	-	-	
51								Start of coring at 50.65 metres. For cored interval, see Core Log Sheet.			
52											
53											
54											
55											

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CORE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56 **Surface RL:** 2.18m AHD **Angle from Horiz. :** 90° **Processed :** SBO
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside **Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m **Bit :** Step 7 **Bit Condition :** Good **Date:** 11/03/2021
Date Started : 1/3/2021 **Date Completed :** 3/3/2021 **Logged by :** Nick Leaver **Date Logged :** 11/3/2021
Note: * indicates signatures on original issue of log or last revision of log

DRILLING						MATERIAL					NATURAL FRACTURES	
SCALE (m)	Drilling & Casing	Water	Drill Depth (m)	(Core Loss / Run %)	RQD (%)	Depth metres	Graphic Log	Description ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin)	Weathering	Estimated Strength $Is_{(50)}$ MPa (● - Axial, O - Diametral) Soil 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH	Spacing (mm) 20 40 100 300 1000	Additional Data (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.
						50.65		Start of coring at 50.65 metres. For Non Cored interval, see Borehole Log Sheet.				
	Step 7 + HQ casing							INTERLAMINATED TO INTERBEDDED SANDSTONE (30%) AND SILTSTONE (30%): sandstone is fine to medium grained, pale grey to grey, indistinctly bedded at 0-15°, siltstone is dark grey, closely to widely spaced tuff, pale brown to dark brown, thickness up to 80mm thick.	SW			50.73m, Pt, 0°, So, Pln, Cn
								50.95m, tuff, pale brown.				50.93m, Jt, 60°, So, Pln, Cn
51								51.2m, geophysics: hole caving in.	Fr			51.02m, Pt, 0°, So, Pln, Cn 51.07m, Fracture (subsidence?), 70°, So, Pln, Cn 51.29m, Pt, 0°, I?, Un, Cn 51.7m, Pt, 5°, Rf, Un, Cn 51.92m, Pt, 5°, So, Pln, Cn
52				(0)				52.3-52.6m, geophysics: increase in natural gamma.				
								52.57m, distinct/abrupt transition from siltstone to sandstone.				52.58m, Fracture (subsidence?), 70° to ENE, Rf, Pln, Cn 52.65m, Pt, 10°, Rf, Pln, Coal?
53			53.65									53.6m, Fracture (subsidence?), So, Pln, Cn
								From 53.7-54.1m, geophysics: hole caving.	XW			
54												54.12m, Pt, 10°, Rf, Un, Cn
								54.35m, tuff, brown, hard, distinct/abrupt transition from siltstone to sandstone.	Fr			54.88m, Fracture (subsidence?), 75° to ENE, So, Pln, Cn
55												

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Job No. 12545790

CORE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 1/3/2021 **Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date Logged :** 11/3/2021	Note: * indicates signatures on original issue of log or last revision of log

DRILLING: Drilling & Casing: Step 7 + HQ casing

Drill Depth (m)	(Core Loss / Run %)	Depth metres	Description	Weathering	Estimated Strength $Is_{(50)}$ MPa	Spacing (mm)	Additional Data
	(0)		INTERLAMINATED TO INTERBEDDED SANDSTONE (30%) AND SILTSTONE (30%): as previous.				
			55.6m, distinct tuff bed ~40mm thick in siltstone sequence.				55.67m, Pt, ~10-15° to W, So, Pln, CLAY
			56.0-56.7m, sandstone fining up sequence.				56.32m, Pt, Rf, Un, Cn
56.65			From 56.54-26.84m, geophysics: minor hole caving.	Fr			56.84m, Pt, Rf, Pln, Cn 56.91m, ~60° to E, Fracture (subsidence?), 60°, Rf, Pln, Cn 56.93m, Pt, 0°, So, Pln, Cn 56.95m, Pt, Rf, Un, Cn 57.39m, Pt, So, Pln, Cn 57.75m, ~70° to SSE, Fracture (subsidence?), 65°, So, Pln, Cn
				XW			57.86m, Pt, 5°, Rf, Un, Cn 57.9m, Jt, 15°, Rf, Un, Cn to W
	(5)		57.9m, abrupt transition from siltstone to sandstone. 58.4m, abrupt transition back to siltstone. 59.28m, healed parting at 30° to W, possible erosional surface?	Fr			58.22m, ~70° to SSE, Fracture (subsidence?), 60°, So, Pln, Cn 58.32m, ~70° to SSE, Fracture (subsidence?), 45°, Rf, Pln, Cn 58.36m, Pt, 0°, Rf, Un, CLAY 58.62m, Pt, 3°, So, Pln, Cn 58.83m, Pt, 5°, Rf, Un, Cn 59.03m, Pt, 10°, So, Pln, Cn 59.21m, Pt, 3°, So, Pln, Cn
59.65		59.50	CORE LOSS: 200mm.				
		59.70	INTERLAMINATED TO INTERBEDDED SANDSTONE (30%) AND SILTSTONE (30%): *(refer to next page for description)* From 59.75-60.4m, geophysics: bore caving.	HW			

Scale (m): 56, 57, 58, 59, 60

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Job No. 12545790

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH5

Position : 384463.9 E 6357114.1 N MGA2020/ 56	**Surface RL:** 2.18m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 1/3/2021 **Date Completed :** 3/3/2021	**Logged by :** Nick Leaver	**Date Logged :** 11/3/2021	Note: * indicates signatures on original issue of log or last revision of log

DRILLING: Progress — SCALE (m), Drilling & Casing, Water; Drill Depth (m); (Core Loss / Run %); RQD (%)
MATERIAL: Depth metres; Graphic Log; Description (ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin)); Weathering; Estimated Strength $Is_{(50)}$ MPa (● - Axial, ○ - Diametral; Soil, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10)
NATURAL FRACTURES: Spacing (mm) (20, 40, 100, 300, 1000); Additional Data (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Drilling & Casing: Step 7 + HQ casing

Drill Depth (m)	(Core Loss / Run %)	Depth (m)	Description	Weathering	Additional Data
61.55	(24)	61.15	INTERLAMINATED TO INTERBEDDED SANDSTONE (30%) AND SILTSTONE (30%): sandstone is fine to medium grained, pale grey to grey, indistinctly bedded at 0-15°, siltstone is dark grey, closely to widely spaced tuff, pale brown to dark brown, thickness up to 80mm thick. 60.3-60.38m, healed fault, host rock up to 20mm, thick infilled by clay, traces of pyrite. From 60.7-61.7m, geophysics: bore caving.	Fr / HW / Fr / HW	60.1m, Pt, 3°, Rf, Un, Cn; 60.29m, Pt, 0°, Rf, Pln, Cn; 60.49-60.36m, CSm; 61.09-61.14m, CSm
		61.55	CORE LOSS: 400mm.		
62.85	(0)	62.38	INTERLAMINATED TO INTERBEDDED SANDSTONE (30%) AND SILTSTONE (30%): sandstone is fine to medium grained, pale grey to grey, indistinctly bedded at 0-15°, siltstone is dark grey, closely to widely spaced tuff, pale brown to dark brown, thickness up to 80mm. 61.93m, 'flame structure' (soft sediment deformation).	Fr	61.58m, Pt, 0°, Rf, Pln, Cn; 61.87m, Pt, 3°, Rf, Un, Cn; 61.94m, Pt, 10°, So, Pln, Un; 62.08m, Fracture (subsidence?), 60°, So, Pln, Cn; 62.35m, ~75° to NE, Fracture (subsidence?), 60°, So, Pln, Cn
63.55	(0)	63.55	INTERLAMINATED SILTSTONE (90%) AND SANDSTONE (10%): siltstone is dark grey, sandstone is fine grained, grey.	Fr	62.45m, ~75° to NE, Fracture (subsidence?), 60°, Rf, Un, Cn; 62.7m, ~75° to NE, Fracture (subsidence?), 60°, So, Pln, Cn; 63.09m, Pt, 0°, So, Pln, Cn; 63.27m, Pt, 10°, So, Pln, Cn; 63.32m, Pt, 10°, So, Pln, Cn; 63.4m, ~75° to NE, Fracture (subsidence?), 60°, So, Pln, Un
65.00	(100)	65.00	VOID: mine subsidence. 63.68m, geophysics: void. At 64.3m, geophysics: base of void. Target Depth		

Scale: 61, 62, 63, 64, 65

End of Borehole at 65.00 metres.

See standard sheets for details of abbreviations & basis of descriptions

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Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH5 1/4	

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021		
	CHECKED S MacKenzie	DATE 24/03/2021		
	SCALE Not To Scale		A4	
	PROJECT No 12545790	FIGURE No GBH5 2/4		

GHD	Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021
		CHECKED S MacKenzie	DATE 24/03/2021
		SCALE Not To Scale	A4
		PROJECT No 12545790	FIGURE No GBH5 3/4

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH5 4/4	

BOREHOLE LOG SHEET

HOLE No. GBH6

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW
Position :	384414.9 E 6357104.9 N MGA2020/ 56
Surface RL:	2.09m AHD
Angle from Horiz. :	90°
Rig Type :	Scout
Mounting:	Truck
Contractor :	Total Drilling Pty Ltd
Driller :	Glen Gearside
Date Started :	23/2/2021
Date Completed :	23/2/2021
Logged by :	Nick Leaver
Processed :	SBO
Checked :	SJM
Date:	11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING / **MATERIAL**

Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description	Moisture Condition	Consistency / Density Index	Comments/ Observations
0–0.40	Auger (0–2.5)	Nil (0–2.5)			0.40		-	[TOPSOIL]: Silty SAND: fine to medium grained, brown, poorly graded, rootlets to 100mm.	M		
0.40–1.40			23/2/21 (at ~1.2)		1.40		-	[FILL]: SAND: medium grained, brown to dark grey, shells and shell fragments present.	M		
1.40–1.80					1.80		CH	Sandy CLAY: high plasticity, dark grey (estuarine).	M	F	
1.80–3.20	Washbore (2.5–5)	HWT casing (2.5–5)			3.20		SP	SAND: medium grained, dark grey, trace of shells and shell fragments (marine).	W	MD	
3.20–4.35					4.35		CI	Sandy CLAY: medium plasticity, dark grey, fine to medium grained sand (estuarine?).	M	F	
4.35–5							SP	SAND: medium grained, dark grey, trace of shell fragments.	W	D-VD	

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

GEO_BOREHOLE_AS1726 2017 12545790 DENISON ST CARRINGTON.GPJ GHD_GEO_TEMPLATE 2.00.GDT 31/3/21

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW			
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
6	Washbore	HWT casing					SP	SAND: as previous.	W	D-VD	
7											
8											
9											
10											

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BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 3 OF 16**	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

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DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore	HWT casing					SP	SAND: as previous.	W	D-VD	
11											
								11.7m, becoming pale grey.			
12											
13											
								13.5, becoming dark grey.			
14											
15											

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 4 OF 16**	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

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DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore	HWT casing					SP	SAND: as previous.	W	D-VD	
					15.70		CI	Sandy CLAY: medium plasticity, grey to dark grey, fine to medium grained sand, traces of shell fragments (estuarine).	M	St	
16											
17											
18											
					18.50		CI	CLAY: medium plasticity, dark grey (estuarine).	M	St	
19											
20											

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BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW			
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					CI	CLAY: as previous.	M	St	
21				U50							21.0m, PP=120/140/130kPa
22											
23											
24											
25											

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver		**Date:** 11/03/2021

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DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Washbore	HWT casing					CI	CLAY: as previous.	M	St	
26					26.40		CH	CLAY: high plasticity, dark grey, with fine to medium grained sand, trace of shell fragments (estuarine).	M	VSt	
27					27.50		CH	CLAY: high plasticity, dark grey, with fine to medium grained sand, trace of shell fragments (estuarine).	M	VSt-H	
28											
29					29.50		CL	CLAY: low plasticity, dark grey, trace of shell fragments (estuarine).	M	VSt-H	
30											

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver		**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing		U50			CL	CLAY: as previous.	M	VSt-H	30.0m, PP=360/420/430kPa
31											
32											
					32.60		CL	CLAY: low plasticity, dark grey (estuarine).	M	VSt	
33											
34											
35											

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Job No. 12545790

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56 **Surface RL:** 2.09m AHD **Angle from Horiz. :** 90° **Processed :** SBO

Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Glen Gearside **Checked :** SJM

Date Started : 23/2/2021 **Date Completed :** 23/2/2021 **Logged by :** Nick Leaver **Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					CL	CLAY: as previous.	M	VSt	
36					36.20		CL	Sandy CLAY: medium plasticity, fine to medium grained sand, trace of shell fragments up to 1mm (estuarine).	M	VSt	
37											
38											
39				U50	39.15		CL	Gravelly CLAY: low plasticity, brown to dark grey, fine to medium gravel up to 15mm (fluvial?).	M	H	39.0m, U50 abandoned due to ground type "Gravelly CLAY" 39.0m, PP=440/520/500kPa
40											

See standard sheets for details of abbreviations & basis of descriptions

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Job No. 12545790

Client : Port of Newcastle			**HOLE No. GBH6**
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW			**SHEET 9 OF 16**
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description: [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Washbore	HWT casing					CL	Gravelly CLAY: as previous.	M	H	
41					40.90		CI	Sandy CLAY: medium plasticity, dark grey, fine to medium grained sand (fluvial?).	M	St-VSt	
42								42.4m, becoming brown.			
43											
44					43.80		-	SANDSTONE AND SILTSTONE?: fine to medium grained, brown, extremely weathered?.	-	-	
45											

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Job No. 12545790

BOREHOLE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 10 OF 16**	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date:** 11/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
46 47 48	Washbore	HWT casing					-	SANDSTONE AND SILTSTONE?: as previous.	-	-	
					48.20		-	CORE LOSS: 300mm.	-	-	
49 50					48.50			Start of coring at 48.5 metres. For cored interval, see Core Log Sheet.			

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CORE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		SHEET 11 OF 16	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 23/2/2021 **Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date Logged :** 26/2/2021	Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling & Casing	Water	Drill Depth (m)	(Core Loss / Run %)	RQD (%)	Depth metres	Graphic Log	Description	Weathering	Estimated Strength $Is_{(50)}$ MPa	Spacing (mm)	Additional Data
46												
47												
48								Start of coring at 48.5 metres. For Non Cored interval, see Borehole Log Sheet.				
	Step 7 + HQ casing		48.91	(0)		48.50		SILTSTONE: dark grey, with laminated to very thinly bedded CLAY, clay is low plasticity, dark grey, moist, firm.	XW	Soil		
49						48.91		CORE LOSS: 230mm.	-			
				(12)		49.14		INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): sandstone is fine to medium grained, grey, siltstone is dark grey, horizontal bedding. 49.2m, geophysics: bore caving. 49.85-49.95m, highly weathered zone.	HW			49.36m, Pt, 1°, So, Pln, Cn, bedding to NW 49.82m, Pt, 0°, So, Pln, Cn 49.83m, Pt, 0°, So, Pln, Cn
50												

Estimated strength scale: Soil, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10; ● - Axial, O - Diametral. Spacing scale: 20, 40, 100, 300, 1000.

Additional Data: (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Description: ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin)

CORE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56 | **Surface RL:** 2.09m AHD | **Angle from Horiz. :** 90° | **Processed :** SBO
Rig Type : Scout | **Mounting:** Truck | **Contractor :** Total Drilling Pty Ltd | **Driller :** Glen Gearside | **Checked :** SJM
Casing Dia. : 114mm/90mm | **Barrel (m) :** 3.0m | **Bit :** Step 7 | **Bit Condition :** Good | **Date:** 11/03/2021
Date Started : 23/2/2021 | **Date Completed :** 23/2/2021 | **Logged by :** Nick Leaver | **Date Logged :** 26/2/2021 | Note: * indicates signatures on original issue of log or last revision of log

DRILLING: Progress — SCALE (m); Drilling & Casing; Water; Drill Depth (m); (Core Loss / Run %); RQD (%)
MATERIAL: Depth metres; Graphic Log; Description — ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin); Weathering; Estimated Strength $Is_{(50)}$ MPa (● - Axial, ○ - Diametral; Soil, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10)
NATURAL FRACTURES: Spacing (mm) (20, 40, 100, 300, 1000); Additional Data (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Drilling & Casing: Step 7 + HQ casing

Drill Depth (m)	Core Loss / Run %	Depth (m)	Description	Weathering
50.90		50.90	INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): as previous. From 50.7-51.3m, geophysics: bore caving.	HW
		51.15	CORE LOSS: 250mm.	-
53.90	(8)	53.90	INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): sandstone is fine to medium grained, grey, siltstone is dark grey, horizontal bedding. 51.35-51.4m, bedding at 30°. 51.63m, abrupt transition from siltstone to sandstone. 51.63-52.24m, sandstone becoming fine to coarse grained. From 52.1-52.2m, geophysics: bore caving. 52.67m, tuffaceous pale brown bed. From 53.8-54.0m, geophysics: bore caving.	Fr
		54.11	CORE LOSS: 210mm.	-
			INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): sandstone is fine to medium grained, grey, massive, siltstone is dark grey, horizontal bedding. 54.15m, tuff. 54.15-54.36m, bedding at 20°.	Fr

Scale: 51, 52, 53, 54, 55

Additional Data:
- 50.32m, Pt, 0°, So, Pln, Cn
- 50.41m, Pt, 0°, So, Pln, Cn
- 50.82m, Pt, 0°, So, Pln, Cn
- 51.6m, Pt, 5°, So, Pln, Cn
- 51.78m, Jt, 30° to E, Rf, Un, Cn
- 51.85m, Jt, 15° to E, Rf, Pln, Cn
- 52.26m, Jt, 35°, So, Pln, Cn
- 52.7m, Pt, 0°, Rf, Pln, Cn
- 52.83m, Pt, 0°, Rf, Pln, Cn
- 53.1m, Fracture (subsidence?), 60°, Rf, Pln, Cn
- 53.21m, Pt, 0°, Rf, Pln, Cn
- 53.66m, Pt, 2°, Rf, Pln, Cn
- 53.72m, Fracture (subsidence), 50°, So, Pln, Cn
- 54.16m, Jt, 20°, So, Pln, Cn
- 54.21m, Jt, 20°, So, Pln, Cn
- 54.24m, Jt, 20°, So, Pln, Cn
- 54.77m, ~70° to E, Fracture (subsidence)

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Job No. 12545790

CORE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 23/2/2021 **Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date Logged :** 26/2/2021	Note: * indicates signatures on original issue of log or last revision of log

DRILLING: Progress – SCALE (m), Drilling & Casing, Water; Drill Depth (m); (Core Loss / Run %); RQD (%)
MATERIAL: Depth metres; Graphic Log; **Description** – ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin); Weathering; Estimated Strength $Is_{(50)}$ MPa (● - Axial, ○ - Diametral; Soil, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10)
NATURAL FRACTURES: Spacing (mm) (20, 40, 100, 300, 1000); Additional Data (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Scale (m)	Drilling & Casing	Drill Depth (m)	Core Loss / Run %	Description	Weathering	Additional Data
	Step 7 + HQ casing		(7)	INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): as previous.	Fr	55.18m, Pt, 5°, So, Pln, Cn 55.43m, Pt, 10°, So, Pln, Cn 55.75m, Pt, 3°, So, Pln, Cn
56				From 56.4-56.8m, geophysics: bore caving.		55.95m, Pt, 1°, Rf, Pln, Cn 56.32m, Pt, 5°, Rf, Pln, Cn
				56.6m, weathered seam.	XW	
		56.90		From 56.8-66.0m, geophysics: bore spalling.		
57						57.15m, Jt, 30°, So, Pln, Cn 57.19m, Pt, 5°, Rf, Pln, Cn 57.48m, Pt, 3°, Rf, Pln, Cn 57.86m, Jt, 20°, Rf, Un, Cn
58			(0)	58.25m, tuffaceous bed.	SW	58.21m, Pt, 0°, So, Pln, Cn 58.49m, Pt, 10°, So, Pln, Cn 58.88m, Jt, 30°, So, Pln, Cn
59				59.37-59.45m, crack, running down core perpendicular to bedding (subsidence fracture?).		59.1m, Pt, 5°, Pln, Cn 59.21m, Jt, 15°, Rf, Un, Cn 59.34m, Pt, 3°, So, Pln, Cn
		59.91		59.7m, abrupt transition from siltstone to sandstone.	Fr	59.7m, Pt, 5°, So, Pln, Py
60						

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Job No. 12545790

CORE LOG SHEET

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 14 OF 16**	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 23/2/2021 **Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date Logged :** 26/2/2021	Note: * indicates signatures on original issue of log or last revision of log

DRILLING — Progress: SCALE (m), Drilling & Casing, Water, Drill Depth (m), (Core Loss / Run %), RQD (%)

MATERIAL — Depth metres, Graphic Log, **Description** (ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin)), Weathering, **Estimated Strength $Is_{(50)}$ MPa** (● - Axial, ○ - Diametral; Soil, VL 0.03, L 0.1, M 0.3, H 1, VH 3, EH 10)

NATURAL FRACTURES — **Spacing (mm)** (20, 40, 100, 300, 1000), **Additional Data** (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Scale (m)	Drilling & Casing	Drill Depth (m)	Core Loss / Run %	Depth (m)	Description	Weathering	Additional Data
60–61.65	Step 7 + HQ casing		(0)		INTERLAMINATED TO INTERBEDDED SANDSTONE (75%) AND SILTSTONE (25%): as previous. 60.7m, brown siltstone band ~100mm thick.	Fr	60.17m, Pt, 0°, So, Pln, Cn 60.31m, Pt, 0°, So, Pln, Cn 60.48m, Pt, 0°, So, Pln, Cn 60.54m, Pt, 0°, So, Pln, Cn 60.65-60.7m, CSm? 60.78m, Pt, 0°, Rf, Pln, Cn 60.86m, Pt, 0°, Rf Pln, Cn 60.9m, Jt, 85° to NE, So, Pln, Py 60.94m, Jt, 20°, Rf, Pln, Cn 60.96m, Jt, 20°, Rf, Pln, Cn 61.17m, Pt, 0°, Rf, Pln, Cn 61.4m, Jt, 60°, Rf, Pln, Py 61.52m, Pt, Rf, Pln, Cn
61.65–65		62.91	(14)	61.65	INTERLAMINATED SILTSTONE (90%) AND SANDSTONE (10%): siltstone is dark grey, sandstone is fine grained, grey to dark grey, distinctly thinly laminated, horizontal, microfractures, extremely closely spaced, associated with bedding.	Fr	61.64m, Jt, 60°, Rf, Pln, Cn 61.66m, Pt, 0°, Rf, Un, Cn 61.72m, Jt, 40°, Rf, Pln, Un 61.77m, Pt, 0°, Rf, Pln, Cn 61.89m, Pt, 0°, So, Pln, Cn 62.01m, Pt, 3°, Rf, Pln, Cn 62.11m, Jt, 60°, So, Pln, Cn 62.13m, Pt, 10°, So, Pln, Cn 62.17m, Jt, 60°, So, Pln, Cn (possible subsidence fracture) 62.3m, Fracture (subsidence?), 70°, Pln, So, Un 62.7m, Jt, 45°, So, Pln, Cn 62.72-62.78m, CSm 62.83m, Fracture (subsidence?), 60°, So, Pln, Cn 63.13-63.19m, CSm 63.34m, Fracture (subsidence?), 60°, So, Pln, Cn 63.61m, Pt, 0°, Rf, Pln, Py 63.8m, Pt, 0°, Rf, Un, Py 64.17-64.19m, CSm 64.25m, Fracture (possible subsidence), 70° to SE, Rf, Pln, Cn 64.55m, Pt, 0°, Rf, Un, Cn 64.94m, Fracture (subsidence?),

Scale marks: 61, 62, 63, 64, 65

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Job No. **12545790**

Client : Port of Newcastle		**HOLE No. GBH6**	
Project : Proposed Commercial Development			
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW		**SHEET 15 OF 16**	
Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm **Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 23/2/2021 **Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date Logged :** 26/2/2021	Note: * indicates signatures on original issue of log or last revision of log

Drilling & Casing	Drill Depth (m)	(Core Loss / Run %)	Depth metres	Description	Weathering	Estimated Strength	Spacing (mm)	Additional Data
Step 7 + HQ casing				INTERLAMINATED SILTSTONE (90%) AND SANDSTONE (10%): as previous.	Fr	L–M	300–1000	60°, So, Pln, Cn; 65.13m, Fracture (subsidence?), 60°, So, Pln, Cn; 65.22m, Fracture (subsidence?), 60°, So, Pln, Cn; 65.4m, Fracture (subsidence), 70° to SW, So, Pln, Cn; 65.65m, Pt, 5°, Rf, Un, Cn
			65.76	SILTSTONE: dark grey, distinctly thinly laminated to laminated horizontal, with microfractures, extremely closely spaced.		L	300–1000	65.93m, Pt, 0°, So, Pln, Cn; 65.98m, Pt, 0°, So, Pln, Cn; 66.02m, Pt, 10°, Rf, Pln, Cn; 66.05m, Fracture, 75°, Rf, Pln, Cn
			66.11	COAL: black and mostly shiny, trace of pyrite, face cleats at 90°, coal is mostly crushed into 20mm pieces with several large sections of coal up to 50mm. 66.19m, tuff layer, dark brown, hard, 2mm thick.		L	20–40	66.11m, Pt, 10°, Rf, Un, Cn; 66.14m, possible crushed zone; 66.2m, possible crushed zone; 66.25, Pt, 5°, So, Pln, CLAY/tuff; 66.26-66.30m, possible crushed
	66.85	(59)	66.30	CORE LOSS: 1270mm. Drilling resistance throughout. From 66.3-71.3m, geophysics: decrease in natural gamma, coinciding with bore spalling/caving.	-			
	68.07		67.57	COAL: black and shinny, trace of pyrite, coal is crushed into chunks up to 20mm with no large sections of core returned to 68.0m. 67.78m, tuff, dark brown, 10mm thick. 67.87-67.91m, tuff, dark brown, with pieces of coal spread through layer. 68.07m, poor drilling conditions/recovery, switch to rock roller (no core recovery).	Fr	L	20–40	68.0m, Jt, 80°, Rf, Pln, Cn
Rock Roller								

Scale (m): 66, 67, 68, 69, 70

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No. 12545790

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH6

Position : 384414.9 E 6357104.9 N MGA2020/ 56	**Surface RL:** 2.09m AHD		**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Casing Dia. : 114mm/90mm	**Barrel (m) :** 3.0m	**Bit :** Step 7	**Bit Condition :** Good	**Date:** 11/03/2021
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver	**Date Logged :** 26/2/2021	Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling & Casing	Water	Drill Depth (m)	(Core Loss / Run %)	RQD (%)	Depth metres	Graphic Log	Description	Weathering	Estimated Strength $Is_{(50)}$ MPa	Spacing (mm)	Additional Data
	Rock Roller							COAL: as previous.		VL–L		
71				(0)		71.10		SANDSTONE: fine to medium grained, grey.	Fr	M–H		71.1m, not cored, no defect data No defects to minor bedding partings indicated on geophysics (ATV) log
72												
73												
74			74.00			74.00		End of Borehole at 74.00 metres. Target Depth				
75												

Column header notes: Progress (Drilling & Casing, Water); Description: ROCK NAME: grain size, colour, fabric and texture, inclusions or minor components, moisture, durability and [COBBLES / BOULDERS / FILL / TOPSOIL] then SOIL NAME: colour, plasticity / primary particle characteristics, secondary and minor components, zoning (origin); Estimated Strength: ● - Axial, ○ - Diametral; Soil 0.03 VL 0.1 L 0.3 M 1 H 3 VH 10 EH; Spacing: 20 40 100 300 1000; Additional Data (joints, partings, seams, zones and veins) Defect type: orientation, roughness and shape, composition or coating, aperture and thickness, other.

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH6 1/6	

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH6 2/6	

	Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
		CHECKED S MacKenzie	DATE 24/03/2021	
		SCALE Not To Scale		A4
		PROJECT No 12545790	FIGURE No GBH6 3/6	

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH6 4/6	

Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street Carrington NSW Core Photographs	DRAWN H Warr	DATE 24/03/2021	
	CHECKED S MacKenzie	DATE 24/03/2021	
	SCALE Not To Scale		A4
	PROJECT No 12545790	FIGURE No GBH6 5/6	

BOREHOLE LOG SHEET

Client : Port of Newcastle
Project : Proposed Commercial Development
Location : 46 Fitzroy Street / 65 Denison Street, Carrington NSW

HOLE No. GBH7

Position : 384407.0 E 6357069.1 N MGA2020/ 56	**Surface RL:** 2.39m AHD	**Angle from Horiz. :** 90°		**Processed :** SBO
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 23/2/2021	**Date Completed :** 23/2/2021	**Logged by :** Nick Leaver		**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	**Description** [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	**Comments/ Observations**
	Auger	Nil	Groundwater Not Encountered		0.10			[TOPSOIL/FILL]: Sandy SILT: brown, fine to medium grained sand, poorly graded, rootlets to 100mm.	M		
					0.78			[FILL]: Silty SAND: fine grained, dark grey.	M		
1				B	1.40			[FILL]: SAND: medium grained, brown, trace shell fragments.	M		
				ASS	1.80			[FILL]: SAND: medium grained, brown to pale grey, trace shells and shell fragments.	M		
					2.00		CI	CLAY: medium plasticity, dark grey, trace organic matter (estuarine).	M	F	ASS confirmed
2								End of borehole at 2.00 metres. Target Depth			
3											
4											
5											

See standard sheets for details of abbreviations & basis of descriptions

GHD
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle 2300 Australia
T: +61 2 4979 9999 F: +61 2 4979 9988 E: ntlmail@ghd.com
CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No.
12545790

GEO_BOREHOLE_AS1726 2017 12545790 DENISON ST CARRINGTON.GPJ GHD_GEO_TEMPLATE 2.00.GDT 31/3/21

BOREHOLE LOG SHEET

Client :	Port of Newcastle
Project :	Proposed Commercial Development
Location :	46 Fitzroy Street / 65 Denison Street, Carrington NSW

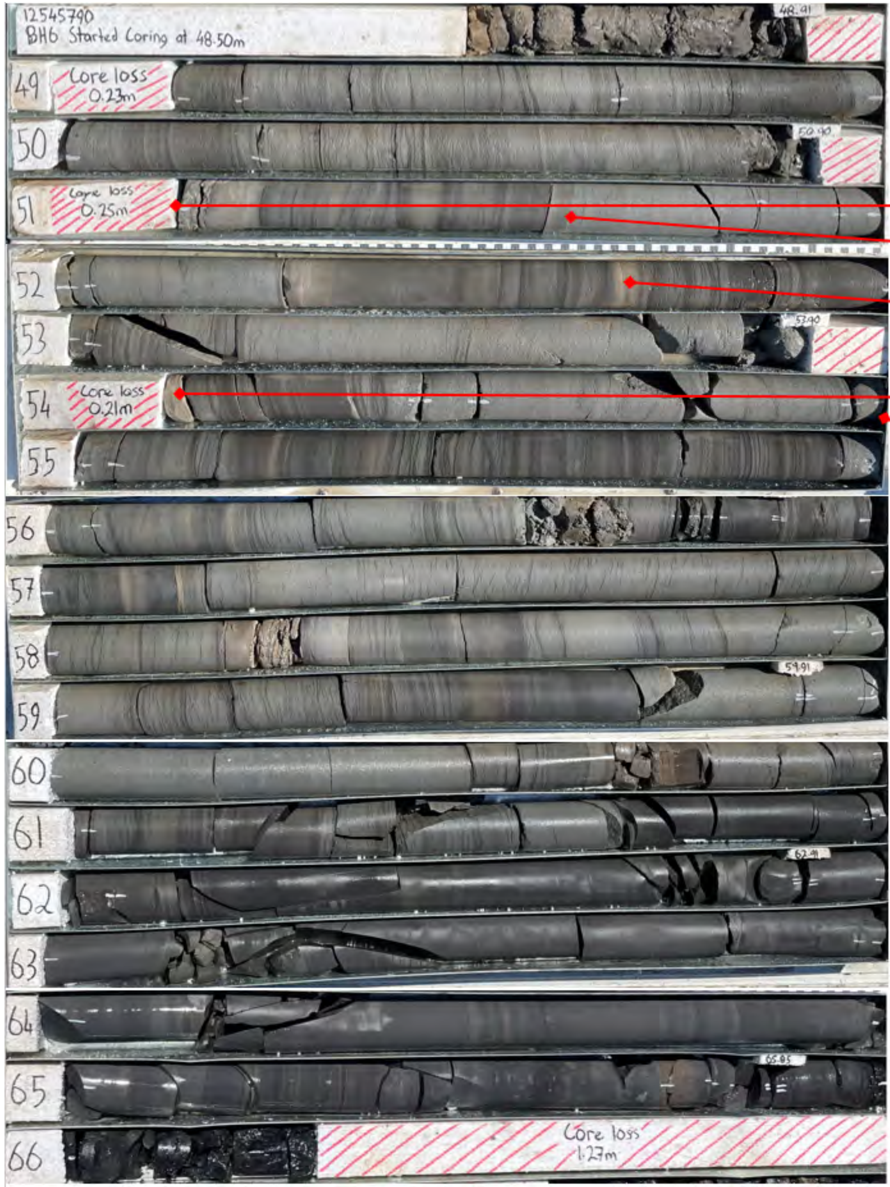
HOLE No. GBH8

SHEET 1 OF 1

Position : 384387.0 E 6357132.0 N MGA2020/ 56	**Surface RL:** 2.06m AHD	**Angle from Horiz. :** 90°	**Processed :** SBO
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Glen Gearside	**Checked :** SJM
Date Started : 22/2/2021	**Date Completed :** 22/2/2021	**Logged by :** Nick Leaver	**Date:** 03/03/2021

Note: * indicates signatures on original issue of log or last revision of log

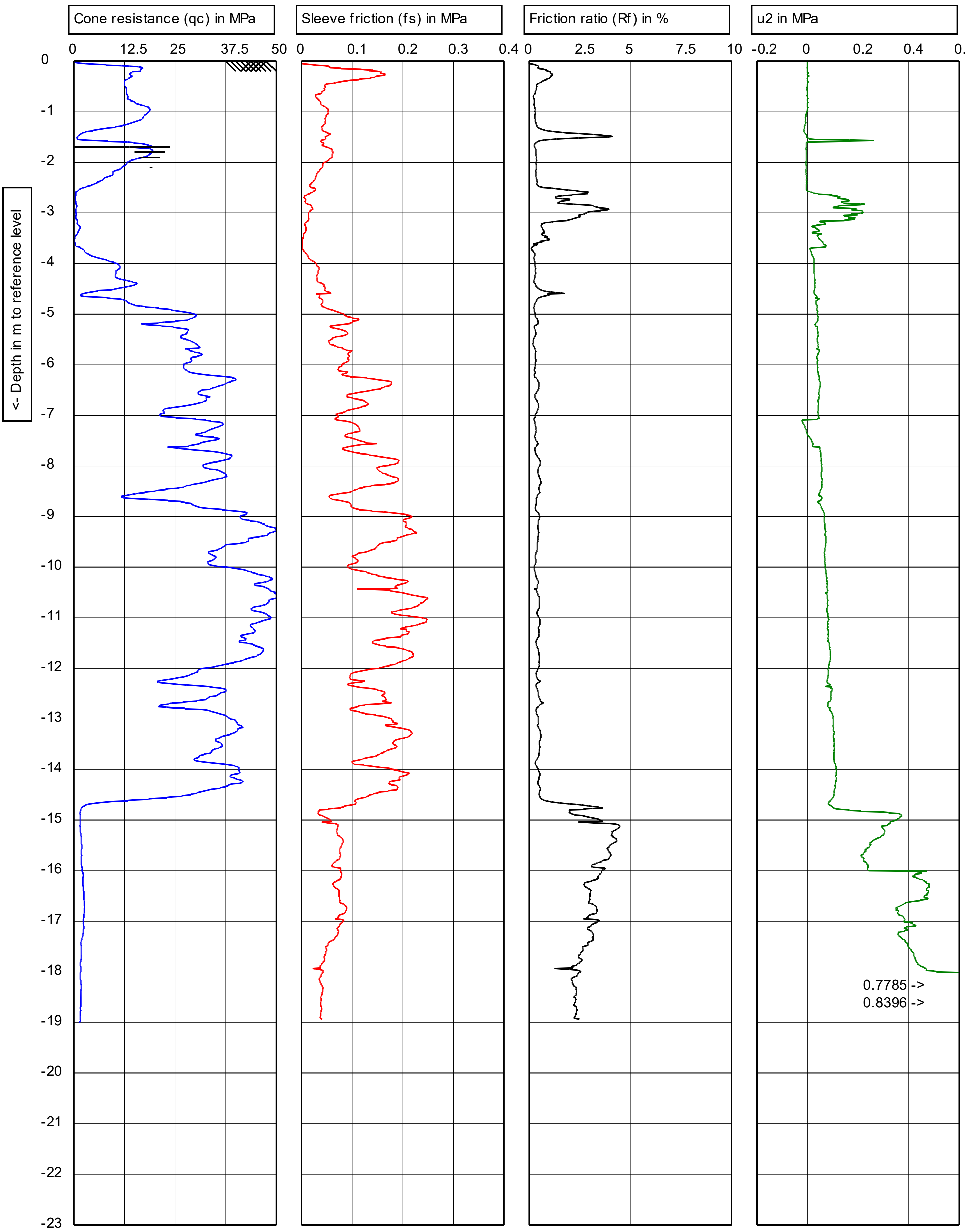
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth metres	Graphic Log	USC Symbol	Description [COBBLES/BOULDERS/FILL/TOPSOIL] then SOIL NAME: plasticity / primary particle characteristics, colour, secondary and minor components, zoning (origin) and ROCK NAME: grain size, colour, fabric / texture, inclusions or minor components, durability, strength, weathering / alteration, defects	Moisture Condition	Consistency / Density Index	Comments/ Observations
	Auger	Nil			0.40			[TOPSOIL/FILL]: Sandy SILT: brown to dark grey, fine to medium grained sand, rootlets up to 50mm.	M		
					0.60			[FILL]: GRAVEL: fine to medium, very angular to sub-angular, grey, gravel up to 25mm.	M		
1			22/2/21	B	1.70			[FILL]: SAND: fine to medium grained, grey/brown, trace coarse gravel and fines.	M		
					1.80		CH	Sandy CLAY: high plasticity, dark grey, coarse grained sand, trace shell fragments and organic matter (estuarine).	W	F	
2					2.00		SP	SAND: medium to coarse grained, dark brown, with fine gravel up to 4mm in size, trace shell fragments (marine).	W	D-VD	
								End of borehole at 2.00 metres. Target Depth			
3											
4											
5											



Top of seam inferred to be ~69.4 m or 5.8 m below

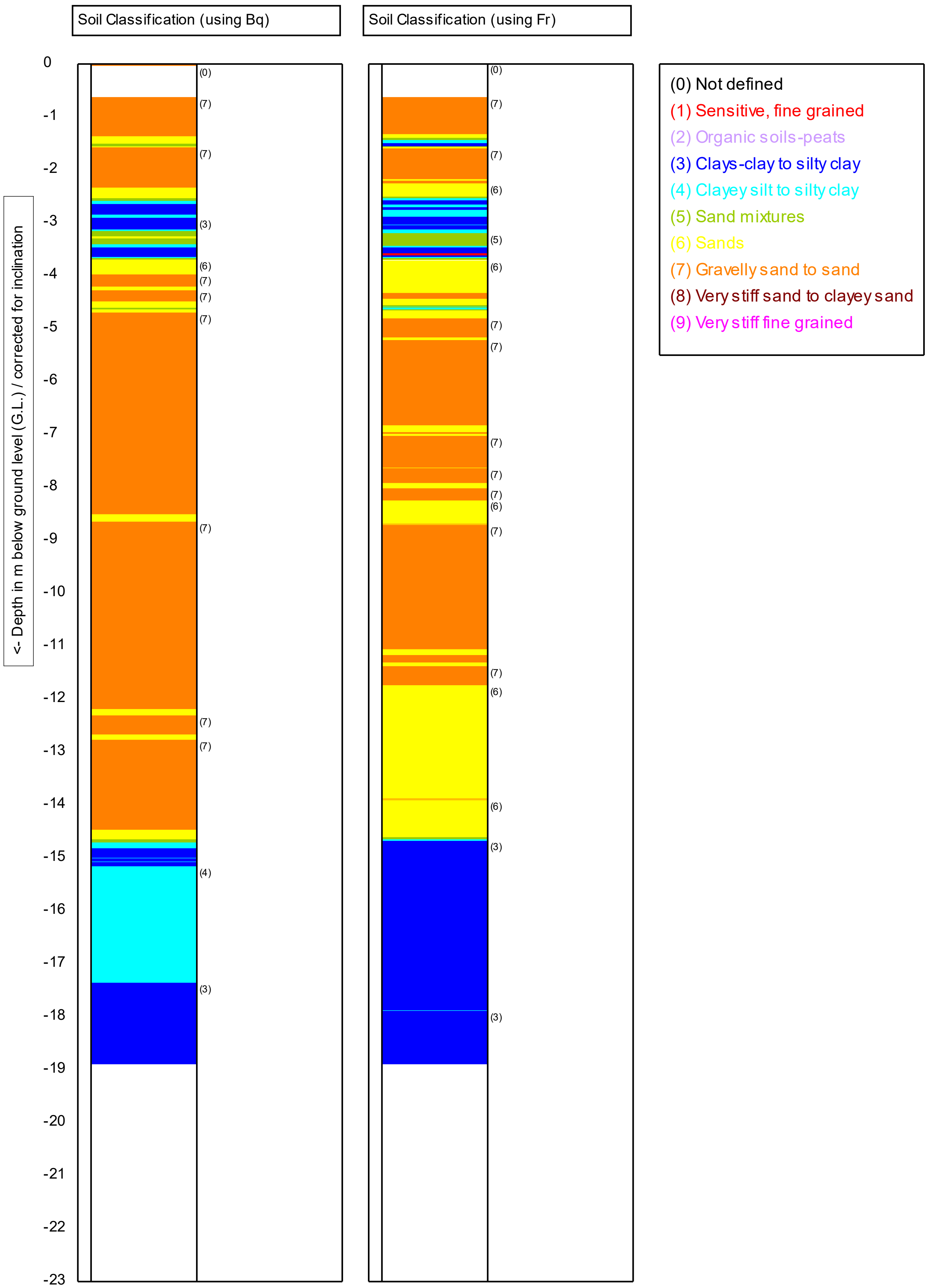
GHD	Port of Newcastle Proposed Commercial Development 46 Fitzroy Street / 65 Denison Street, Carrington Stratigraphic Correlation	DRAWN S Mackenzie	DATE 29/03/2021	
		CHECKED	DATE	
		SCALE Not To Scale		A4
		PROJECT No 12545790	FIGURE No	

Appendix D – Cone Penetrometer Test plots



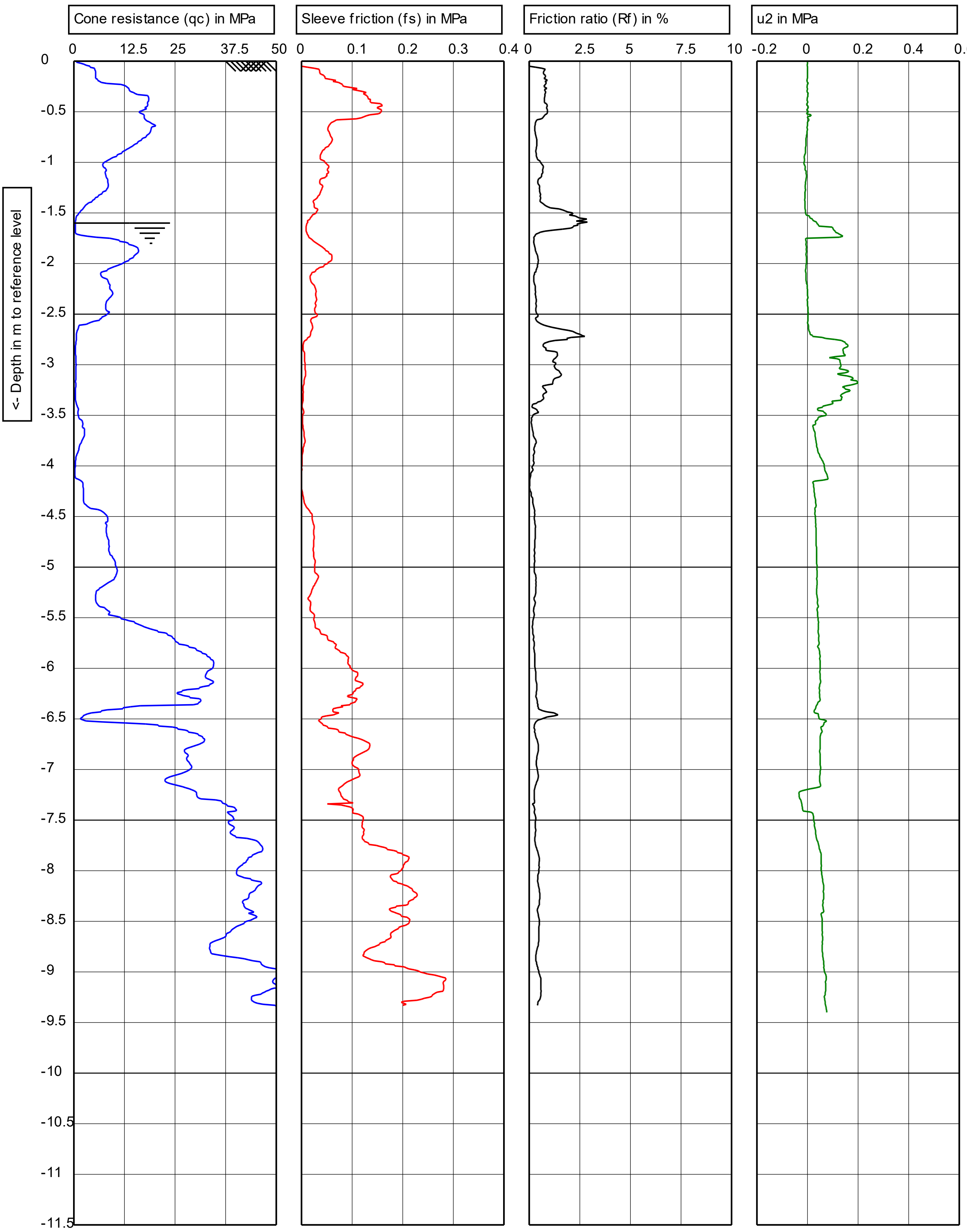
NEWSYD GEOTECHNICAL TESTING **Ph. 0408 292638**	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Testtype TE1	Predrill:	**0.00 m Predrilled**
		G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
	Project:	**Geotechnical Investigation**	Cone no.:	**C10CFIIP.C19137**
	Location:	**Denison St Carrington**	Project no.:	**12545790**
	Position:	**0, 0**	CPT no.:	**CPT-1** 1/3

1.44



NEWSYD GEOTECHNICAL TESTING Ph. 0408 292638	ISO 22476-1:2012 Application class 1 Test type TE1		Predrill: 0.00 m Predrilled
u2 150 cm² 10 cm²	G.L.: **0.00 m**	W.L.: **-1.70 m**	Date: **12/02/2021**
	Project: Geotechnical Investigation		Cone no.: **C10CFIIP.C19137**
	Location: Denison St Carrington		Project no.: **12545790**
			CPT no.: **CPT-1** 2/4

1.48



NEWSYD GEOTECHNICAL TESTING
Ph. 0408 292638

u2
150 cm²
10 cm²

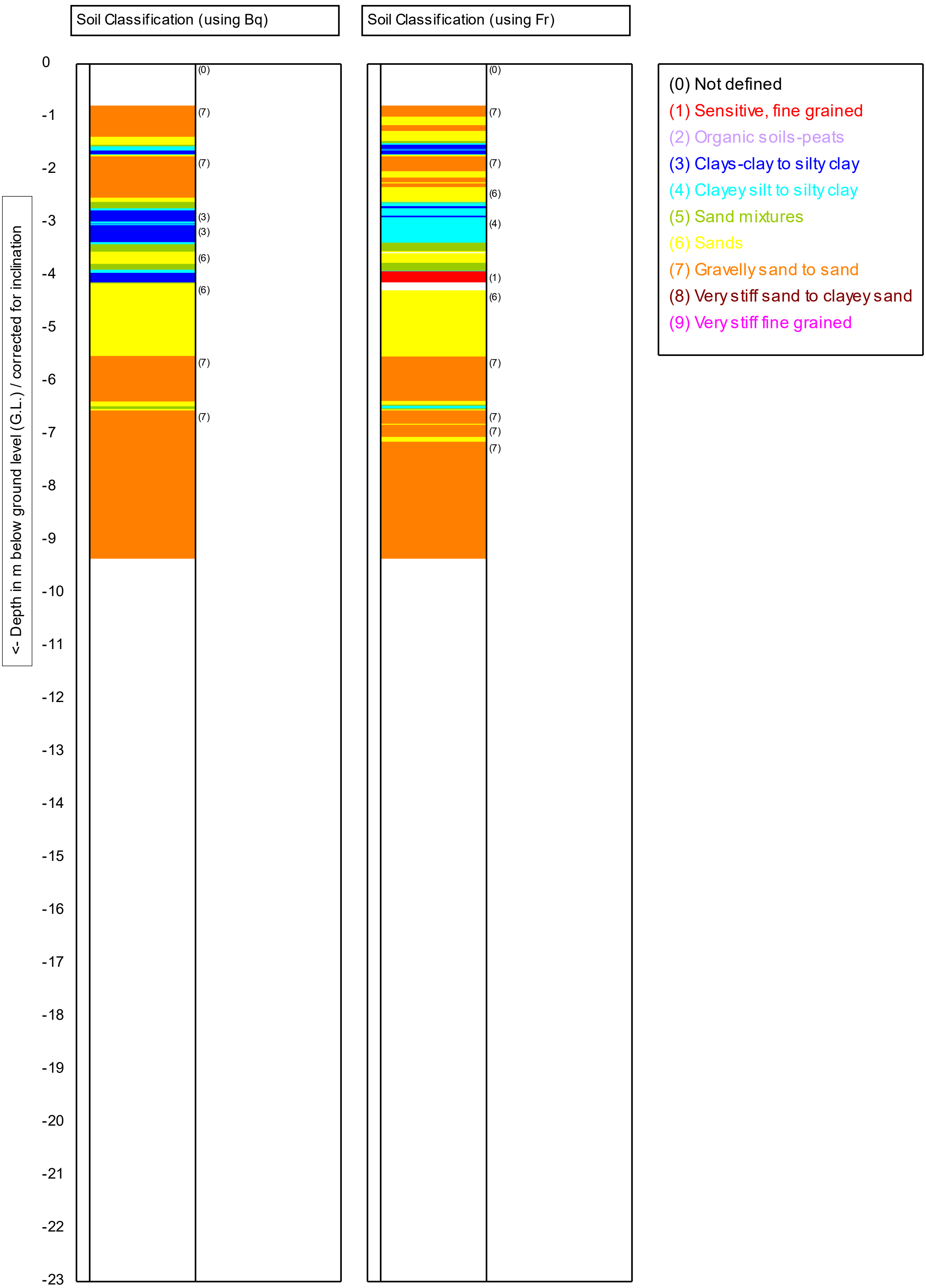
ISO 22476-1:2012 Application class 1 Testtype TE1

G.L.: **0.00 m** W.L.: **-1.60 m**

Project: **Geotechnical Investigation**
Location: **Denison St Carrington**
Position: **0, 0**

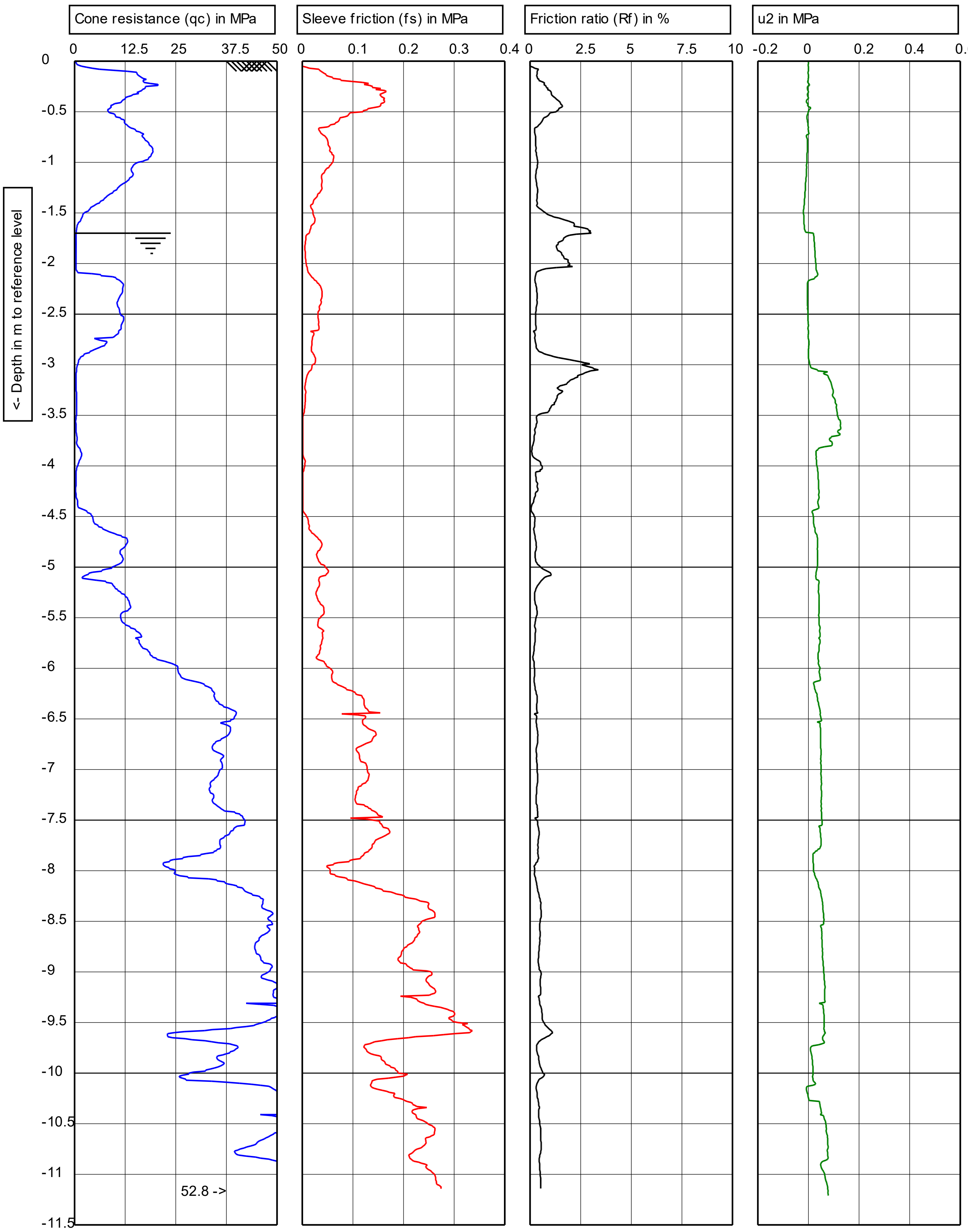
Predrill: **0.00 m Predrilled**
Date: **12/02/2021**
Cone no.: **C10CFIIP.C19137**
Project no.: **12545790**
CPT no.: **CPT-2** **1/3**

1.44



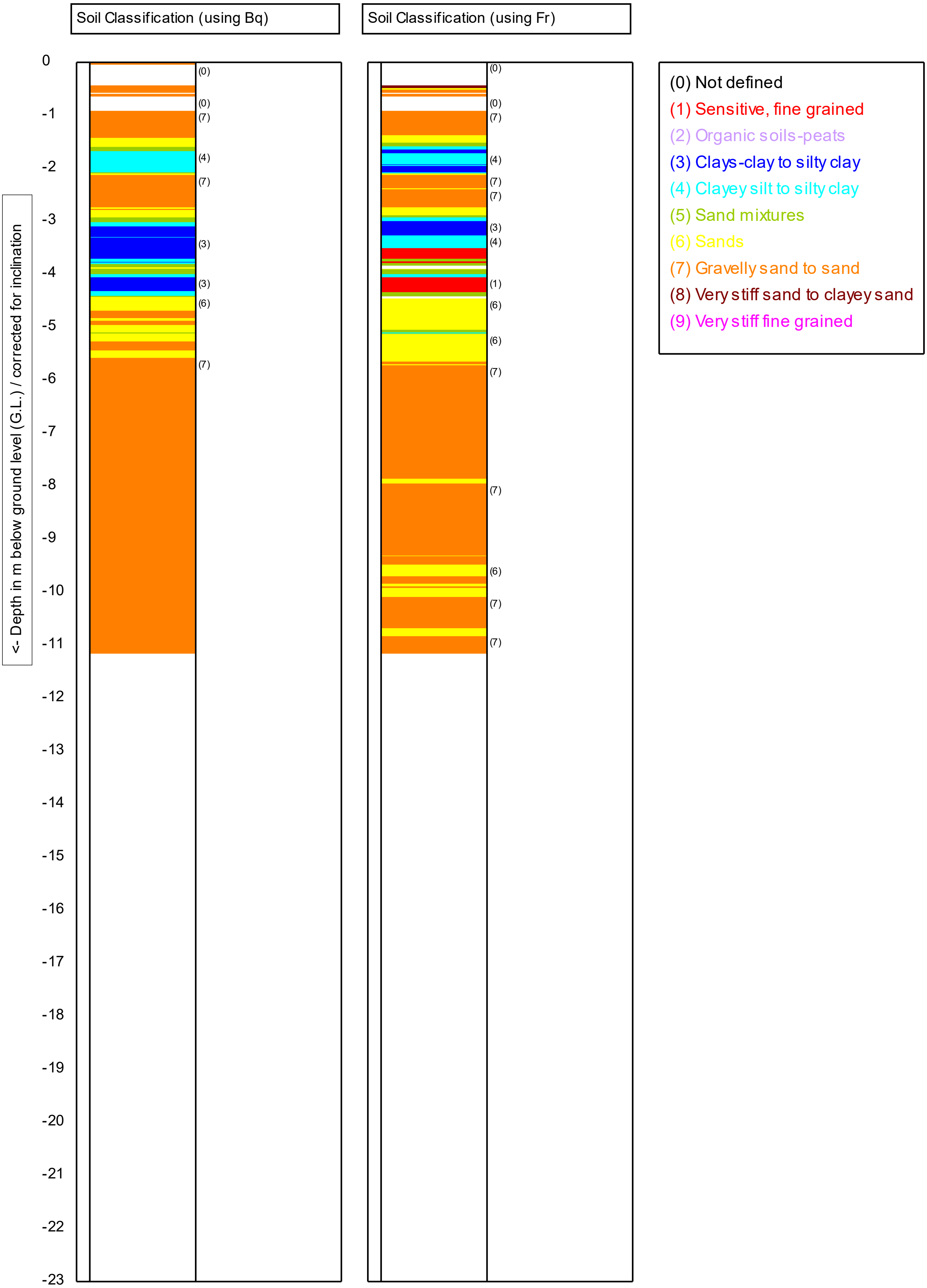
NEWSYD GEOTECHNICAL TESTING Ph. 0408 292638	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Test type TE1		Predrill:	**0.00 m Predrilled**
		G.L.: **0.00 m**	W.L.: **-1.60 m**	Date:	**12/02/2021**
	Project:	Geotechnical Investigation		Cone no.:	**C10CFIIP.C19137**
	Location:	Denison St Carrington		Project no.:	**12545790**
				CPT no.:	**CPT-2** 2/4

1.48



NEWSYD GEOTECHNICAL TESTING Ph. 0408 292638	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Testtype TE1	Predrill:	**0.00 m Predrilled**
		G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
	Project:	**Geotechnical Investigation**	Cone no.:	**C10CFIIP.C19137**
	Location:	**Denison St Carrington**	Project no.:	**12545790**
	Position:	**0, 0**	CPT no.:	**CPT-3** 1/3

1.44



NEWSYD GEOTECHNICAL TESTING
Ph. 0408 292638

u2
150 cm²
10 cm²

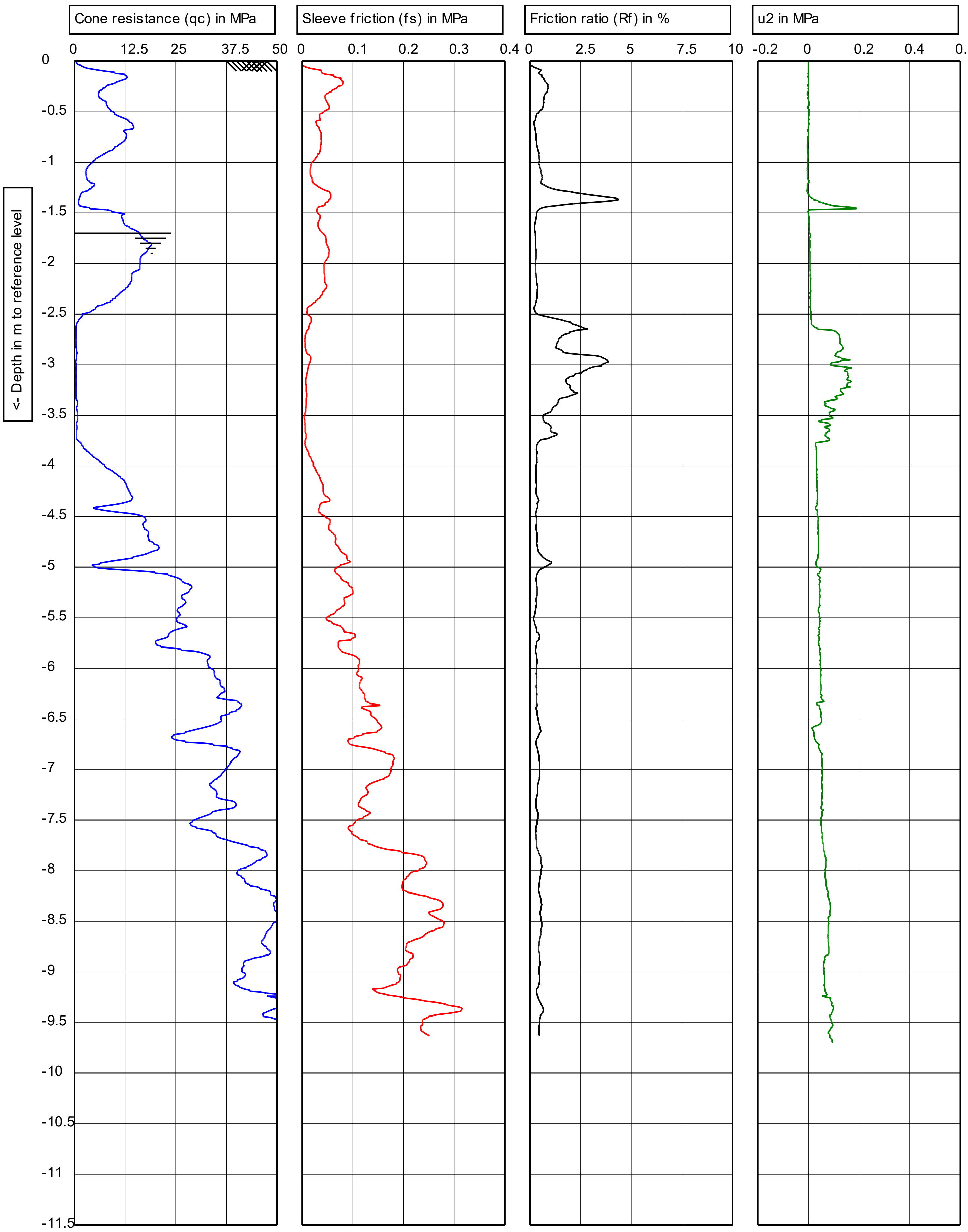
ISO 22476-1:2012 Application class 1 Test type TE1

G.L.: **0.00 m** | W.L.: **-1.70 m**

Project: Geotechnical Investigation
Location: Denison St Carrington

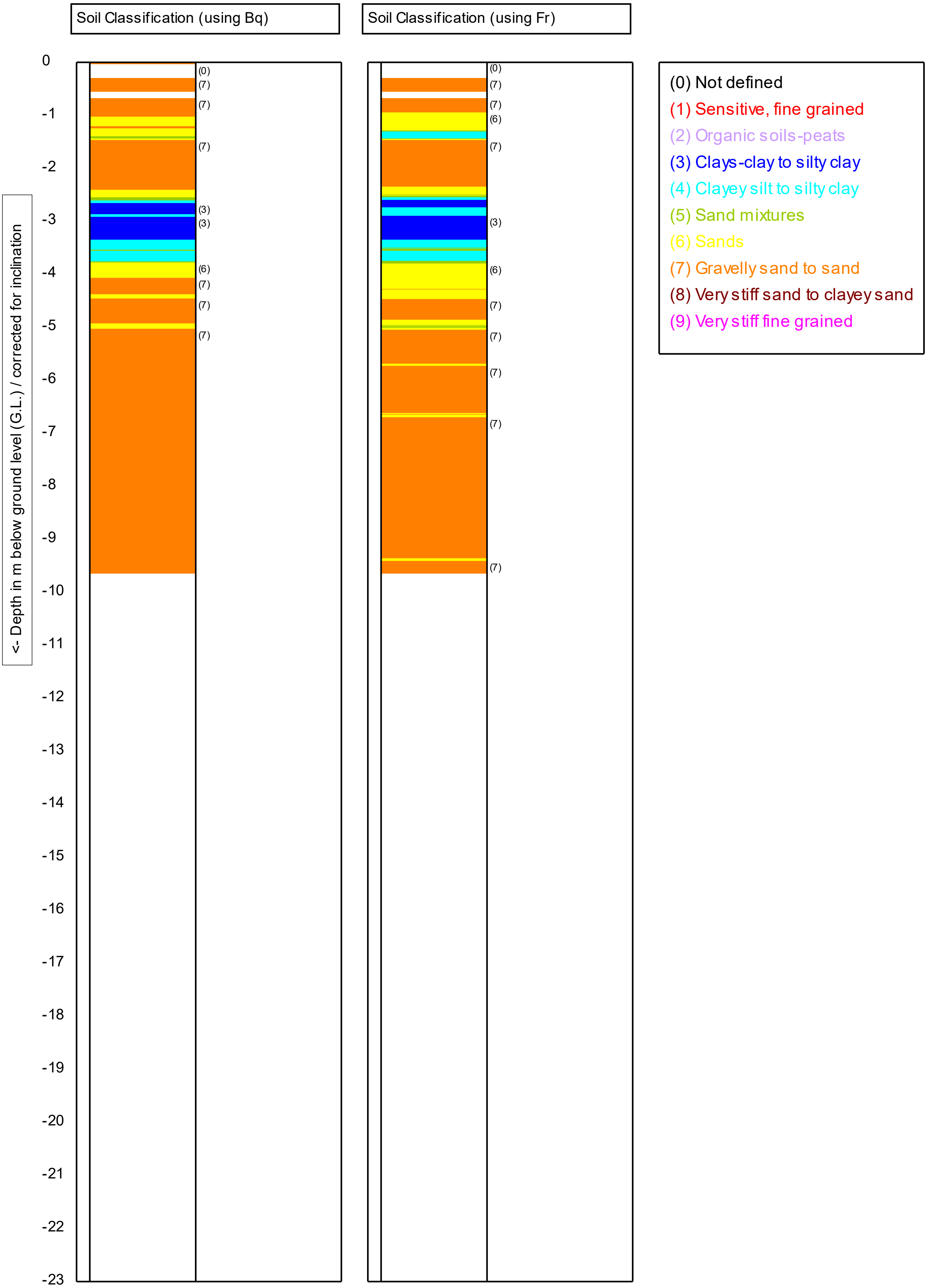
Predrill:	**0.00 m Predrilled**
Date:	**12/02/2021**
Cone no.:	**C10CFIIP.C19137**
Project no.:	**12545790**
CPT no.:	**CPT-3** **2/4**

1.48



NEWSYD GEOTECHNICAL TESTING Ph. 0408 292638	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Testtype TE1	Predrill:	**0.00 m Predrilled**
		G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
	Project:	**Geotechnical Investigation**	Cone no.:	**C10CFIIP.C19137**
	Location:	**Denison St Carrington**	Project no.:	**12545790**
	Position:	**0, 0**	CPT no.:	**CPT-4** 1/3

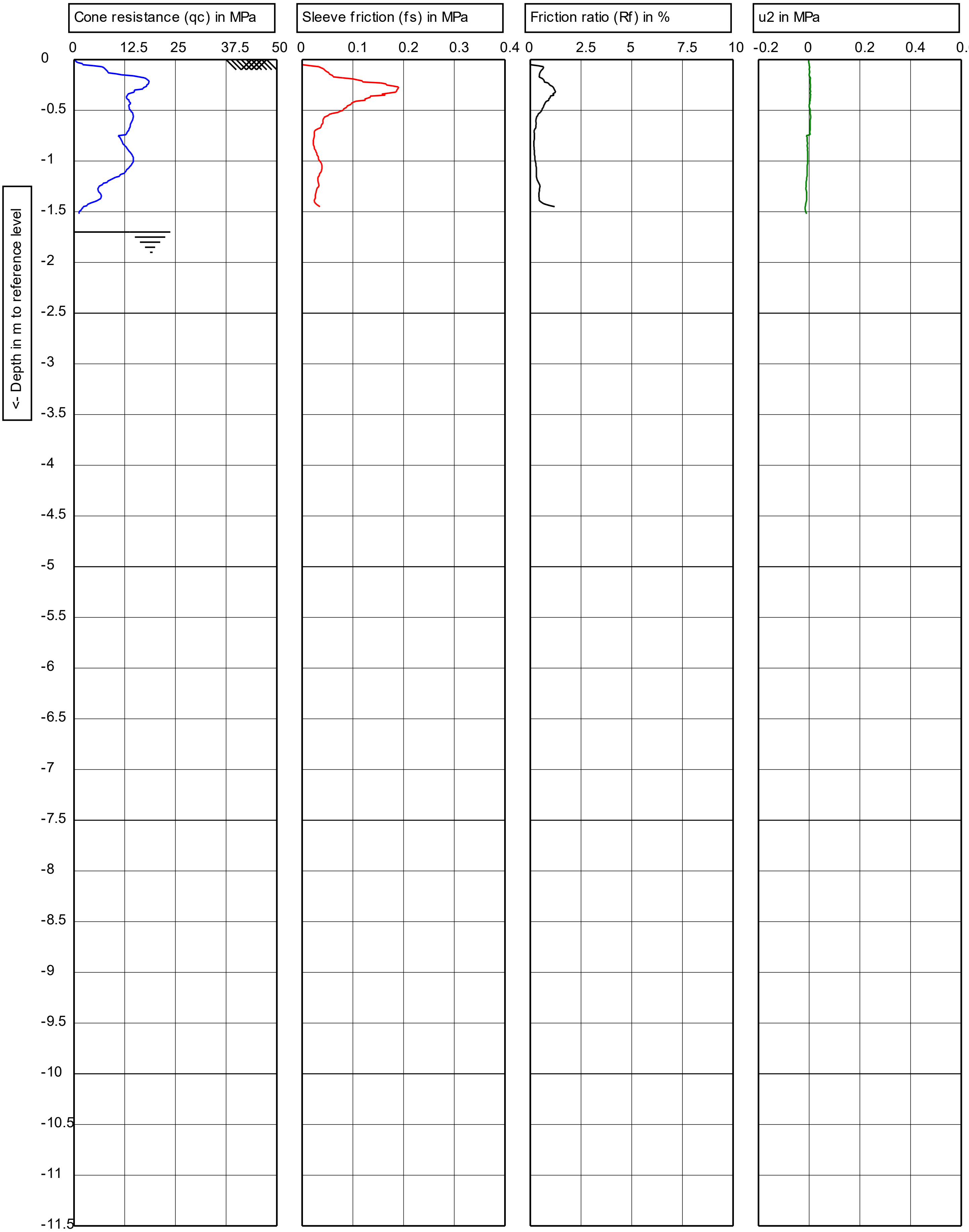
1.44



NEWSYD GEOTECHNICAL TESTING
Ph. 0408 292638

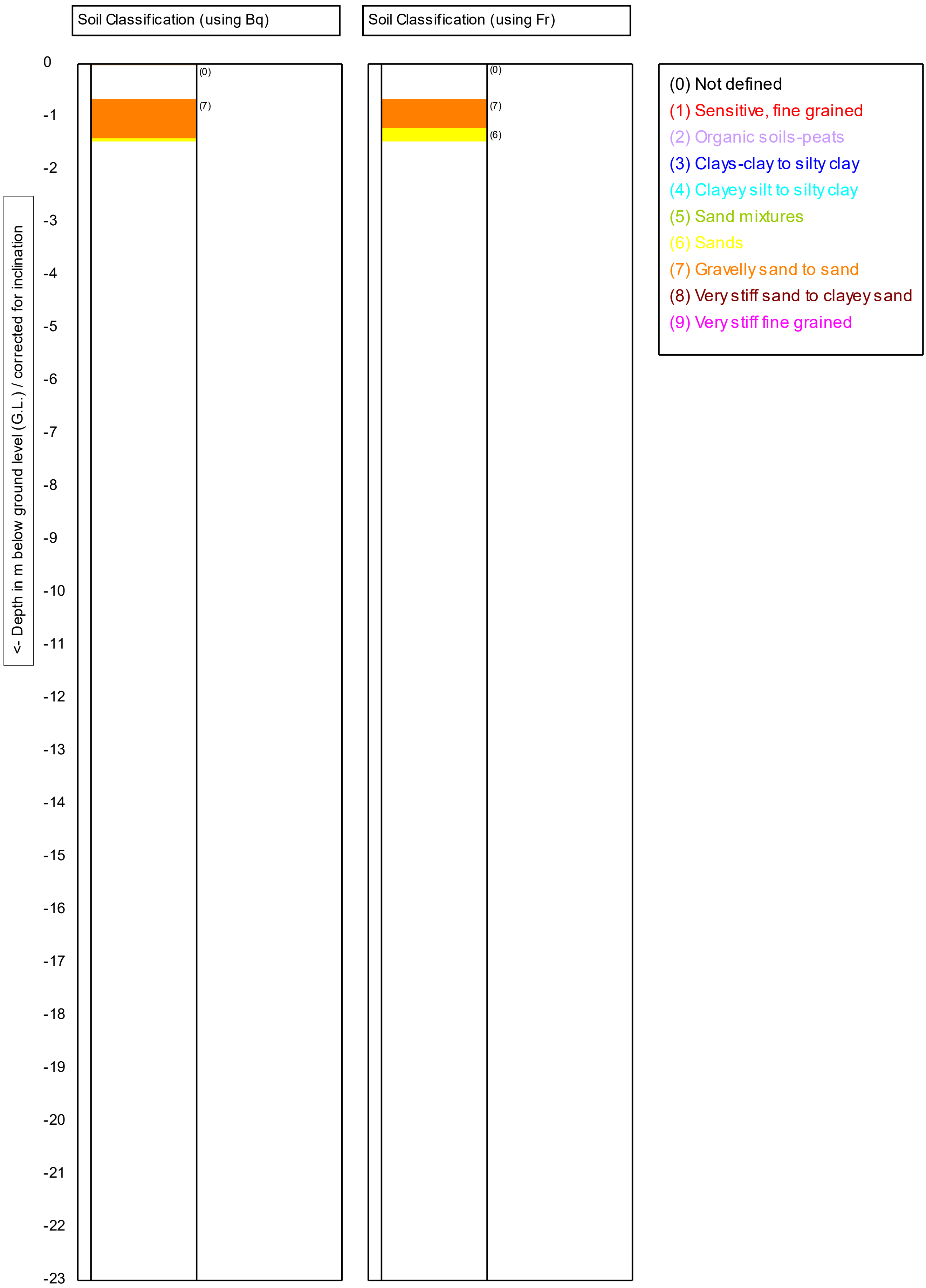
u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Test type TE1	Predrill:	**0.00 m Predrilled**
	G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
Project:	Geotechnical Investigation	Cone no.:	**C10CFIIP.C19137**
Location:	Denison St Carrington	Project no.:	**12545790**
		CPT no.:	**CPT-4** 2/4

1.48



NEWSYD GEOTECHNICAL TESTING **Ph. 0408 292638**	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Testtype TE1	Predrill:	**0.00 m Predrilled**
		G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
	Project:	**Geotechnical Investigation**	Cone no.:	**C10CFIIP.C19137**
	Location:	**Denison St Carrington**	Project no.:	**12545790**
	Position:	**0, 0**	CPT no.:	**CPT-5** 1/3

1.44



NEWSYD GEOTECHNICAL TESTING
Ph. 0408 292638

u2 150 cm² 10 cm²

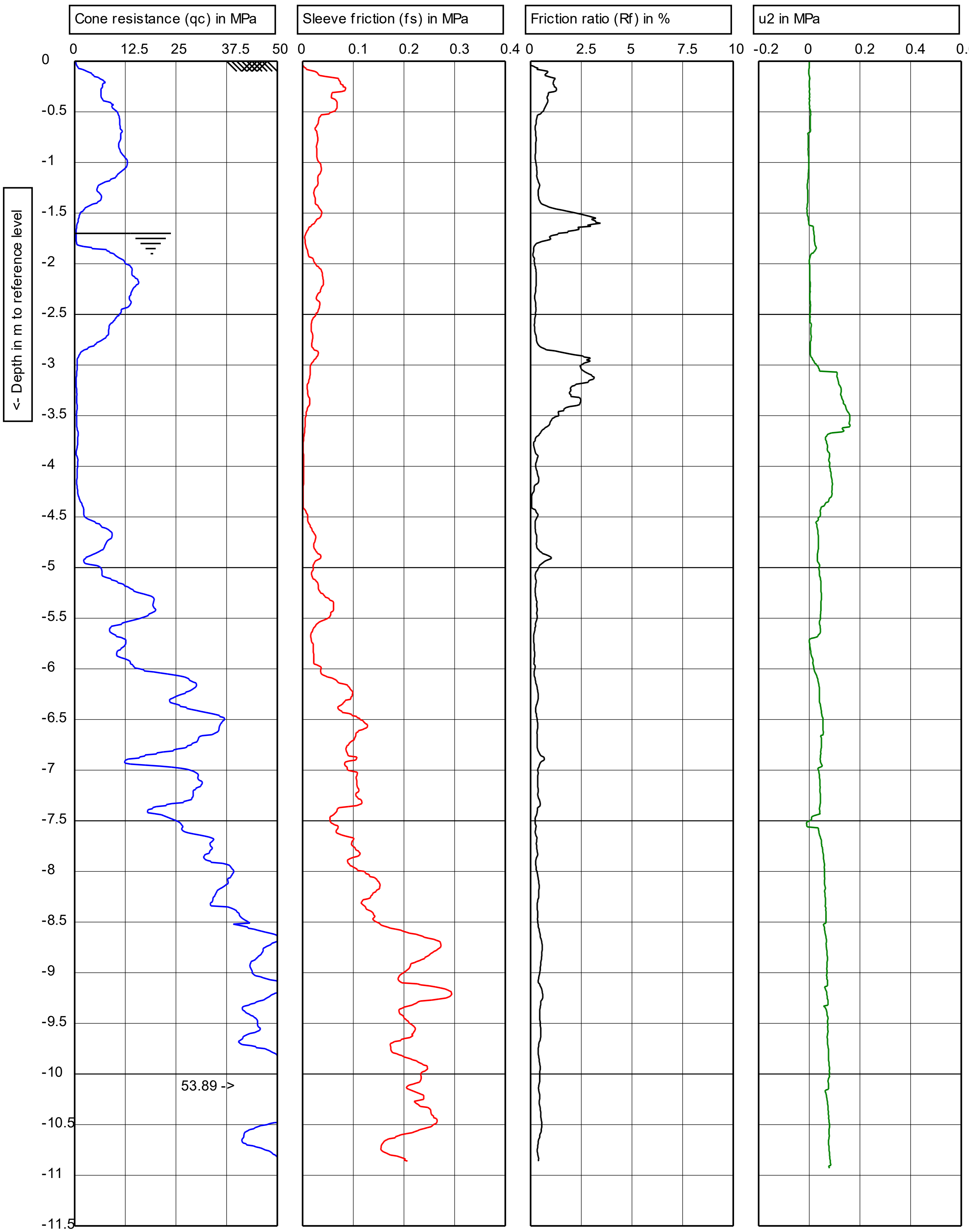
ISO 22476-1:2012 Application class 1 Test type TE1

G.L.: **0.00 m** W.L.: **-1.70 m**

Project: Geotechnical Investigation
Location: Denison St Carrington

Predrill: **0.00 m Predrilled**
Date: **12/02/2021**
Cone no.: **C10CFIIP.C19137**
Project no.: **12545790**
CPT no.: **CPT-5** **2/4**

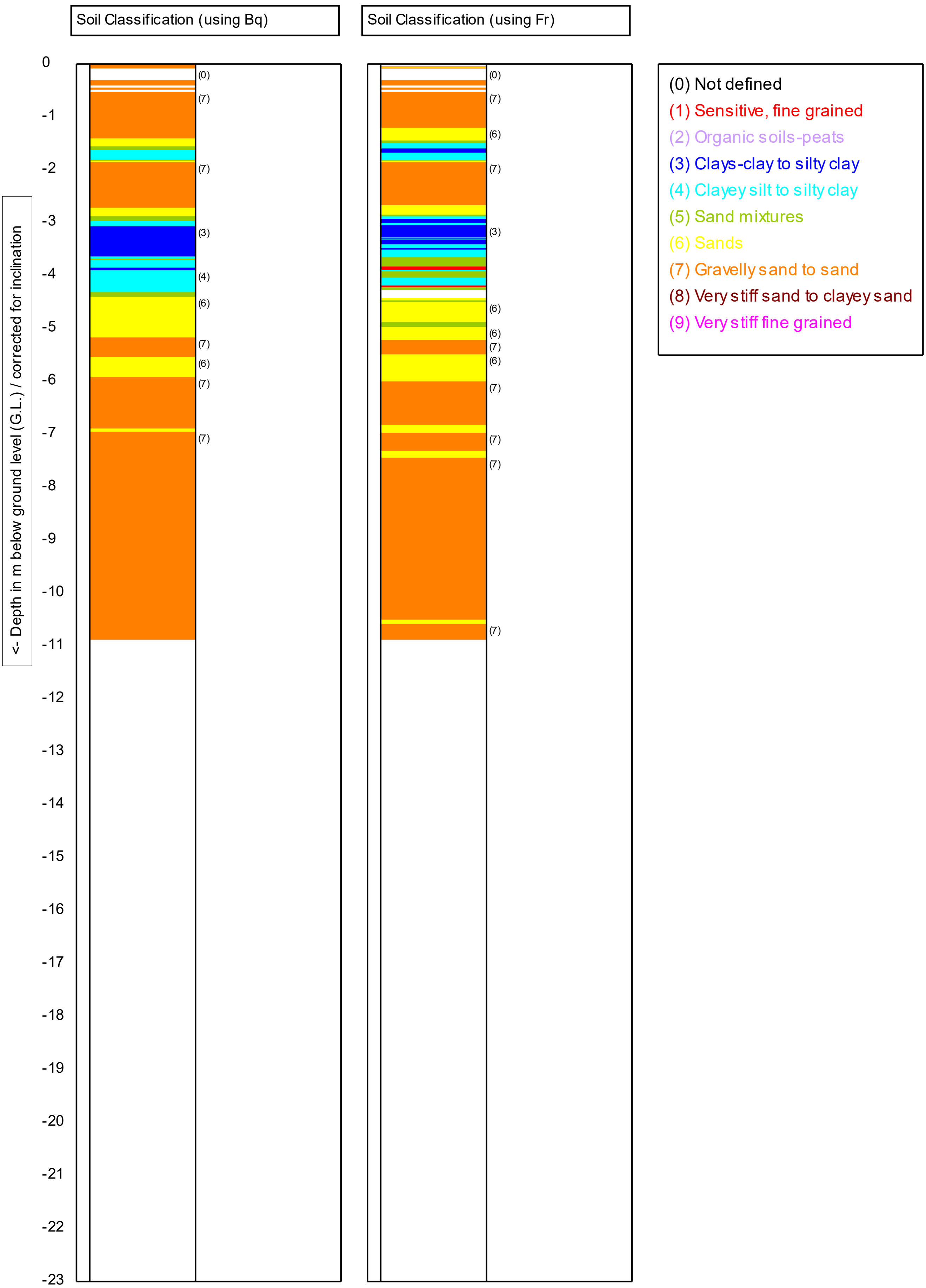
1.48



NEWSYD GEOTECHNICAL TESTING
Ph. 0408 292638

u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Testtype TE1	Predrill:	**0.00 m Predrilled**
	G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
Project:	**Geotechnical Investigation**	Cone no.:	**C10CFIIP.C19137**
Location:	**Denison St Carrington**	Project no.:	**12545790**
Position:	**0, 0**	CPT no.:	**CPT-5A** 1/3

1.44



NEWSYD GEOTECHNICAL TESTING Ph. 0408 292638	u2 150 cm² 10 cm²	ISO 22476-1:2012 Application class 1 Test type TE1	Predrill:	0.00 m Predrilled
		G.L.: **0.00 m** W.L.: **-1.70 m**	Date:	**12/02/2021**
		Project: Geotechnical Investigation	Cone no.:	**C10CFIIP.C19137**
		Location: Denison St Carrington	Project no.:	**12545790**
			CPT no.:	**CPT-5A** 2/4

1.48

Appendix E – Wireline logging / ATV reports

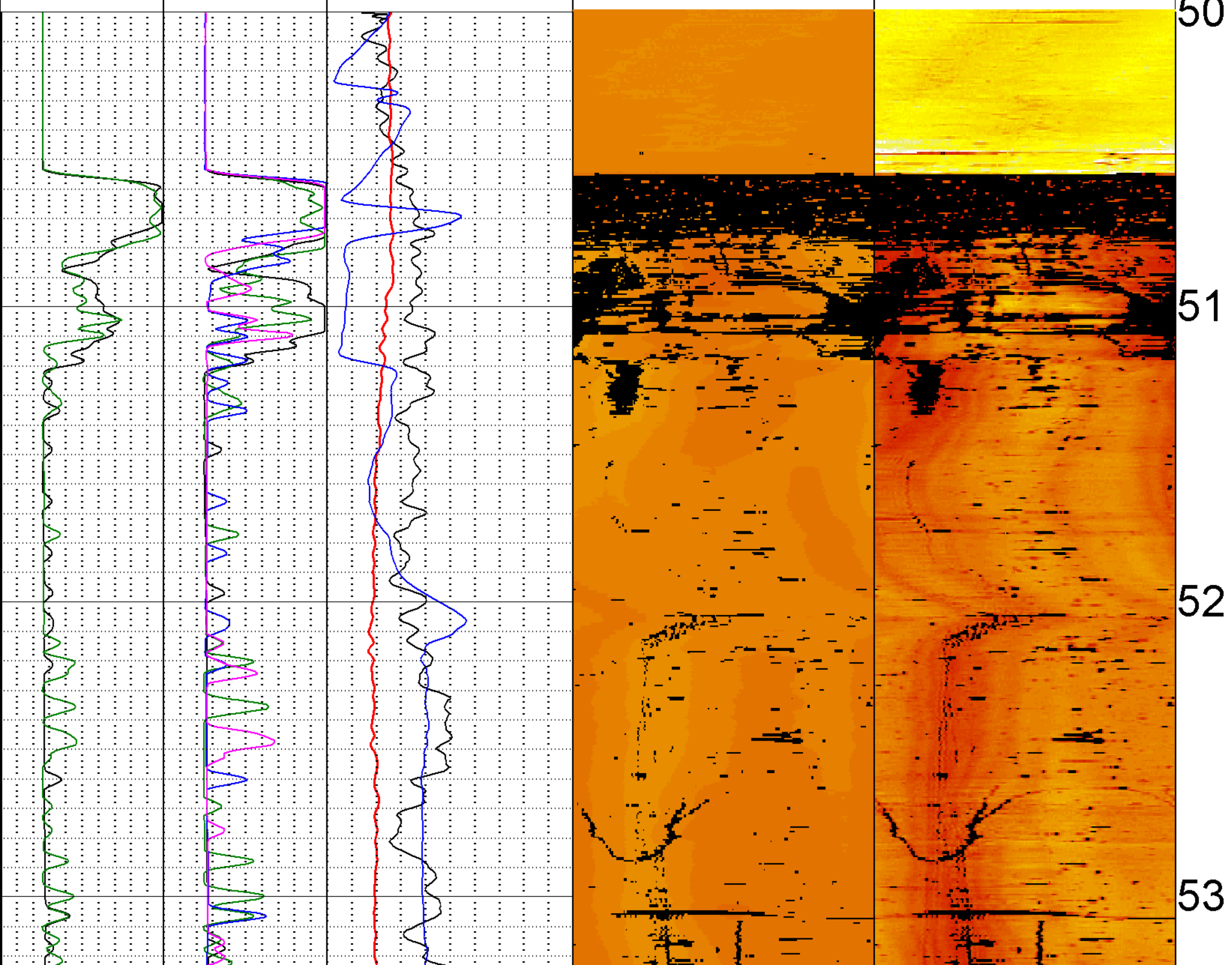
1:20 BH05 TELEVIEWER

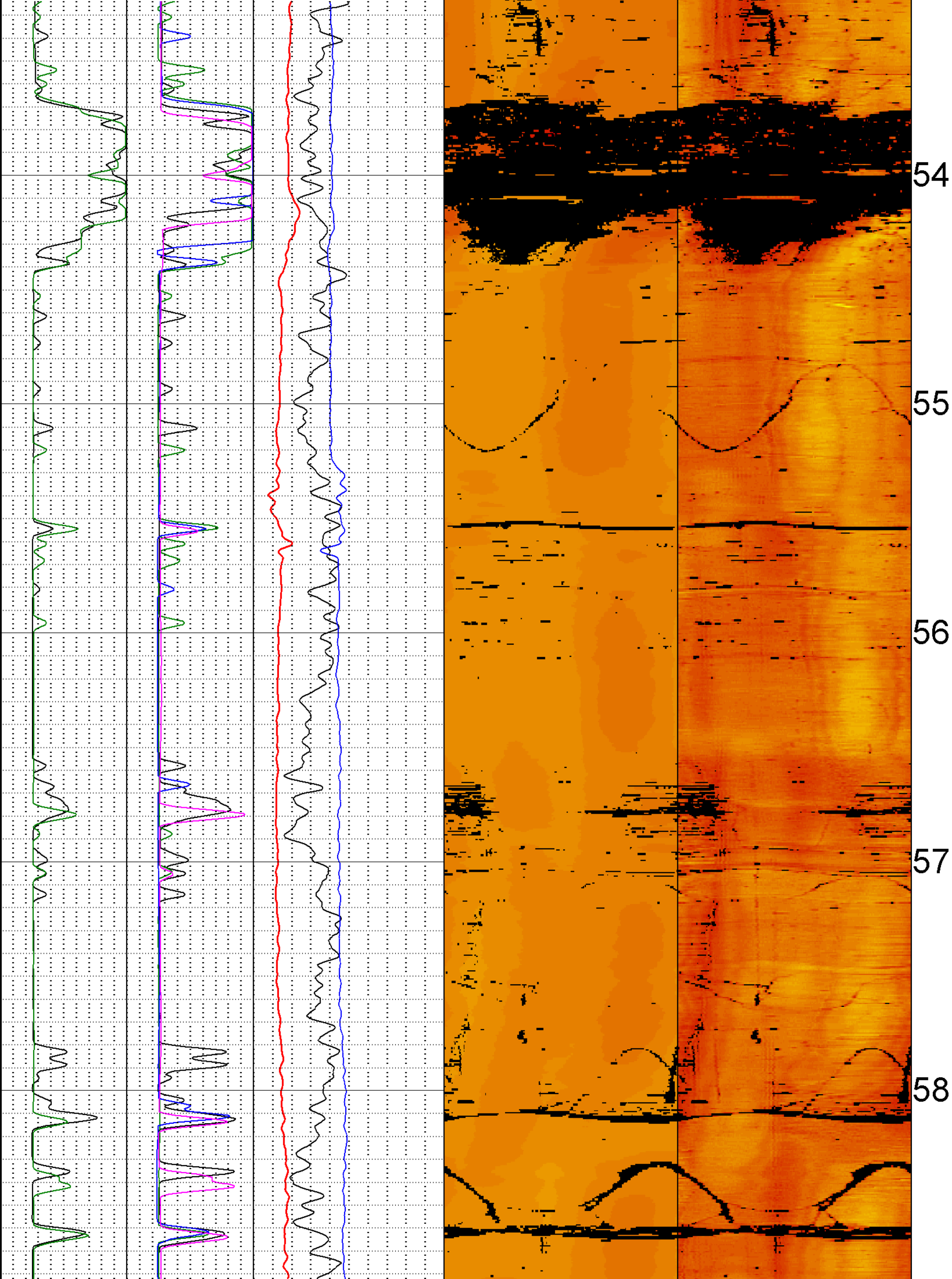
LOG PARAMETERS

MATRIX DENSITY : 2.65
NEUTRON MATRIX : SANDSTONE
MATRIX DELTA T : 177
MAGNETIC DECL : 0
ELECT. CUTOFF : 99999
BIT SIZE : 9.6 CM
PRESENTATION : \804A_JL44.0 -- 04/22/2020
DISPLAY7_JL44

METERS

Track	Curve	Units	Scale left	Scale right
2	CALIPER4	INCH	0	36
2	CALIPER3	INCH	0	36
3	SANGB	DEG	0	360
1	CALIPERY	CM	0	36
2	CALIPER2	INCH	0	36
3	SANG	DEG	0	4
1	CALIPERX	CM	0	36
2	CALIPER1	INCH	0	36
3	GAMMA	API-GR	0	300
4	T_TIME..USEC	0 – 180 – 360	20	114
5	AMPL..MV	0 – 180 – 360	0	1500





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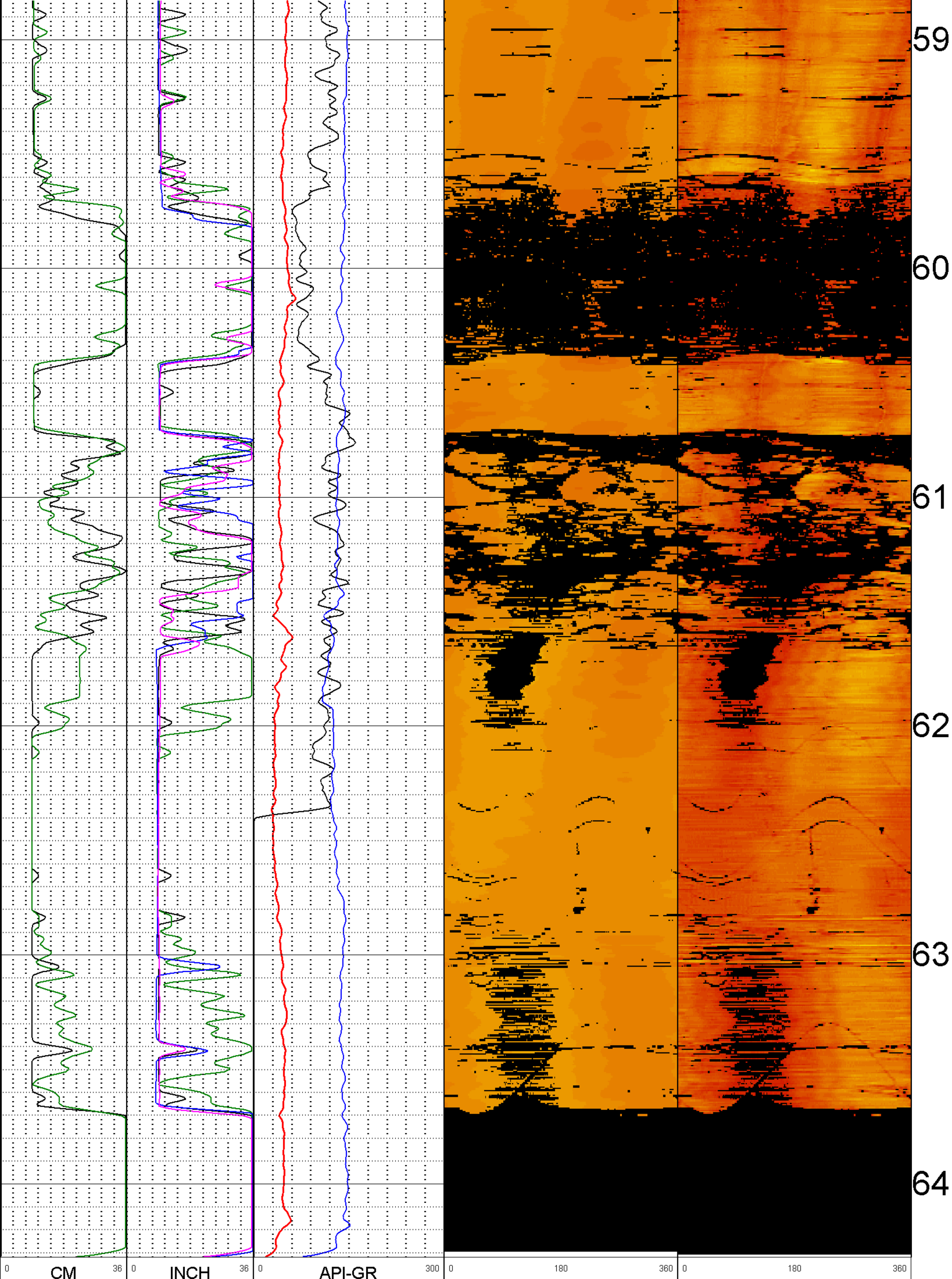
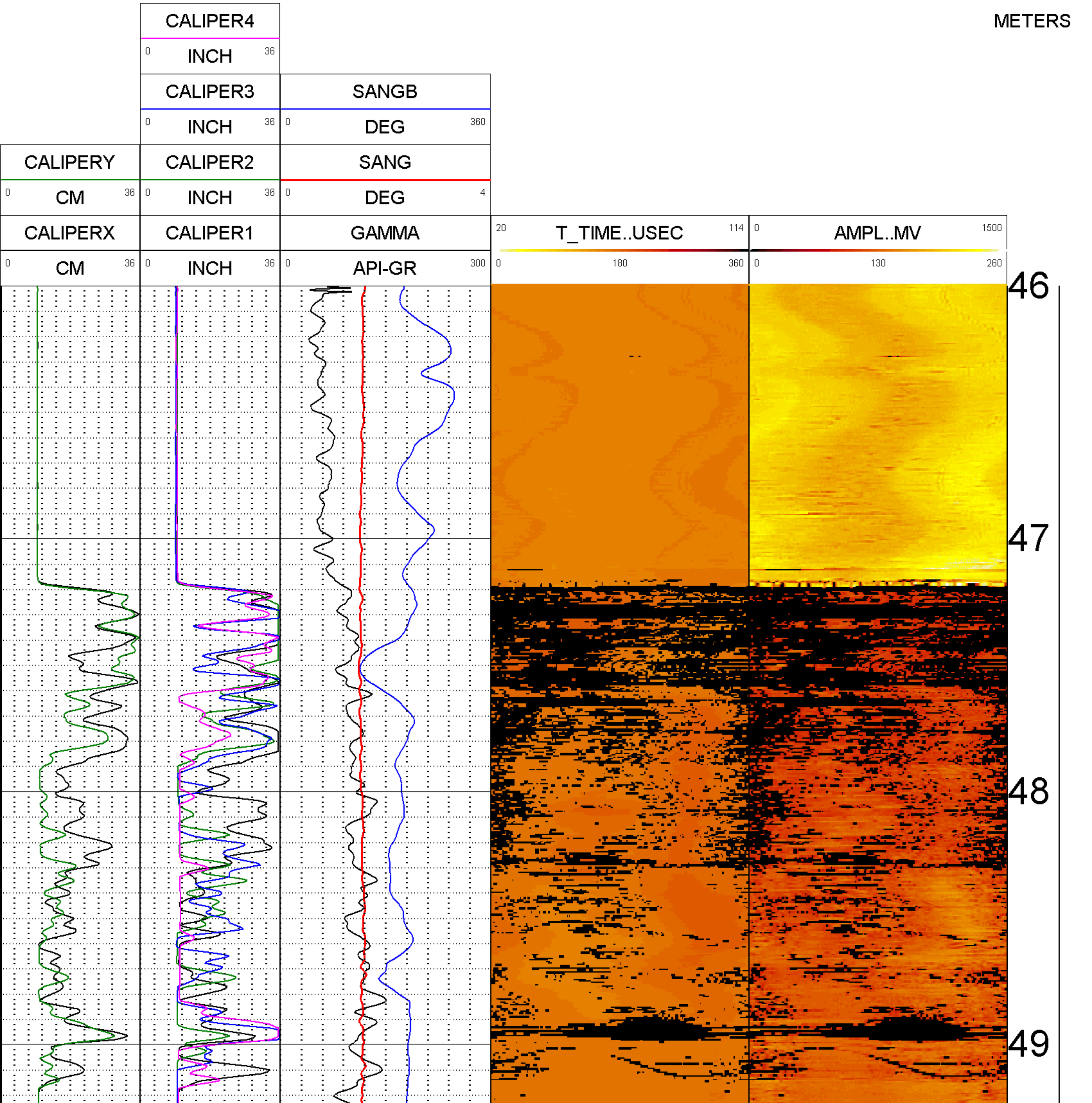
55
56
57
58

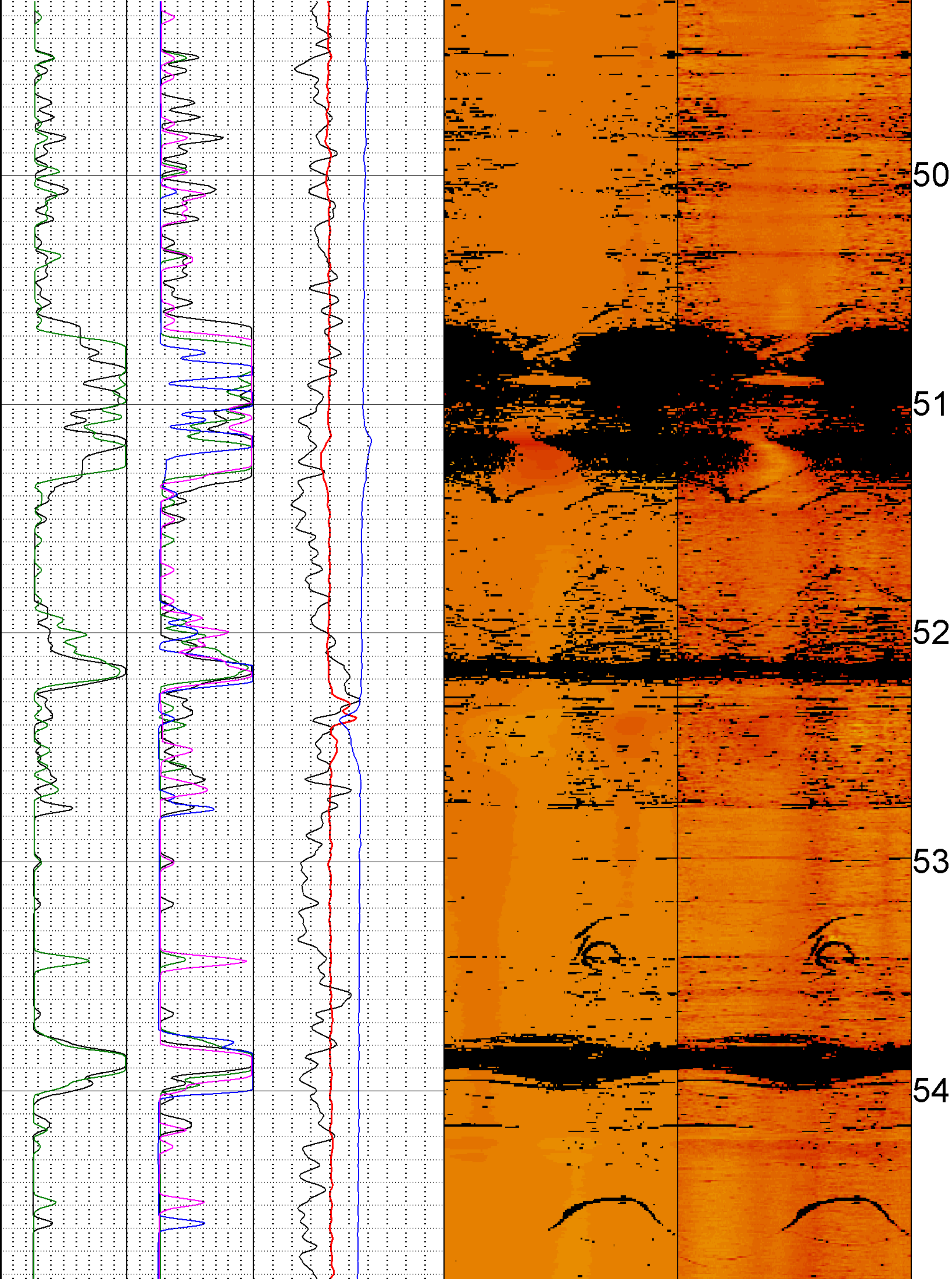

59
60
61
62
63
64
0
CM
36
0
INCH
36
0
API-GR
300
0
180
360
0
180
360

1:20 BH06 TELEVIEWER

LOG PARAMETERS

MATRIX DENSITY : 2.65
NEUTRON MATRIX : SANDSTONE
MATRIX DELTA T : 177
MAGNETIC DECL : 0
ELECT. CUTOFF : 99999
BIT SIZE : 9.6 CM
PRESENTATION : \804A_JL44.0 -- 04/22/2020
DISPLAY7_JL44





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51
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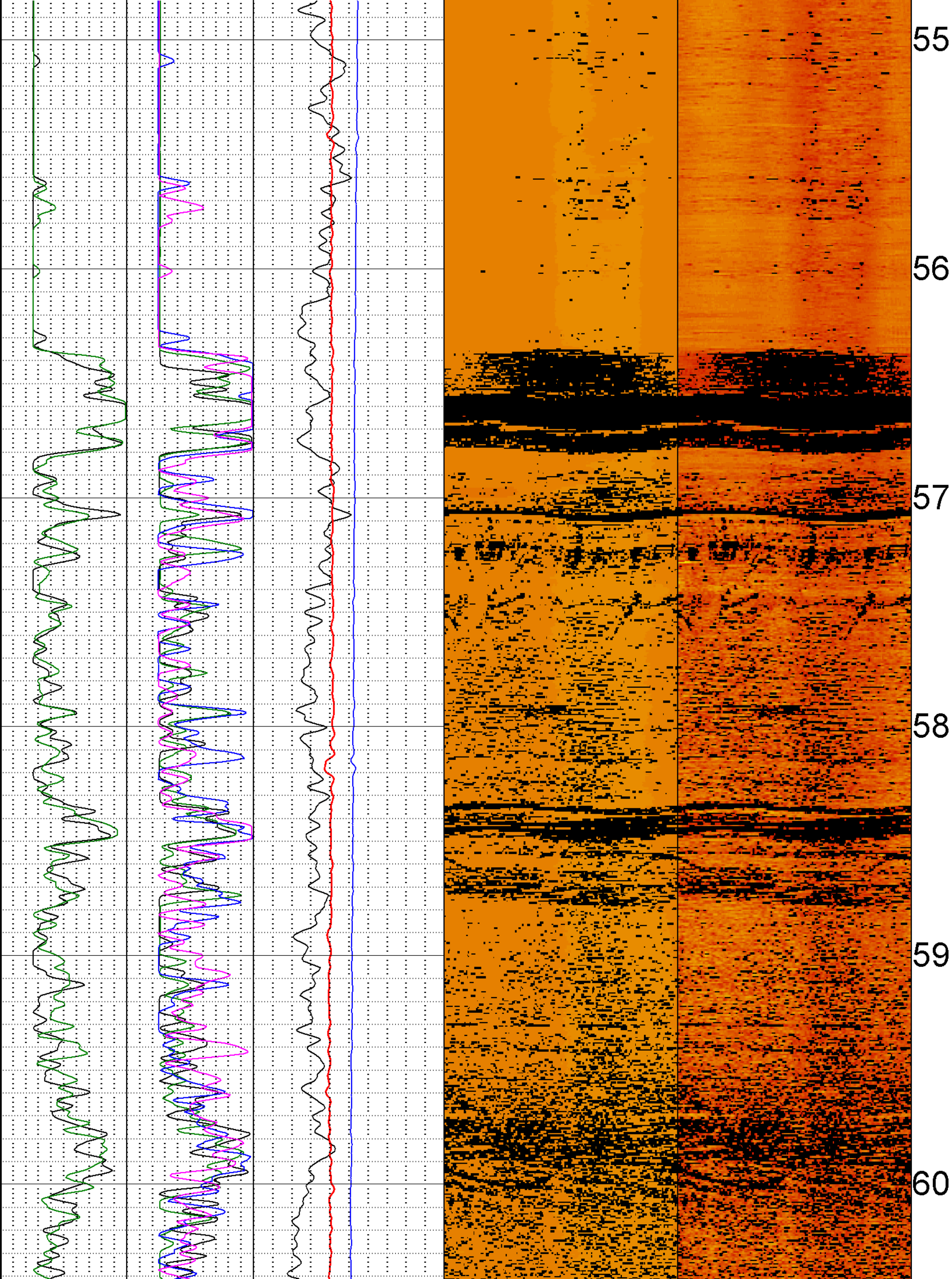
53
54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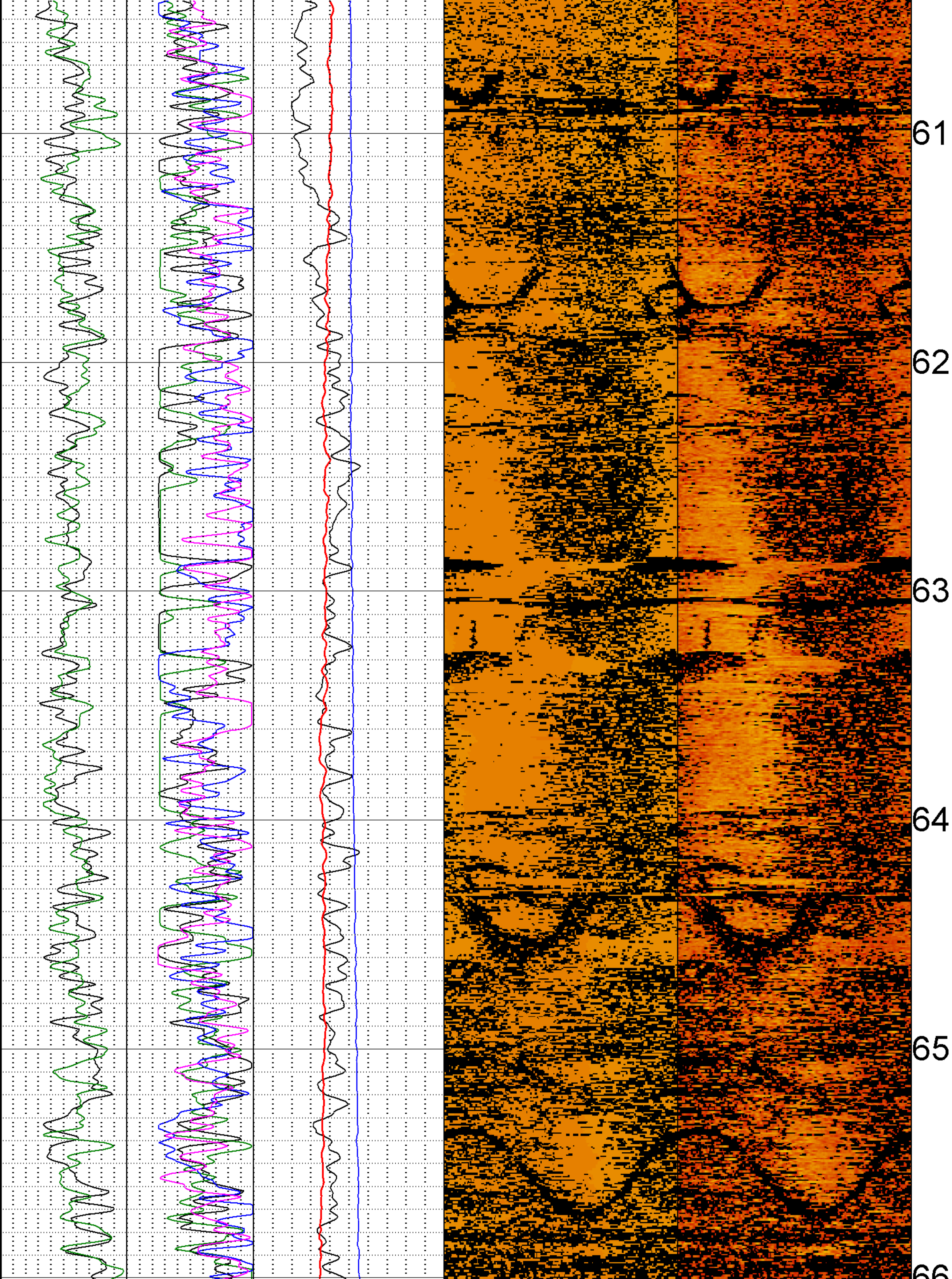
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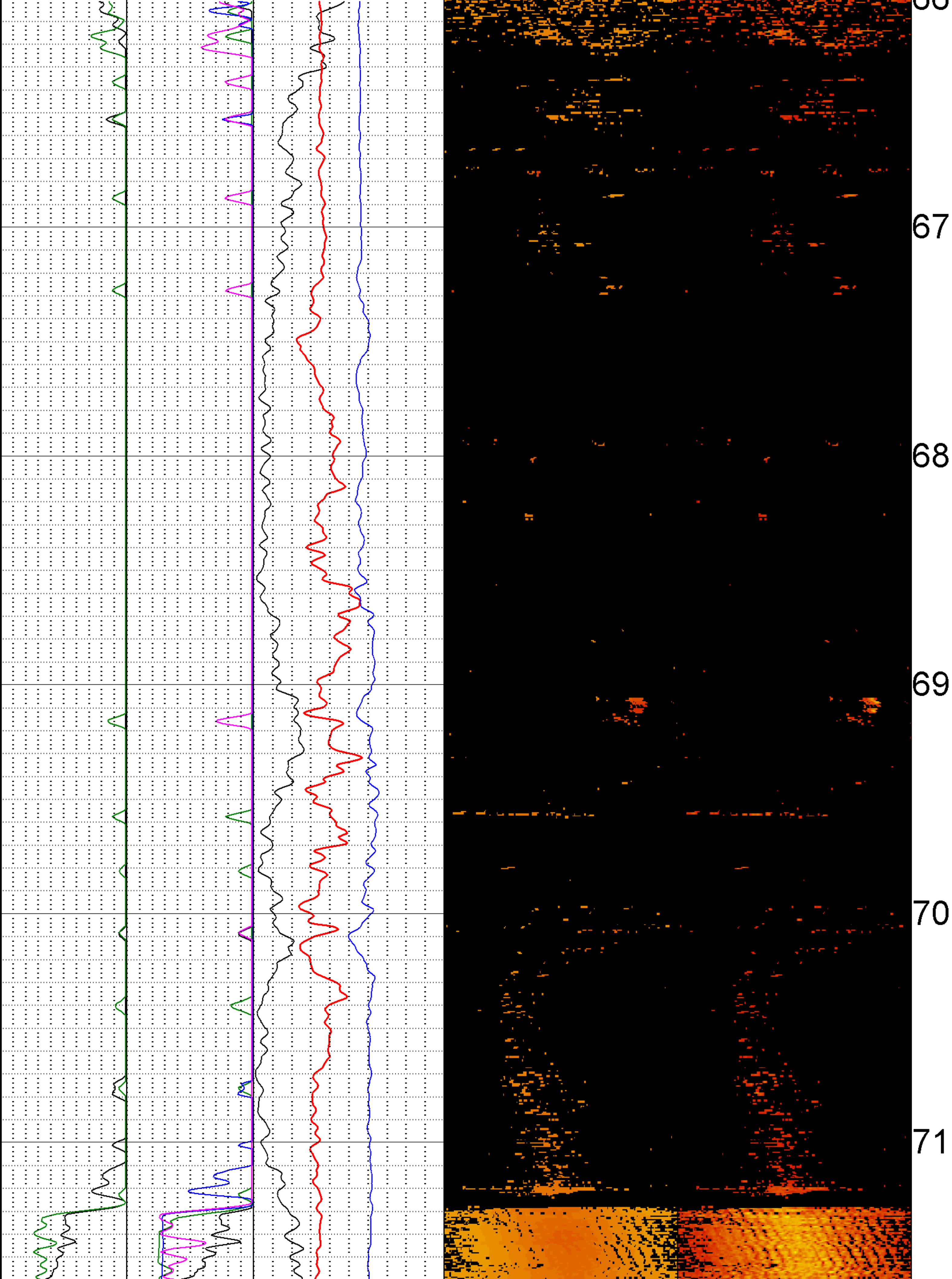
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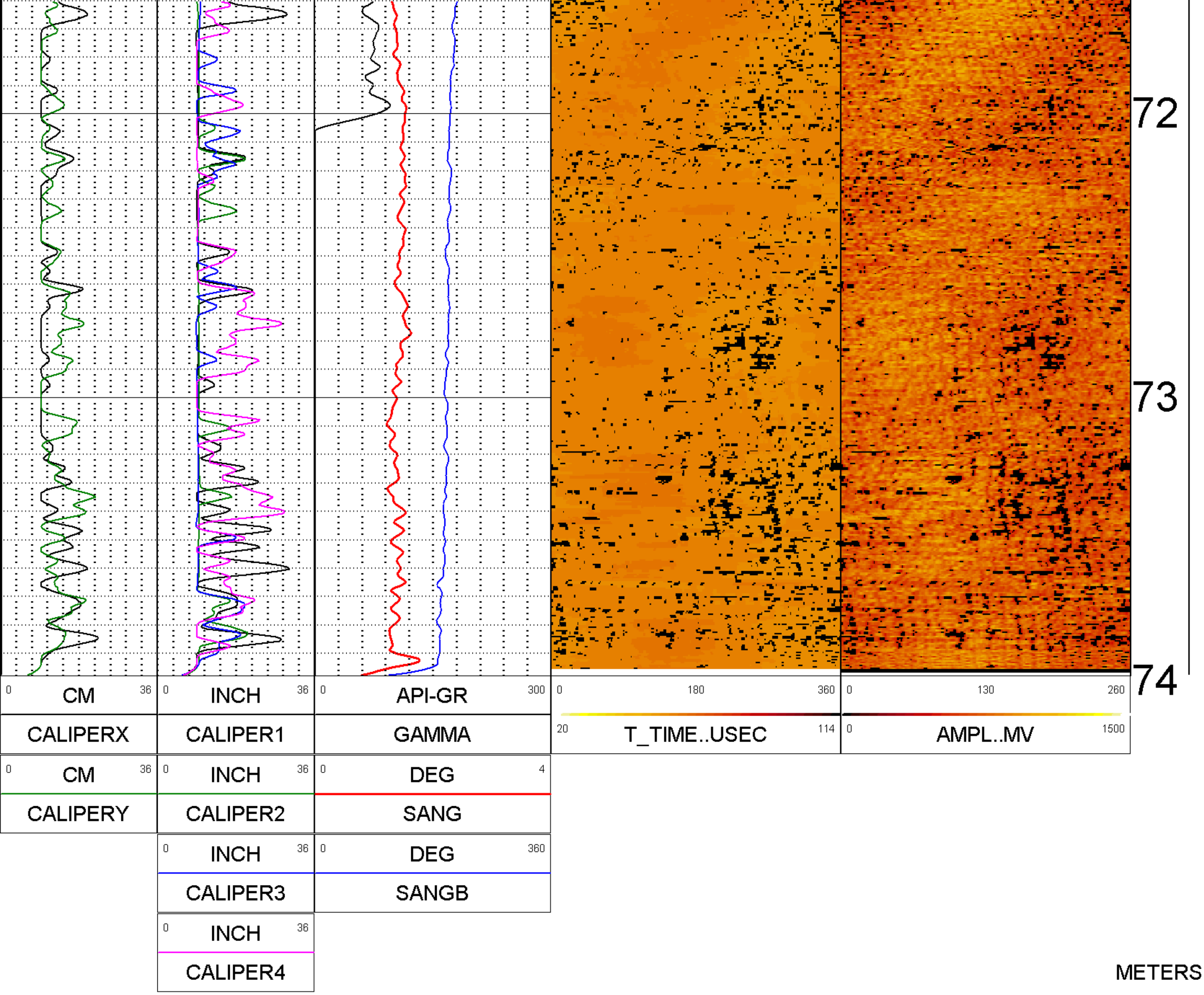

72
73
74
0 CM 36
CALIPERX
0 INCH 36
CALIPER1
0 API-GR 300
GAMMA
0 180 360
20 T_TIME..USEC 114
0 130 260
0 AMPL..MV 1500
0 CM 36
CALIPERY
0 INCH 36
CALIPER2
0 DEG 4
SANG
0 INCH 36
CALIPER3
0 DEG 360
SANGB
0 INCH 36
CALIPER4
METERS

Appendix F – Laboratory test reports

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

Material Test Report

Report No: SYD2100347
Issue No: 1

Accredited for compliance with ISO / IEC 17025 - Testing

NATA Accreditation No: 679

Approved Signatory: Jure G Vukovic

Date of Issue: 17/03/2021

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

Client: Port of Newcastle
L4, 251 Wharf Rd
Newcastle NSW 2300

Project: 12545790 Carrington

Sample Details

GHD Sample No	SYD21-0073-01
Sampled By	Sampled by GHD
BH / TP No.	BH1
Depth (m)	0.85-1.00
Soil Description	SAND trace Clay and Gravel: grey/brown

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	9.5	
Date Tested		9/03/2021	
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	**1.79**	
Standard OMC (%)		**11.5**	
Retained Sieve (mm)		19	
Oversize Material (%)		0	
Curing Time (h)		32	
Date Tested		9/03/2021	
CBR at 2.5mm (%)	AS 1289.6.1.1 - 2017	**16**	
Dry Density before Soaking (t/m³)		1.70	
Density Ratio before Soaking (%)		95.0	
Moisture Content before Soaking (%)		11.6	
Moisture Ratio before Soaking (%)		99.0	
Dry Density after Soaking (t/m³)		1.70	
Density Ratio after Soaking (%)		95.0	
Swell (%)		0.0	
Moisture Content of Top 30mm (%)		15.1	
Moisture Content of Remaining Depth (%)		16.5	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		0	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Moisture Content		AS 1289.2.1.1	
Date Tested		16/03/2021	

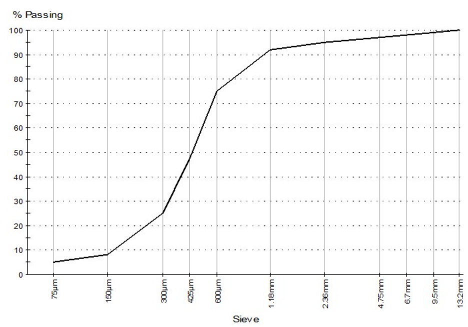
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 11/03/2021

Note: Sample Washed

Sieve Size	% Passing	Limits
13.2mm	100	
9.5mm	99	
6.7mm	98	
4.75mm	97	
2.36mm	95	
1.18mm	92	
600µm	75	
425µm	47	
300µm	25	
150µm	8	
75µm	5	

Chart



Comments

N/A

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

Material Test Report

Report No: SYD2100348
Issue No: 1

Client:	Port of Newcastle L4, 251 Wharf Rd Newcastle NSW 2300
Project:	12545790 Carrington

Accredited for compliance with ISO / IEC 17025 - Testing

NATA Accreditation No: 679

Approved Signatory: Jure G Vukovic

Date of Issue: 17/03/2021

THIS DOCUMENT SHALL NOT BE REPRODUCED EXCEPT IN FULL

Sample Details

GHD Sample No	SYD21-0073-02
Sampled By	Sampled by GHD
BH / TP No.	BH2
Depth (m)	0.40-2.00
Soil Description	SAND with Gravel: yellow/grey/brown

Other Test Results

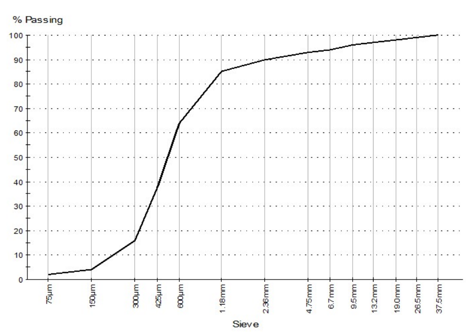
Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	9.2	
Date Tested		1/03/2021	
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	**1.74**	
Standard OMC (%)		**13.0**	
Retained Sieve (mm)		19	
Oversize Material (%)		2	
Curing Time (h)		32	
Date Tested		2/03/2021	
CBR at 5.0mm (%)	AS 1289.6.1.1 - 2017	**30**	
Dry Density before Soaking (t/m³)		1.67	
Density Ratio before Soaking (%)		96.0	
Moisture Content before Soaking (%)		12.9	
Moisture Ratio before Soaking (%)		99.5	
Dry Density after Soaking (t/m³)		1.68	
Density Ratio after Soaking (%)		96.0	
Swell (%)		-0.5	
Moisture Content of Top 30mm (%)		15.0	
Moisture Content of Remaining Depth (%)		16.3	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		2	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Moisture Content		AS 1289.2.1.1	
Date Tested		8/03/2021	

Particle Size Distribution

Method:	AS 1289.3.6.1
Drying by:	Oven
Date Tested:	4/03/2021
Note:	Sample Washed

Sieve Size	% Passing	Limits
37.5mm	100	
26.5mm	99	
19.0mm	98	
13.2mm	97	
9.5mm	96	
6.7mm	94	
4.75mm	93	
2.36mm	90	
1.18mm	85	
600µm	64	
425µm	38	
300µm	16	
150µm	4	
75µm	2	

Chart



Comments

N/A

Sydney Laboratory
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web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax:(02) 9462 4710

Material Test Report

Report No: SYD2100349
Issue No: 1

Client:	Port of Newcastle L4, 251 Wharf Rd Newcastle NSW 2300
Project:	12545790 Carrington

Accredited for compliance with ISO / IEC 17025 - Testing

NATA Accreditation No: 679

Approved Signatory: Jure G Vukovic

Date of Issue: 17/03/2021

Sample Details

GHD Sample No	SYD21-0073-03
Sampled By	Sampled by GHD
BH / TP No.	BH7
Depth (m)	0.50-1.50
Soil Description	SAND: yellow/grey/brown

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	9.0	
Date Tested		1/03/2021	
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	**1.67**	
Standard OMC (%)		**13.0**	
Retained Sieve (mm)		19	
Oversize Material (%)		0	
Curing Time (h)		32	
Date Tested		2/03/2021	
CBR at 2.5mm (%)	AS 1289.6.1.1 - 2017	**11**	
Dry Density before Soaking (t/m³)		1.59	
Density Ratio before Soaking (%)		95.5	
Moisture Content before Soaking (%)		13.1	
Moisture Ratio before Soaking (%)		100.5	
Dry Density after Soaking (t/m³)		1.59	
Density Ratio after Soaking (%)		95.5	
Swell (%)		0.0	
Moisture Content of Top 30mm (%)		16.9	
Moisture Content of Remaining Depth (%)		18.6	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		0	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Moisture Content		AS 1289.2.1.1	
Date Tested		8/03/2021	

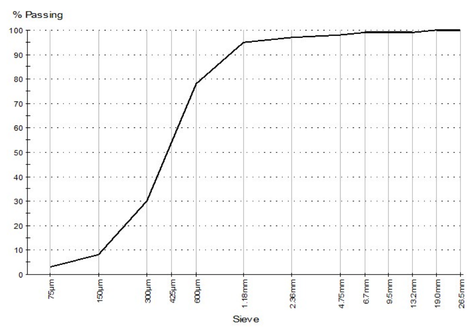
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 4/03/2021

Note: Sample Washed

Sieve Size	% Passing	Limits
26.5mm	100	
19.0mm	100	
13.2mm	99	
9.5mm	99	
6.7mm	99	
4.75mm	98	
2.36mm	97	
1.18mm	95	
600µm	78	
425µm	54	
300µm	30	
150µm	8	
75µm	3	

Chart



Comments

N/A

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

Material Test Report

Report No: SYD2100350
Issue No: 1

Client: Port of Newcastle
L4, 251 Wharf Rd
Newcastle NSW 2300

Project: 12545790 Carrington

Accredited for compliance with ISO / IEC 17025 - Testing

NATA Accreditation No: 679

Approved Signatory: Jure G Vukovic

Date of Issue: 17/03/2021

Sample Details

GHD Sample No	SYD21-0073-04
Sampled By	Sampled by GHD
BH / TP No.	BH8
Depth (m)	0.60-1.20
Soil Description	SAND trace Clay and Gravel: grey/brown

Other Test Results

Description	Method	Result	Limits
Moisture Content (%)	AS 1289.2.1.1	5.5	
Date Tested		9/03/2021	
Standard MDD (t/m³)	AS 1289.5.1.1 - 2017	**1.83**	
Standard OMC (%)		**10.5**	
Retained Sieve (mm)		19	
Oversize Material (%)		0	
Curing Time (h)		32	
Date Tested		9/03/2021	
CBR at 2.5mm (%)	AS 1289.6.1.1 - 2017	**14**	
Dry Density before Soaking (t/m³)		1.74	
Density Ratio before Soaking (%)		95.0	
Moisture Content before Soaking (%)		10.3	
Moisture Ratio before Soaking (%)		99.0	
Dry Density after Soaking (t/m³)		1.74	
Density Ratio after Soaking (%)		95.0	
Swell (%)		0.0	
Moisture Content of Top 30mm (%)		14.2	
Moisture Content of Remaining Depth (%)		15.0	
Compaction Hammer Used		Standard	
Surcharge Mass (kg)		4.50	
Period of Soaking (Days)		4	
Retained on 19 mm Sieve (%)		0	
CBR Moisture Content Method		AS 1289.2.1.1	
Sample Moisture Content		AS 1289.2.1.1	
Date Tested		16/03/2021	

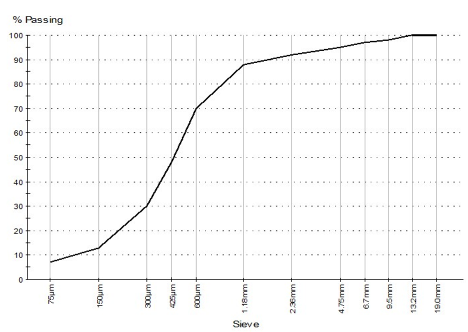
Particle Size Distribution

Method: AS 1289.3.6.1
Drying by: Oven
Date Tested: 11/03/2021

Note: Sample Washed

Sieve Size	% Passing	Limits
19.0mm	100	
13.2mm	100	
9.5mm	98	
6.7mm	97	
4.75mm	95	
2.36mm	92	
1.18mm	88	
600µm	70	
425µm	48	
300µm	30	
150µm	13	
75µm	7	

Chart



Comments

N/A

Shear Vane (Pilcon) - Report

Report No: SYD2100351

Client:	**Port of Newcastle**	Job No:	12545790
Project:	**Proposed Commercial Development**	Sample No:	-
Location:	**65 Denison St, Carrington, NSW**	Test Hole No:	-
		Depth (m) :	-

Test Procedure: Inhouse GG1209

Sample ID			**SHEAR VANE TEST INFORMATION**				
BH / TP	**Sample Depth (m)**	**Test Depth (m)**	**Type**	**Rotation Rate (°/min.)**	**Vane Size (mm)**	**Vane Shear Strength, s (kPa)**	**Comments**
BH03	15.5-16.0	15.9	Peak	360	19	**113**	CLAY; grey
			Residual	360	19	**34**	
BH04	15.9-16.35	16.25	Peak	360	19	**116**	CLAY; dark grey
			Residual	360	19	**28**	
			Peak				
			Residual				
			Peak				
			Residual				
			Peak				
			Residual				
			Peak				
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			Residual				
			Peak				
			Residual				
			Peak				
			Residual				

NOTES:

Tested By:	AM
Date Tested:	1/03/2021
Checked By:	JV
Date:	17/03/2021

GHD Pty Ltd
Unit 5 / 43 Herbert Street Artarmon, N.S.W. 2064
Telephone: (02) 9462 4860

CERTIFICATE OF ANALYSIS

Work Order	: **EB2105109**	Page	: 1 of 4
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: SAM MACKENZIE	Contact	: Andrew Epps
Address	: PO BOX 5403 NEWCASTLE WEST NSW, AUSTRALIA 2302	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8639
Project	: Denison St, Carrington	Date Samples Received	: 26-Feb-2021 09:30
Order number	: 12545790	Date Analysis Commenced	: 01-Mar-2021
C-O-C number	: ----	Issue Date	: 04-Mar-2021 11:54
Sampler	: ----		
Site	:		
Quote number	: EN/005		
No. of samples received	: 6		
No. of samples analysed	: 6		

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.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

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.

- ASS: EA037 (Rapid Field and F(ox) screening): pH F(ox) Reaction Rate: 1 - Slight; 2 - Moderate; 3 - Strong; 4 - Extreme
- EA037 ASS Field Screening: NATA accreditation does not cover performance of this service.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH1 0.45m	BH2 1.4m	BH3 1.5-1.95m	BH3 3.0-3.45m	BH4 1.5-1.95m
			Sampling date / time	24-Feb-2021 00:00	24-Feb-2021 00:00	24-Feb-2021 00:00	24-Feb-2021 00:00	24-Feb-2021 00:00
Compound	CAS Number	LOR	Unit	EB2105109-001	EB2105109-002	EB2105109-003	EB2105109-004	EB2105109-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.6	8.1	8.0	8.9	8.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	91	413	196	98	240
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.9	8.0	8.0	8.7	8.0
ø pH (Fox)	----	0.1	pH Unit	6.1	5.7	1.9	4.6	5.5
ø Reaction Rate	----	1	-	2	2	3	1	2
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	15.6	19.6	42.6	21.5	27.9
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	10	870	190	120	320
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	10	30	50	20	20

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	BH7 1.6m	----	----	----	----
			Sampling date / time	24-Feb-2021 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit	EB2105109-006	--------	--------	--------	--------
				Result	----	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.7	----	----	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	232	----	----	----	----
EA037: Ass Field Screening Analysis								
ø pH (F)	----	0.1	pH Unit	8.8	----	----	----	----
ø pH (Fox)	----	0.1	pH Unit	2.2	----	----	----	----
ø Reaction Rate	----	1	-	4	----	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	33.4	----	----	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	300	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	190	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2106388**	Page	: 1 of 3
Client	: **GHD PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: SAM MACKENZIE	Contact	: Andrew Epps
Address	: PO BOX 5403 NEWCASTLE WEST NSW, AUSTRALIA 2302	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61 7 3552 8639
Project	: Denison St, Carrington	Date Samples Received	: 09-Mar-2021 15:32
Order number	: ----	Date Analysis Commenced	: 11-Mar-2021
C-O-C number	: ----	Issue Date	: 11-Mar-2021 16:31
Sampler	: ----		
Site	:		
Quote number	: EN/005		
No. of samples received	: 3		
No. of samples analysed	: 3		

NATA
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.

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- Analytical Results

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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.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

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.

- ASS: EA033 (CRS Suite):Retained Acidity not required because pH KCl greater than or equal to 4.5
- ASS: EA033 (CRS Suite): Laboratory determinations of ANC needs to be corroborated by effectiveness of the measured ANC in relation to incubation ANC. Unless corroborated, the results of ANC testing should be discounted when determining Net Acidity for comparison with action criteria, or for the determination of the acidity hazard and required liming amounts.
- ASS: EA033 (CRS Suite): Liming rate is calculated and reported on a dry weight basis assuming use of fine agricultural lime ($CaCO_3$) and using a safety factor of 1.5 to allow for non-homogeneous mixing and poor reactivity of lime. For conversion of Liming Rate from 'kg/t dry weight' to 'kg/m3 in-situ soil', multiply 'reported results' x 'wet bulk density of soil in t/m3'.

Analytical Results

Sub-Matrix: PULP (Matrix: SOIL)			Sample ID	BH1 0.45m	BH3 1.5 - 1.95m	BH7 1.6m	----	----
			Sampling date / time	24-Feb-2021 00:00	24-Feb-2021 00:00	24-Feb-2021 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2106388-001	EB2106388-002	EB2106388-003	--------	--------
				Result	Result	Result	----	----
EA033-A: Actual Acidity								
pH KCl (23A)	----	0.1	pH Unit	**10.6**	**6.9**	**7.9**	----	----
Titratable Actual Acidity (23F)	----	2	mole H+ / t	<2	<2	<2	----	----
sulfidic - Titratable Actual Acidity (s-23F)	----	0.02	% pyrite S	<0.02	<0.02	<0.02	----	----
EA033-B: Potential Acidity								
Chromium Reducible Sulfur (22B)	----	0.005	% S	**0.024**	**0.860**	**1.30**	----	----
acidity - Chromium Reducible Sulfur (a-22B)	----	10	mole H+ / t	**15**	**537**	**814**	----	----
EA033-C: Acid Neutralising Capacity								
Acid Neutralising Capacity (19A2)	----	0.01	% CaCO3	**12.4**	**1.90**	**2.58**	----	----
acidity - Acid Neutralising Capacity (a-19A2)	----	10	mole H+ / t	**2470**	**380**	**515**	----	----
sulfidic - Acid Neutralising Capacity (s-19A2)	----	0.01	% pyrite S	**3.96**	**0.61**	**0.83**	----	----
EA033-E: Acid Base Accounting								
ANC Fineness Factor	----	0.5	-	**1.5**	**1.5**	**1.5**	----	----
Net Acidity (sulfur units)	----	0.02	% S	<0.02	**0.45**	**0.75**	----	----
Net Acidity (acidity units)	----	10	mole H+ / t	<10	**283**	**470**	----	----
Liming Rate	----	1	kg CaCO3/t	<1	**21**	**35**	----	----
Net Acidity excluding ANC (sulfur units)	----	0.02	% S	**0.02**	**0.86**	**1.30**	----	----
Net Acidity excluding ANC (acidity units)	----	10	mole H+ / t	**15**	**537**	**814**	----	----
Liming Rate excluding ANC	----	1	kg CaCO3/t	**1**	**40**	**61**	----	----

Appendix G – GHD 2020b: Mine Subsidence Assessment report

Port of Newcastle Operations Pty Ltd

46 Fitzroy Street, Carrington

Mine Subsidence Assessment

May 2020

Table of contents

Table index

Appendices

1. Introduction

GHD was engaged by Port of Newcastle (PON) to undertake a mine subsidence assessment for four proposed development options at a currently vacant site, 46 Fitzroy Street, Carrington (Lot 33, DP 1078910).

The site and surrounding area is undermined by abandoned mine workings in the Borehole Seam of coal at about 67 m to 70 m depth. Mining occurred between 1884 to 1904 at the Wickham and Bullock Island Colliery.

The subject site and surrounding area is within a gazetted mine subsidence district administered by Subsidence Advisory NSW (SA NSW) under the *Coal Mine Subsidence Compensation Act 2017.* SA NSW is an approval authority for surface improvements.

Development options being considered include on-ground car parking and light industrial or commercial buildings between one and three storeys as follows:

Option 1	Two buildings: one of 3 storeys and the other 2 storeys with on-ground parking
Option 2	Two buildings: one of 3 storeys and the other 2 storeys with undercroft and on-ground parking
Option 3	Two buildings: both 2 storeys with on-ground parking
Option 4	Three buildings: all 2 storeys with on-ground parking.

For non-residential development such as this, SA NSW assessment will be based on their *Development Application – Merit Assessment Policy* (SA NSW, 2018).

The purpose of this report is initially to inform PON on development options with respect to mine subsidence constraints and anticipated SA NSW requirements. Secondly, this report could be submitted to SA NSW as part of Development Applications or formal enquiries to assist SA NSW with making their determinations.

This report first presents the assessment findings, including descriptions of the anticipated subsurface conditions (geology) and mining. The report then discusses subsidence hazards and the likelihood that such events will occur. Lastly, the report relates the anticipated SA NSW requirements for the development options being considered by PON.

2. Description of geology and mining

2.1 Geological setting

The site comprises a land surface raised above natural level by placement of fill over alluvial soil deposits. The surface elevation is about 2 to 3 m above Australian Height Datum (AHD).

The depth to top of bedrock is interpreted to be between 40 and 50 m based on reference to a geotechnical report for the Carrington grain silo (Public Works, 1984) and sections of both the Wickham and Bullock Island Colliery “Winding Shaft” and “Fan Shaft” included on Record Tracing RT579 (Wickham and Bullock Island Colliery. 1906). The location of these features relative to the site is shown in the below figure.

Figure 2-1 Site location and selected surrounding features

The shaft sections extracted from RT579 are shown in the figure below with annotations provided to show our interpretation of them.

Note that the original downhole descriptions align with the base of each unit to which they refer.

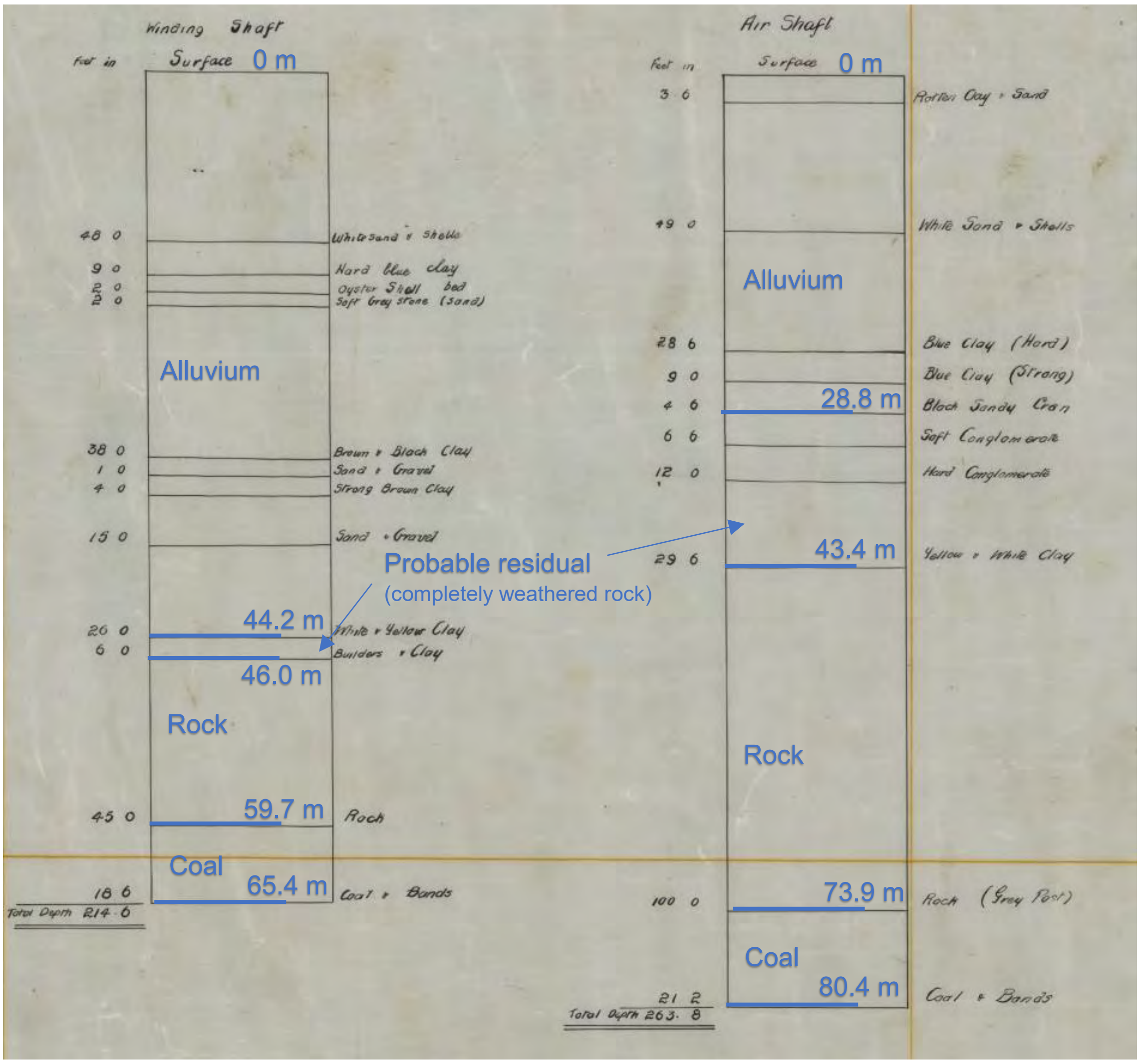

Figure 2-2 Shaft sections from RT579 with annotations in blue

While the geotechnical characteristics of the alluvial soils beneath the site are not known, they are likely to be primarily sand and silty sand units in the upper 15 m and, below this, layers of clay and sand. This is illustrated by a cross section included in the *Third report on the collieries adjacent to Ferndale* (NSW Royal Commission on Collieries. 1886), a portion of which is shown below, with annotations in blue.

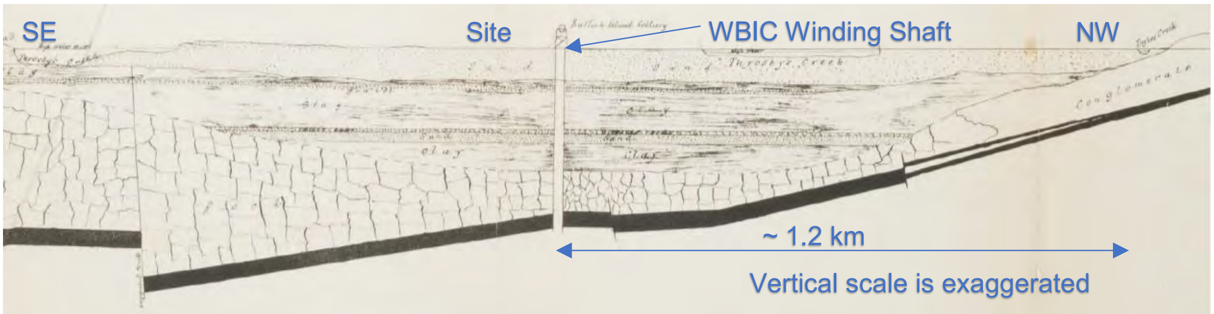

Figure 2-3 Section cc from Plan 1 NSW Royal Commission third report (1886)

Bedrock is expected to be interbedded sandstone and siltstone with minor tuffaceous beds and carbonaceous laminations of the Lambton Formation. This includes the Borehole Seam and below this the Waratah Sandstone unit, the base (oldest unit) of the Newcastle Coal Measures.

Further discussion on the thickness and depth of the Borehole Seam, as well as a geological fault that passes through the site is presented in the following sections.

2.2 Borehole Seam depth

The depth of the Borehole Seam is known from mining records. In particular, the two plans of the workings referred to here as M12137 and RT579 respectively. Extracts of these are included in Appendix A as Figure 2 and Figure 3 respectively. These plans were supplied by the NSW Department of Planning Industry and Environment to GHD under a confidentiality deed. We draw your attention to the limitations and disclaimer included in Section 6 and on the figures.

These plans both show the mine workings of the Wickham and Bullock Island Colliery in the Borehole Seam yet they show slightly different information and so review of both is useful.

RT579 is the mine record tracing for mining of the Borehole Seam in the Wickham and Bullock Island Colliery. It is the formal record of mining, updated as mining progressed. RT579 is signed *"Examined and found correct, 13th January 1906, John T Tennant, Insp of Collieries".* Despite this assertion of correctness, the plan should not be considered an accurate representation of the final mine workings.

The M12137 plan is of the "Delta Collieries" of which the Wickham and Bullock Island Colliery was one, along with adjacent mines of the time such as Hetton Colliery and Stockton Colliery, that were also mining the Borehole Seam under the tidal Hunter River "delta". The M12137 plan is not dated formally although it does include dates of mining, survey traverses, names of main headings and bords, and importantly spot levels of the mine roof. For example, the winding shaft has a spot level of 202.55 feet (61.7 m) and the fan shaft 246.00 feet (75.0 m). RT579 also includes spot levels referenced to below high water mark.

The table below provides a comparison of spot levels from RT579 and M12137.

Table 2-1 Mine roof spot levels beneath site (below high water mark)

Survey Station	Location	RT579	M12137	Difference
2a	western edge of the site along the "Engine Road" – west of fault	221.84 feet (67.6 m)	221.8 feet (67.6 m)	No difference
483		225.60 feet (68.8 m)	224.86 feet (68.5 m)	RT579 roof is 0.74 m lower
483a	south edge of site – west of fault	227.05 feet (69.2 m)	-	RT579 roof west of fault is 0.73 m lower than M12137 roof east of fault
495	south edge of site – east of fault	-	224.64 feet (68.5 m)	
Between 495 and 496	southeast corner of the site – east of fault	227.80 feet (69.4 m)	-	0.23 m lower than at 483a

The above roof levels agree generally with a seam dip of 1 in 40 (1.4°) to the southeast between the winding shaft and fan shaft as indicated on RT579.

The difference between roof levels on RT579 and M12137 of about 0.73 m is unresolved. It may be due to a change in datum or survey errors.

Both plans show a fault passing through the Borehole Seam beneath the site (red line in Figure 2 and Figure 3) with RT579 indicating a 6 foot (~1.8 m) displacement with the downside on the east as indicated by convention with the direction of the arrow. However, the difference in roof level across this fault between station 483a and 495, about 20 m apart, appears to be 0.73 m and in the wrong direction. The reason for this is also unresolved.

2.3 Borehole Seam thickness and working height

The thickness of the coal seam is shown on RT579 as graphical sections at specific locations as well as referenced in other historical records. As well as indicating the overall thickness of coal, the basic lithology of the seam is often also provided and gives a basis for comparison of the mining height (the height of coal mined) to other historical records.

Mining at Wickham and Bullock Island Colliery initially consisted on taking the lower part of the seam (the bottoms). This included a stone band called the “jerry” with another stone band called the “morgan” forming the roof. Perhaps months to years later (after 1890), the main part of the seam (the tops) was also taken with this including the morgan and coal above it, sometimes called “little tops”.

More specific information about mining height and seam thickness is available from historic sources and is useful to compare. The table below provides a summary.

Table 2-2 Borehole Seam thickness

Location	Source	Total Seam (m)	Mined seam (m)	
			Tops [1]	Bottoms [2]
Winding shaft	Section from RT579. 1906	5.7	-	- -
Winding shaft	Section from NSW Royal Commission on Collieries. 1886	5.9	4.5	1.4
Fan shaft	Section from RT579. 1906	6.5	-	-
Pre 1890 workings	Kingswell. 1890 p.42	5.6	-	2.4 to 3.7 [3]
Pre 1886 workings – south side dips section	NSW Royal Commission on Collieries. 1886	-	-	1.8
Pre 1890 workings	NSW Royal Commission on Collieries. 1886	5.7	4.6	1.5 to 1.8

1. Tops: second workings Morgan up to roof coal (includes the morgan)
2. Bottoms: first workings base of seam up to the morgan (includes the jerry)
3. *“The total thickness worked varies from 8ft. to 12ft., but eventually the top coal will also be taken down.”*

The mining height reported by Kingswell (1890) is at odds with primary sources such as the record tracing and Royal Commission report. While it may be an error, it could also refer to a part of the mine (pre 1890) where they mined a thicker section, including both the morgan and jerry, which was later abandoned in favour of a thinner bottoms using the morgan as the roof.

In the vicinity of the site, the total seam thickness is expected to be about 6 m with the bottoms comprising about 1.8 m and the tops 4.2 m such that the maximum mining height (tops and bottoms) was the full seam thickness of 6 m.

2.3.1 Mining layout

The mining layout is known as bord and pillar working. Initially headings were developed, in this case passing down the western side of the site, and off these, bords were extracted (with short “cut-throughs” between adjacent bords) to form pillars of coal (coal remaining in place). Areas of pillars between main bords are called districts.

The extent of mining in 1886 is indicated in Plan 5 of the NSW Royal Commission on Collieries report (1886). An extract of this is shown in Figure 2-4 (below) together with the approximate location of the site. The text west of Fitzroy Street reads, “Faces 9th July 1886”. From this we know that mining beneath the site occurred after 1886. From records of subsidence events discussed in Section 2.3.2, we know mining in this district was complete ten years later in 1896, though probably earlier.

A fire in December 1903 forced the company to seal and abandon the northern workings (Coulin 1995) and by 1905 all mining had ceased (Department of Mines NSW.1905).

Figure 2-4 Extract from 1886 Royal Commission third report, Plan 5

Up to at least 1890, only the bottom coal was being mined and the nominal mining layout was for 6 yard (~5.5 m) wide bords and 8 yard (~7.3 m) wide pillars. Later, the layout was altered to have both pillars and bords nominally 6 yard (~5.5 m) wide (Kingswell. 1890).

Scaling off RT579, the nominal bord and pillar width beneath the site appears to be 6 yards (~5.5 m). However, this was what was aimed for rather than what was achieved. The actual bords as mined are expected to be slightly wider and the pillars slightly narrower.

Beneath the site, the grid of pillars is interrupted by a fault. East of the fault, the pillars are more or less regular. However, between the fault and the development headings, the pillars are shortened to accommodate, in part, a change in bord orientation made necessary by the fault.

The taking of “tops” occurred in many areas of the mine, including beneath the site. This is incidated on RT579 and M12137 as either shading or “T + B”. With reference to Figure 3 in Appendix A, mining of the tops occurred:

- In every bord west of the site, on the other side of the (main) development headings
- Beneath the site in every second or third bord
- To the north, south and east of the site, as above (on the eastern side of the main headings)

Mining a 6 m thick section of coal by hand would have been very dangerous. However, once the timber supports were removed and the morgan released, the tops are likely to have readily fallen to the floor where they could be loaded from adjacent bords in relative safety.

2.3.2 Known subsidence events

Historical records provide details of trough subsidence events that were observable on the ground surface as they were occurring underground as pillar 'crushes'. In the area of interest around Carrington, subsidence events occurred in 1896 and 1901/02. A summary of these events from historical references is provided below.

The approximate boundaries of these crushes are understood to be shown on a Delta Collieries overview map. This map is not part of the NSW Department of Planning Industry and Environment collection and was not available for our use. SA NSW may possess a digitised version indicating a subsidence event about 60 m to the south of the site and to the west of the development headings which pass down the western edge of the site. This is believed to be part of the 1896 Darvall Street crush described below.

1896

On page 87 of the 1896 annual mine report (Department of Mines NSW,1896) is the following entry: *"W&BI Colliery, In August last an extension fall of roof took place in the dip workings, stopping the mine for 4 weeks. The fall originated and spread over a large area of 6 yard bords and 6 yard pillars workings from which the full section of available coal had been taken. Since the accident the manager has been asked to increase the size of future pillars, and refrain as far as possible from extracting "top band" coal in the bords. To these requests the manager agreed, and is now making all future pillars 8 yards wide and no "top band" coal was being got during the time of last inspection".*

On August 25th 1896, The Sydney Morning Herald reported: *"…the appearance of a "crack" in the main road…", "…to extend from 50 yards from the north end of the Carrington Bridge 193 yards north, the widest part being about half-way, and there about 4½in. in width."* This and the remainder of the article refers to the Wickham not Carrington side of Thorsby Creek.

On September 7th 1896, the Newcastle Morning Herald and Miners' Advocate reported: *"In the 4th right hand ganning bord, up as far as the first fall took place, we found that the last big fall had crushed her very badly just here. It is our opinion that she has crushed down right from the 7th right hand almost back to the 2nd right hand. We may mention that we saw no signs of extra water coming off."*

The following day this same paper reported: *"On Monday morning 24th ultimo* [latest]*, the miners employed on the dip side of the drawing shaft ceased work and left the mine because of an extensive fall of roof which took place the previous day in the abandoned workings of the 4th, 5th and 6th right hand districts."*

The districts are labelled on M12137. The subject site is within the first left hand district and opposite the first right hand district. The second right hand bord is about 70 m south of the site. This area is shown in RT579 to have been mined with tops and bottoms in every bord. It is also crossed by several faults that roughly run parallel with Thorsby Creek.

On the 10th September 1896, The Sydney Morning Herald reported that: "*another fall of roof… alleged crush took place*". This was clearly visible on the eastern approach to the Wickham and Carrington Bridge which connects Denison Street Carrington with Hannell Street, Wickham. *"Ominous cracks on the surface of the eastern approach to the bridge, about 7 in number, appear about 100 yards* [~90 m] *from Denison Street or 30 yards* [~27 *m*] *from the bridge coming south. Some are 2m in width, and some are less. Part of the centre of the approach to the bridge from Denison Street approach appears to have suffered a decadence of an inch or two and a portion of the handrail has given way. Pinching was heard (rumbling noises)".*

This above bridge is the now removed Darvall Street bridge rather than the existing Cowper Street bridge which was a railway bridge at this time. This is shown on Figure 2 in Appendix A although Darvall Street should be about 60 m south of the site rather than along its southern boundary. The below map from 1910 shows this (Barrett, 1910) – see Figure 2-5.

Coulin (1995) describes this as: *"A "crush" in workings of the Wickham Bullock Island Colliery in September 1896, which halted work for many weeks, caused the Darvall Street Bridge to develop a list of several inches in a southerly direction and Darvall Street, west of Denison Street, sank two feet and damaged the water main leading to the island. Twelve months after the "crush" in the colliery's workings, the Wickham Bullock Island Coal Co. forwarded council a cheque for restoration of the depression in Darvall Street."*

Figure 2-5 1910 map showing Thorsby Creek and Darvall Street bridge

Fourteen days later, on the 24th September 1896, the Sydney Morning Herald report: *"an extensive fall of roof which took place the previous day in the abandoned workings of the 4th, 5th and 6th right hand districts. Since then further falls of the roof have taken place in those districts. Despite these districts being overlaid by tidal waters, there is not the least sign of additional water having release by these falls"*

The abovementioned 4th, 5th and 6th right hand districts are well south of the subject site and Darvall Street bridge and underlie Thorsby Creek.

No mention of subsidence or “crushes” in the left hand district or along the main development headings was found in the newspaper articles referenced.

1901 and 1902

Coulin (1995) reports that: *“On 3 October 1901, there was a subsidence in Hargrave Street and a burst water main. Many houses were affected by minor inconveniences but the council chambers suffered serious cracking. Subsidence damage to the chambers, Young and Hargrave Streets. Once again the subsidence had occurred in workings with only six-yard pillars. Subsidence’s occurred again on 9 and 10 February 1902. Broken mains flooded the corner of Young and Hargrave Streets and some houses were damaged. Further settlement caused considerable damage to the council chambers and the nearby tennis court became a total wreck. Council commenced restoring Hargrave Street in August 1903. The extent of the settlement after the subsidence was such that up to 3 feet 9 inches of material was necessary in places to restore the street to its original level.”*

3. Pillar stability and subsidence

3.1 Introduction

Some surrounding areas of the mine workings are known to have failed. That is, the pillars have crushed and surface ground subsidence has resulted as discussed in Section 2.3.2. We do not know if the workings beneath the site and immediate surrounds have failed. As such, for this assessment, we assume that they have not and could therefore do so in the future.

The likelihood of future widespread pillar failure and hence subsidence is dependent on many factors. Of primary relevance are:

- The vertical load (stress) on the pillars from the weight of the overlying soil and rock
- The ability of the overburden rock (in this case about 20 to 30 m thick) to distribute this load amongst the available supporting pillars
- The strength of the supporting pillars, or more correctly: the stress-strain behaviour of the pillars under sustained load

The first two factors are easier to estimate than the third. The strength of a pillar is itself a function of many factors but primarily it is associated with the width of the pillar, its relative height and the strength of the coal forming it. With an estimate of average pillar stress and pillar strength, a factor of safety (FoS) can be calculated. Here, failure is when the pillar begins to deform plastically rather than its peak strength.

A statistical analysis drawing on a database of failed and unfailed pillars has been published by the University of NSW (Galvin *et al* 1998) to derive a likelihood of failure. The procedure is intended for the design of pillars in new mines and is limited to areas of pillars that are not effected by such things as faults and is not recommended for pillars with width to height ratios (w/h) less than 2. Despite these limitations, and largely due to a lack of convenient alternative, the UNSW rectangular pillar formula (Galvin *ibid*) is commonly used.

For workings with irregular layouts and more complex geological conditions such as the subject site, numerical analysis can be used to both assess pillar factor of safety and the consequence (subsidence) of pillar failure. We note that such calculations are not linked to the UNSW correlation of FoS to likelihood of failure and attempts to make such correlations can be misleading. However, by any method, the calculated factor of safety of the pillars is expected to be low when a mining section of ‘tops and bottoms’ is used and the weakening effects of the fault on pillars considered. More sophisticated methods to calculate pillar factor of safety are not considered warranted given the uncertainties of the mine layout.

If the pillars in this area have not already failed they may do so in the future. Calculations can be undertaken to estimate the subsidence (i.e. settlement, strain, tilt) that might result and buildings can be designed to accommodate these effects to a limited degree and at a cost. Alternatively, or in conjunction with designing buildings to accommodate subsidence, the mine workings can be significantly filled with cementitious grout to both increase pillar factor of safety to a degree by providing pillar rib support, but primarily to reduce the magnitude of subsidence to more manageable levels by increasing their post-failure stiffness.

The prediction of subsidence is complex and requires knowledge of the mine workings, the geomechanical behaviour of the overburden soil and rock, and a hypothetic scenario/s to analyse. A highly useful resource are descriptions of past nearby subsidence events as discussed in Section 2.3.2. These accounts can be used to calibrate or ‘reality check’ subsidence calculations. This is discussed further in Section 3.3.

3.2 Pillar stability by UNSW rectangular pillar formula

The criteria required by SA NSW (2018) relies on the UNSW rectangular pillar formula.

Pillar stability calculations for typical 'average' pillars beneath the site have been made and are presented in Table 3-1. These address six cases, all considering pillars 10 yards (9.1 m) and 20 yards (18.2 m) in length to give a range of stresses and factors of safety for each case.

Case 1 represents the likely, worst credible case during mining (Case 1b) and the situation now (Case 1a). Case 2 represents a likely case where only bottoms of coal were taken (i.e. mining height 1.8 m). Case 3 reflects SA NSW requirements with respect to B1 and B2 building categories. That is:

- For B1 buildings: pillar height is full seam thickness and workings are dewatered
- For B2 buildings: as for B1 but also the pillar width is reduced by 0.5 m

For flooded workings, an effective stress at the top of the coal seam of 0.84 MPa has been used. For dewatered workings an effective stress of 1.5 MPa is used. This is based on 45 m of soil at 2 t/m^3 and 24 m of rock at 2.5 t/m^3. Acceleration due to gravity of g = 10 m/s^2 is used for consistency with the UNSW methodology.

Table 3-1 Summary of UNSW pillar stability calculations

Case	Pillar width (m)	Pillar height (m)	Pillar width to height ratio	Bord width (m)	Average pillar stress (MPa)	Factor of Safety (FoS)
Case 1a • tops and bottoms • flooded	5.5	6.0	0.9	5.5	2.7 to 2.2	1.7 to 2.1
Case 1b • tops and bottoms • dewatered					4.8 to 3.9	0.95 to 1.2
Case 2a • bottoms only • flooded	5.5	1.8	3.1	5.5	2.7 to 2.2	12.5 to 12.6
Case 2b • bottoms only • dewatered					4.8 to 3.9	2.6 to 3.2
Case 3a – for B1 • full seam height • dewatered	5.5	6.0	0.9	5.5	4.8 to 3.9	0.95 to 1.2
Case 3b – for B2 • full seam height • dewatered • reduced pillar width	5.0		0.8		5.3 to 4.3	0.82 to 1.0

As discussed in Section 3.1, the UNSW pillar design methodology (Galvin *ibid*) provides a correlation of factor of safety to likelihood of failure based on statistical analysis of a database of failed and unfailed pillars. This is shown in the below table. Caution is needed in using this as it is questionable that the types of pillars that have been assessed (being slender and fault effected) are within the empirical database used to derive this correlation.

Table 3-2 Factor of safety to likelihood of failure correlation (Galvin *ibid*)

Likelihood of Failure	Factor of Safety
8 in 10	0.87
5 in 10	1.00
1 in 10	1.22
5 in 100	1.30
2 in 100	1.38
1 in 100	1.44
1 in 1000	1.63
1 in 10000	1.79
1 in 100000	1.95
1 in 1000000	2.11

3.3 Surface subsidence

3.3.1 Background on systematic assessment of tilt, curvature and strain

Tilt

Tilt is the first derivative of the vertical subsidence profile, or the rate of change of vertical subsidence. It is calculated as the change in vertical subsidence between two points divided by the horizontal distance between those two points. The base length is typically the standard mine survey peg spacing of 1/20th the depth of mining.

Tilt should primarily be considered in the context of surface infrastructure serviceability. For example, providing generous falls for roof gutters and wet area floors.

Curvature

Curvature is the second derivative of subsidence, or the rate of change of tilt. It is calculated as the change in tilt between two adjacent sections (bays) of the tilt profile divided by the average length of those sections. The radius of curvature (R) is expressed as follows.

$$R = \frac{\text{sum of the lengths of successive bays}}{2\ x \text{ differential tilt between them}}$$

Building length (L) should take differential deflection (Δ) into consideration through review of the design radius of curvature (R). The following from Burland and Wroth (1974) provides the mathematical relationship:

$$\Delta = \frac{L^2}{8R}$$

For example, a 10 km radius of curvature and 50 m long building results in differential deflection of 31 mm.

Consideration of curvature is also relevant in the context of ensuring adequate fall (post subsidence) for drainage elements such as stormwater drains and gravity sewers.

Strain

Strain is the first derivative of horizontal movement, or the rate of change of horizontal movement. It is calculated as the change in horizontal length of a section of the subsidence profile divided by the initial horizontal length of that section.

$$Strain = \frac{\text{new horizontal distance} - \text{original horizontal distance}}{\text{original horizontal distance between the pegs}}$$

By convention, tensile strains are positive and compressive strains negative.

3.3.2 Estimated subsidence

Descriptions of nearby subsidence events in Section 2.3.2 indicate up to about 2 feet (~0.6 m) of subsidence occurred at Darvall Street, south west of the site where tops and bottoms were taken in every bord. About 930 m north at Hargreave Street, 3 feet 9 inches (~1.1 m) of subsidence was reported to occur in 1901/1902. This area is shown on RT579 and is also where tops and bottoms were taken in every bord.

Geotechnical assessments by Coffey Geotechnics at Cottage Creek in 2009 (referenced in Coffey, 2019) about 650 m to the south, concluded that mine roof convergences of between 0.1 m and 1.65 m had occurred. These ‘crushes’ would have translated to surface subsidence to some lesser magnitude as a function of the overburden characteristics.

At the subject site, there is about 20 to 30 m of rock overlying the mine workings and above this alluvial clays and sands. This is likely to be similar to conditions at Darvall Street. However, the mine record tracing shows tops and bottoms were only taken in every second or third bord beneath the site, reducing the amount of coal extracted and hence subsidence. However, many of the pillars beneath the site are shorter, having the opposite effect. Additionally, the fault passing beneath the site may locally increase roof convergence although the effects wouldn’t be reflected on the ground surface due to the ‘smoothing’ effect of the overlying soils - in particular, the thick clay unit in the base of the alluvial sequence.

The behaviour of the soil in response to mine roof convergence would dictate the profile of the surface subsidence. That is, the ground strains and curvature of the trough. This profile shape can be estimated using soil mechanics theory employed in estimating surface subsidence profiles resulting from volume loss in tunnels.

The subsidence profile shown in Figure 3-2 has been developed by assuming the overburden rock has no ‘smoothing’ effect and that a stepped roof convergence “Δ” occurs. This is a conservative but valid assumption given the presence of the fault. The effects of this stepped convergence is translated through the overlying soils based on soil mechanics theory as per the method of Mair *et al* (1993). Here, the value Δ is adjusted to result in a maximum surface subsidence S_{max} of a nominal 0.6 m (about 2 feet), to reasonably match historical records.

The assumed subsidence profile is two-dimensional. That is, the convergence Δ is assumed to have infinite length (into and out of the page).

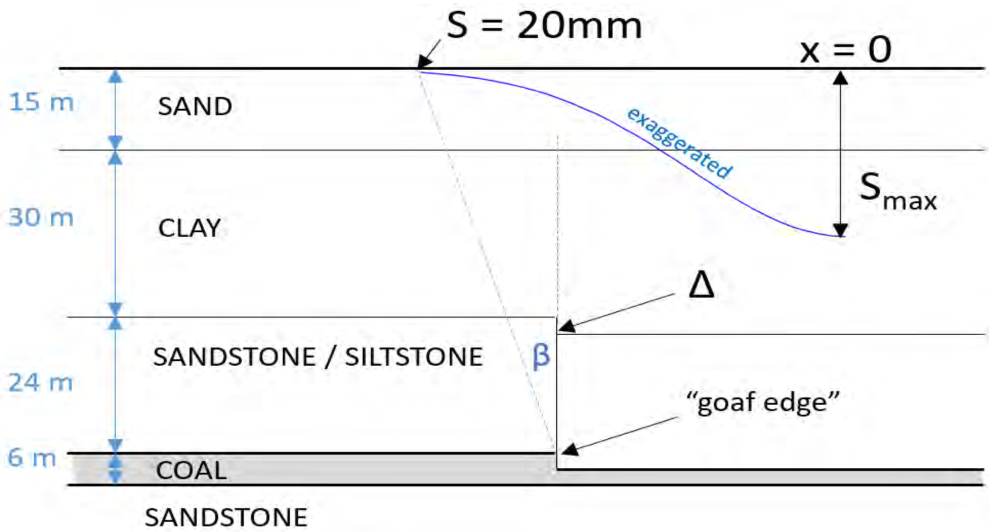

Figure 3-1 Modelled subsidence case

The above modelled scenario represents a 'worst credible case' event where full convergence occurs on one side of a 'goaf edge' or fault vertical plane but not on the other side. In reality, it is likely that some crushing of pillars on both sides of this plane would occur due to abutment loading conditions. This would have the effect of spreading the subsidence trough over a slightly larger area and hence reducing the maximum strains, tilts and curvatures.

A key input parameter for the subsidence profile calculation in Mair *et al* (1993) is the parameter 'K' which changes the maximum extent of the trough and so affects strain, tilt and curvature. The larger the K value, the wider the trough and hence lesser the strain, tilt and curvatures.

While the concept is the same as 'angle of draw' (β) in mine subsidence with a subsidence limit of 20 mm adopted, the behaviour of soil is different to the rock that the commonly adopted 26.5° (1H:2V) angle of draw is based upon. K is based on soil mechanics and is a function of soil type and depth (derived originally through semi-empirical methods). K values for clays are typically between 0.4 and 0.7 and for sand about 0.3.

For this analysis we have used:

- K of 0.3 for sand and 0.6 for clay, weighted average of 0.5.
- Δ of 1.26 m to result in an S_{max} of 0.6 m.

The resulting profile and associated strains, curvature and tilts are shown below.

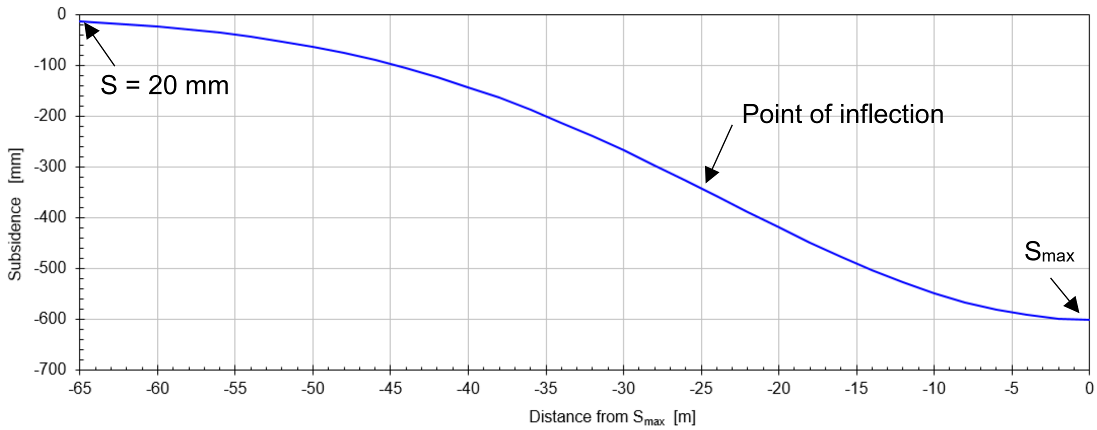

Figure 3-2 Resultant surface subsidence profile

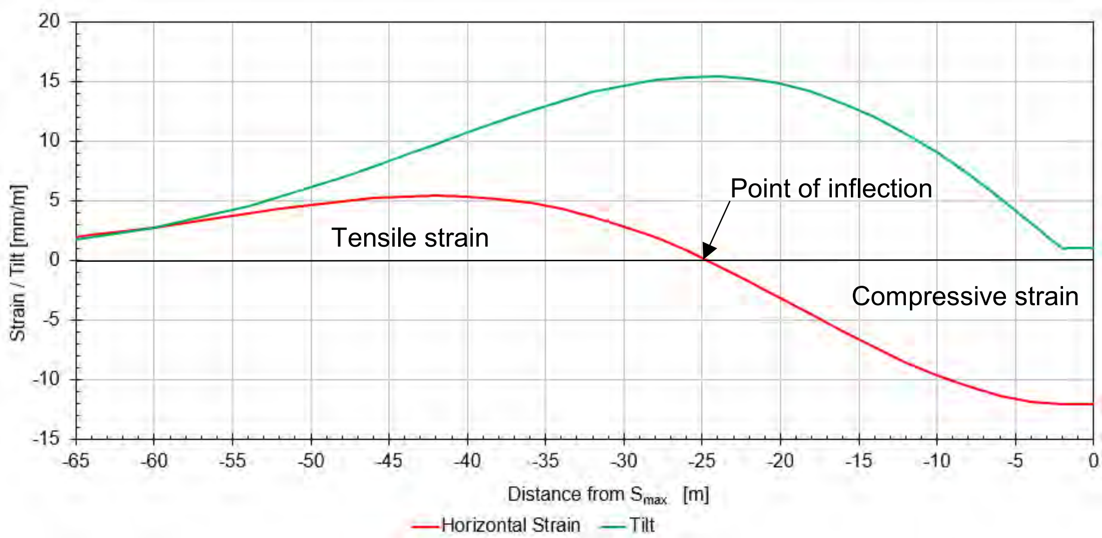

Figure 3-3 Resultant strain and tilt profile

S_{max} is defined at x = 0 m in the above figures. The point of inflection is at x = - 25 m and is where horizontal strain is zero and tilt is maximum. The limit of subsidence is at x = - 65 m where S = 20 mm.

The maximum subsidence parameters from the above analysis are:

- Maximum subsidence S_{max} : 's' adjusted to result in a nominal 0.6 m
- Maximum tensile strain E+ = 5.4 mm/m (over a 10 m bay length)
- Maximum compressive strain E- = 12.1 mm/m (over a 10 m bay length)
- Maximum tilt T = 15.4 mm/m (over a 10 m bay length)
- Minimum radius of curvature = 0.1 km

4. SA NSW Policy and development options

4.1 Introduction

Development options being considered include on-ground car parking and light industrial or commercial buildings between one and three storeys as follows:

Option 1	Two buildings: one of 3 storeys and the other 2 storeys with on-ground parking
Option 2	Two buildings: one of 3 storeys and the other 2 storeys with undercroft and on-ground parking
Option 3	Two buildings: both 2 storeys with on-ground parking
Option 4	Three buildings: all 2 storeys with on-ground parking

For non-residential development such as this, SA NSW assessment will be based on their Development Application – Merit Assessment Policy (SA NSW. 2018). We understand this document is currently under review by SA NSW.

4.2 SA NSW Merit Assessment Policy

The Merit Assessment Policy classifies proposed building developments into three categories, shown in the below table. The four proposed development options are expected to fall within either the B1 or B2 categories, provided the construction cost is less than five million.

Table 4-1 SA NSW Building Categories

SA NSW category	General Classification of Building type
B1	• up to and including 3 storeys (including rooftop access) • < 50 m maximum plan footprint dimension • no basement • no load bearing masonry construction • up to and equal to $3 M construction cost
B2	• up to and including 4 storeys (including basements and rooftop access); or • Between $3 M to $5 M construction cost; or • > 50 m in maximum plan footprint dimension
B3	• greater than 4 storeys (including basements and rooftop access); or • > 100 m maximum plan footprint dimension • Greater than $5 M construction cost; or • Use - Hospital Wards, Operating theatres, critical public infrastructure, Public Buildings with high trafficability (i.e. school halls etc.)

The SA NSW assessment requirements for each building category are then a function of the perceived level of geotechnical uncertainty as either low, medium or high, based on the level of confidence and understanding of the following weighted factors.

- Geological environment (R1) - weighting 2
- Level of geotechnical investigation (R2) - weighting 2
- Type of coal mine plans and records (R3) - weighting 3
- Method used to assess stability and impact (R4) - weighting 3

An uncertainty factor (UF) is then calculated by summing the products of R weightings and their uncertainty value (U) and finally subtracting 10 as follows:

Uncertainty Factor (UF) = (R1 x U + R2 x U + R3 x U x R4 x U) – 10

Where:

- Low uncertainty, U = 1
- Moderate uncertainty, U = 2
- High uncertainty, U = 3

Table C2 of the policy provides the reference descriptions for uncertainty categories.

For the subject site, our assessment of the SA NSW uncertainty factor (UF) is 17 as shown in the table below.

Table 4-2 SA NSW Uncertainty Factor calculation

Factor	Weighting	Uncertainty	Product	Comment
R1	2	3	6	Fault present
R2	2	3	6	No boreholes within 50 m
R3	3	3	9	Hand working, irregular
R4	3	2	6	Conservative UNSW inputs
		uncertainty factor (UF)	**17**	Product sum less 10

An uncertainty factor greater than 10 is “High Uncertainty”. From 6 to 10 is Moderate Uncertainty.

Table C3 of the Merit Assessment Policy sets out SA NSW’s “Estimated Conditions of Approval for Trough Subsidence Risk”. Different conditions are given depending on whether the assessed pillar (panel) factor of safety (FoS) and pillar width to height ratio is less than or greater than nominated criteria. For High Uncertainty cases such as this, the nominated criteria are:

- Pillar FoS 2.1 for B1 and B2 buildings
- Pillar width to height ratio 4 for B1, and 5 for B2 buildings.

On both of these criteria, the subject site exceeds the criteria and as such the more onerous approval conditions apply as set out in Table C3 of the Merit Assessment Policy.

For B3 buildings, High Uncertainty is not acceptable. If the uncertainty factor (UF) could be reduced to 6 to 10 (i.e. Moderate Uncertainty) through geotechnical investigation, the nominated criteria for B3 buildings would be:

- Pillar FoS 2.1 for B3 buildings (if uncertainty reduced to moderate)
- Pillar width to height ratio 4 for B3 buildings (if uncertainty reduced to moderate.)

Again, the more onerous approval conditions apply.

5. Summary and conclusions

5.1 Summary

From our current understanding, mine convergence (crush) and trough subsidence has not occurred beneath the site and thus could do so in the future. The pillar factor of safety is not sufficiently high or certain to conclude that the risk associated with pillar failure is tolerable for either B1, B2 or B3 building categories.

In the absence of data (new historical information and / or borehole drilling at the site) indicating the mine workings have fully crushed, the SA NSW Merit Assessment Policy requires that buildings be designed to accommodate design subsidence parameters.

An estimate of subsidence effects (strain, tilt and curvature) resulting from a nominal surface subsidence (S_{max}) of 0.6 m based on historic subsidence in the area, resulted in the following:

- Maximum tensile strain E+ = 5.4 mm/m
- Maximum compressive strain E- = 12.1 mm/m
- Maximum tilt T = 15.4 mm/m
- Minimum radius of curvature = 0.1 km

These exceed the SA NSW values for both B1 and B2 building categories set out in Table C3 of the Merit Assessment Policy, triggering the additional “structurally safe to occupants” design requirements.

The anticipated SA NSW design requirements are summarised in Table 5-1. Reference must also be made to Table C3 of the Merit Assessment Policy for additional approval requirements.

Table 5-1 SA NSW subsidence design parameters

SA NSW Policy requirements Table C3	Relevant design parameters	
	Category B1	Category B2
Structure must be designed to be “safe, serviceable and any damage from mine subsidence shall be limited to ‘slight’ in accordance with AS2870 (Damage Classification), and readily repairable”.	• ± 3 mm/m strain • 4 mm/m tilt • 5 km radius of curvature	• ± 5 mm/m strain • 7 mm/m tilt • 2 km radius of curvature
AND		
Structure must both satisfy the above and in addition remain structurally safe to occupants taking into account additional estimated subsidence impact.	• + 5.4 mm/m horizontal strain (tensile) • - 12.1 mm/m horizontal strain (compressive) • 15.4 mm/m tilt • 0.1 km radius of curvature	
Reference must also be made to Table C3 “Estimated Conditions of Approval for Trough Subsidence Risk” of the Merit Assessment Policy for additional approval requirements.		

For Category B3, High Uncertainty is not acceptable. Geotechnical investigation would be required. If investigation resulted in a reduction to Moderate Uncertainty, the relevant requirements as per Table C3 of the Merit Assessment Policy would be:

> *“Structure must be designed to be "safe, serviceable and readily repairable" under the predicted subsidence impact parameters”.* AND
>
> *“If estimated subsidence impact greater than specified, subsidence impact must be either eliminated or mitigated by a suitable means such as the emplacement of grout into the mine workings, or another suitable engineered mitigation measure put forward for SA NSW acceptance.”*

We interpret the above to mean that if Category B3 buildings can not be designed to be *"safe, serviceable and readily repairable"* for the predicted subsidence, some other means of mitigation (such as grouting) would be needed.

If new information was sourced, demonstrating that the mine workings beneath the site have fully crushed, SA NSW may still require design for some lesser subsidence parameters to address the possibility of residual subsidence.

5.2 Conclusions

There are potential structural solutions available for B1 and B2 building categories. The viability of these solutions are dependent on the types of structures and their sizes and should be assessed by a qualified Structural Engineer with experience in design of similar buildings to meet mine subsidence requirements.

Geotechnical investigation may find that the mine workings have already collapsed. In that case, reduced subsidence design parameters are likely to be justifiable. However, we think it is unlikely that the workings here have collapsed on the information currently in hand. Additionally, the number of boreholes required to demonstrate that full collapse has occurred is, pragmatically, unknown and almost certainly more than two.

Grouting of the mine workings could be undertaken to reduce the subsidence design parameters for B1 and B2 building categories and thereby reduce the building constraints and structural costs associated with design for subsidence.

For the B3 building category, geotechnical investigation is required. If this investigation found that the mine workings have already fully collapsed, the buildings would need to be designed to accommodate nominal residual subsidence parameters. If the workings have not collapsed, grouting would be required as well as design for some nominal residual subsidence parameters.

6. Limitations

This report has been prepared by GHD for Port of Newcastle and may only be used and relied on by Port of Newcastle for the purpose agreed between GHD and Port of Newcastle as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any person other than Port of Newcastle arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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

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

Specifically, this Report does not take into account the effects, implications and consequences of or responses to COVID-19, which is a highly dynamic situation and rapidly changing. These effects, implications, consequences of and responses to COVID-19 may have a material effect on the opinions, conclusions, recommendations, assumptions, qualifications and limitations in this Report, and the entire Report must be re-examined and revisited in light of COVID-19. Where this Report is relied on or used without obtaining this further advice from GHD, to the maximum extent permitted by law, GHD disclaims all liability and responsibility to any person in connection with, arising from or in respect of this Report whether such liability arises in contract, tort (including negligence) or under statute.

Any excerpts of original mine survey plans or record tracings and any data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitation) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning is not responsible or liable to any person for any loss or liability arising out of or in connection with use of any such excerpts or derived data.

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Appendices

Appendix A – Figures

Paper Size ISO A4

0 0.0085 0.017 0.0255 0.034

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Port of Newcastle Operations Pty Ltd
PoN - 46 Fitzroy St Carrington
Mine Subsidence Assessment

Project No.	**12527619**
Revision No.	**A**
Date	**05/05/2020**

Location plan

FIGURE 1

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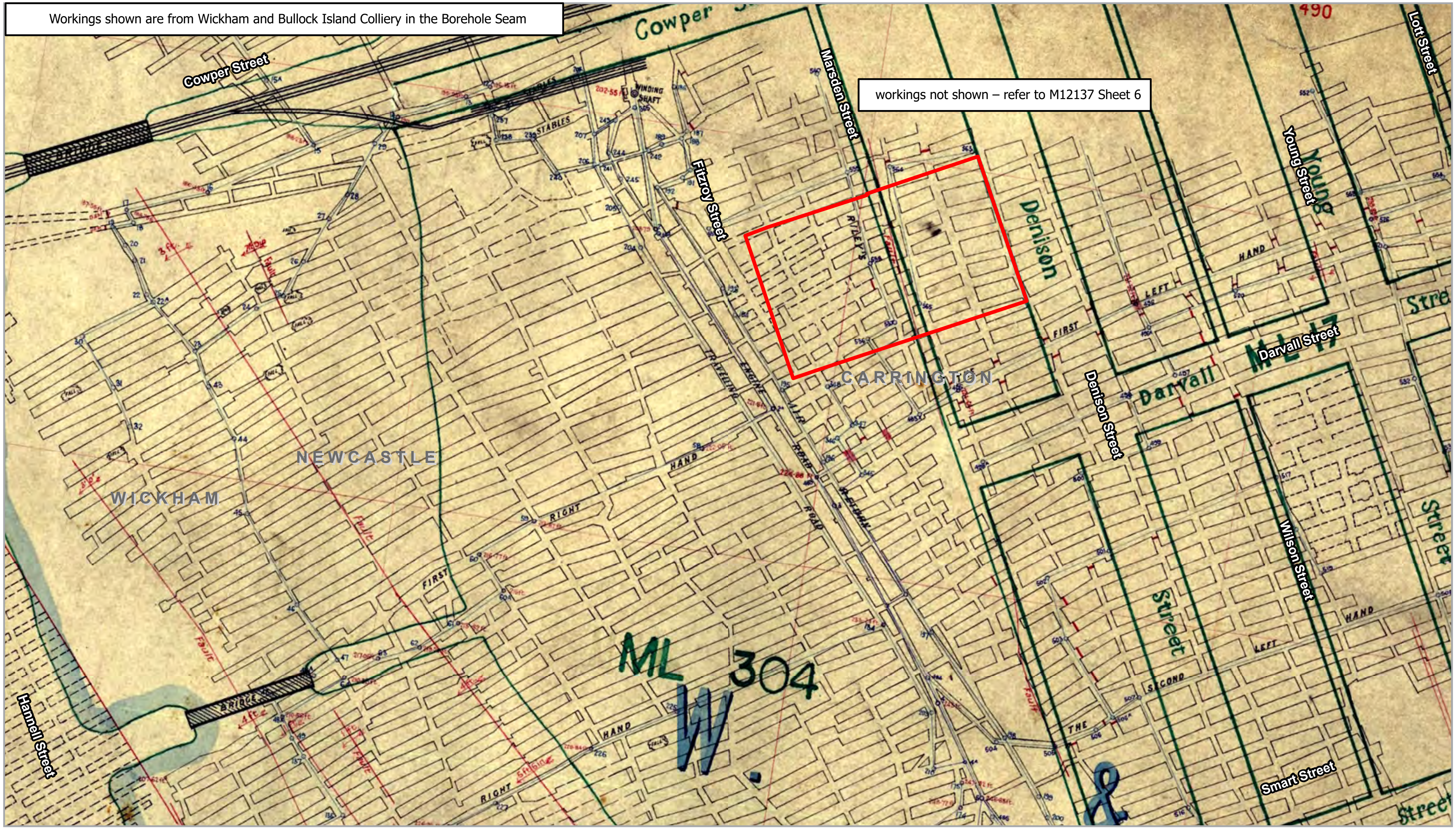

Legend

Site Boundary

Disclaimer

Any excerpts of original mine survey plans or record tracings and any data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitation) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning is not responsible or liable to any person for any loss or liability arising out of or in connection with use of any such excerpts or derived data.

Paper Size ISO A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Port of Newcastle Operations Pty Ltd
PoN - 46 Fitzroy St Carrington
Mine Subsidence Assessment

M12137 Sheet 4 Delta Colliery plan extract

Project No. **12527619**
Revision No. **A**
Date **05/05/2020**

FIGURE 2

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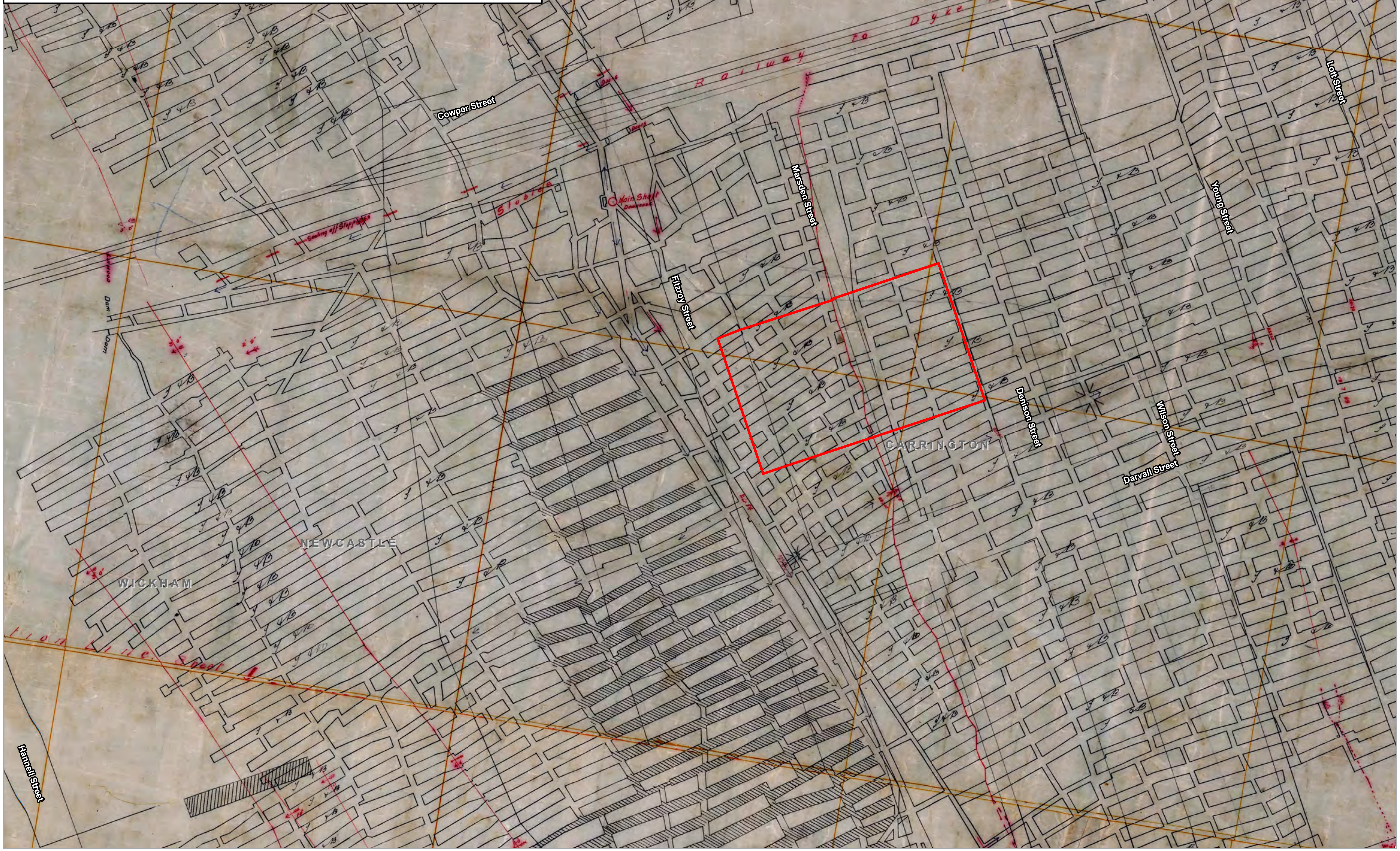
Print date: 08 May 2020 - 16:04

Data source: LPI: DCDB/DTDB, 2017. De Witt Consulting: M12137.R13121370.Plan of workings - sheet 4 (pt 1) of 13. 2chinch.jpg.. Created by: kschroder-turner

Workings shown are from Wickham and Bullock Island Colliery in the Borehole Seam



Legend

Site Boundary

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Paper Size ISO A3

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Port of Newcastle Operations Pty Ltd
PoN - 46 Fitzroy St Carrington
Mine Subsidence Assessment

Record Tracing RT579 extract

Project No. **12527619**
Revision No. **A**
Date **08/05/2020**

FIGURE 3

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Print date: 08 May 2020 - 16:03

Data source: LPI: DCDB/DTDB, 2017. De Witt Consulting: RT0579.R10000566.Plan of workings- sheet 1 (pt 1) of 4. 1ch1inch.jpg/RT0579.R10000566.Plan of workings- sheet 2 (pt 1) of 4. 1ch1inch.jpg.. Created by: kschroder-turner

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	S.Mackenzie	A.Leventhal	on file	S.Mackenzie	Sam Mackenzie	21/05/20

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Appendix H – Correspondence with Subsidence Advisory NSW

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Tel 02 4908 4300 | www.subsidenceadvisory.nsw.gov.au
24 Hour Emergency Service: Free Call 1800 248 083
ABN 81 913 830 179

MEETING MINUTES – EBA20-00035
46 Fitzroy Street, Carrington
4 May 2020

Time: 10:00 AM – 11:00 AM
Venue: Via Zoom
Attendees: Shane McDonald SANSW Risk Engineer (**SM**), Kieran Black SANSW Technical Manager (**KB**), Sam Mackenzie GHD (**SMa**), Greg Williams (**GW**) Monteath & Powys, David Morris (**DM**) Port of Newcastle, Andrew Phillips Monteath & Powys (**AP**), Andrew Stone (**AS**) Port of Newcastle
Minutes: Jo Delarue SANSW Admin Officer (**JD**)

NO	DISCUSSION/ACTION	OWNER
1.0	**INTRODUCTION** Introductions via Zoom	
2.0	**DISCUSSION**	
	SMa advised that he hasn't undertaken any pillar calculations or numerical modelling for this site, he is in the process of completing a desktop study. They are currently exploring feasibility of investigation before they can progress. No creeps to their knowledge for this area, however he is looking into royal commission information.	SMa
	SA NSW indicated that there could be a crush event mapped to the South of the site – will look into the records and get back to SMa as it could be approx. 60m away.	SM
	Amended architectural plans were raised on the screen and GW provided a summary of the proposal to the group.	GW
	Changes they have proposed with design include; no basement carparking, reduced to 3 storeys for Building A and 2 storeys for Building B. Want to get SA NSW's thoughts on this design and what conditions may be imposed?	GW
	SA NSW indicated that conditions would depend on whether the buildings would fall within a B2 or B3 category, KB shared the SA NSW Merit Policy on the screen and provided an explanation of Table C1.	KB
	GW considers the buildings to fall within the requirements for a B2 structure, however they are awaiting the costs from the quantity surveyor. He clarified the length in relation to the 50m footprint and SA NSW responded that a B2 would include up to a 100m footprint.	GW & SM
	SA NSW added that cost was a factor in determining whether the buildings fall within B2 or B3, and that the development would be assessed as a whole if both buildings are lodged as the one application which includes the combined cost.	KB
	GW indicated that they could lodged them as 2 separate applications with SA NSW so that they comply with a B2 requirement. SMa asked if the cost factor was flexible relating to the building	GW & SMa

NO	DISCUSSION/ACTION	OWNER
	categorisation.	
	SA NSW responded that decisions would be the driven by the policy so it cost wouldn't be flexible.	KB
	Discussion between GW, SMa & SA NSW regarding requirements for possible investigation for the site, questions were raised regarding the likelihood of SA NSW asking for drilling on the site.	GW, SMa & KB
	SA NSW indicated they need to review the Desktop Study as a first step to understand the subsidence risk. Once the application is submitted with the desktop study SA NSW can provide comment.	KB
	SMa & AS indicated that they are looking to gain a better understanding of what SA NSW would require regarding further investigation so they can make a reasonably informed decision as to what could be developed for this site.	SMa & AS
	SA NSW shared the Merit Assessment Policy on screen to provide an indication of conditions that may be applicable for the proposal. Based on the uncertainty factor there are different requirements. As the calculations haven't been completed for the site the parameters are not clear at this stage. The best thing at this stage is to undertake the desktop assessment and then run it through the merit policy/submit to SA NSW with the plans for assessment.	KB
	Brief discussion between SMa, GW and KB regarding requirements of possible drilling investigation and if historical data/documents for the site would be relevant.	SMa, GW & KB
	SANSW indicated that the first step needs to be the desktop study, prior to that we can't provide details on what conditions or further investigations may be required.	KB
	GW indicated that the desktop won't be ready for some specific dates the project needs to meet regarding proposed options for the development.	GW
	SA NSW indicated that if the site was grouted and the risk was removed there won't be any restrictions on what can be built.	KB
	GW replied that grouting wouldn't be a financially viable option, so they want to design something that will be allowable on the site as it is. In summary, SMc needs to provide the desktop study. We will be proposing either a B1 or B2 building for this site and we will have a QS report to cover the costings.	GW
	SA NSW added that the policy indicates that the building has to be 'safe' (under B2) in relation to the estimated worst case parameters where they exceed nominal parameters as defined in the policy.	SM
	AS queried if they can avoid submitting the buildings separately relating to the combined cost for the categorisation (B2/B3)?	AS
	SA NSW responded that we have to go by the policy, so no if they are submitted together they would be assessed as a whole development including the cost.	KB
3.0	**CONCLUSION** SA NSW suggested the desktop study is finalised, then lodged as a formal enquiry or application so a response can be provided.	KB

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	S Mackenzie	A Leventhal	**A Leventhal*	S Mackenzie	Sam Mackenzie	29/04/2021

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