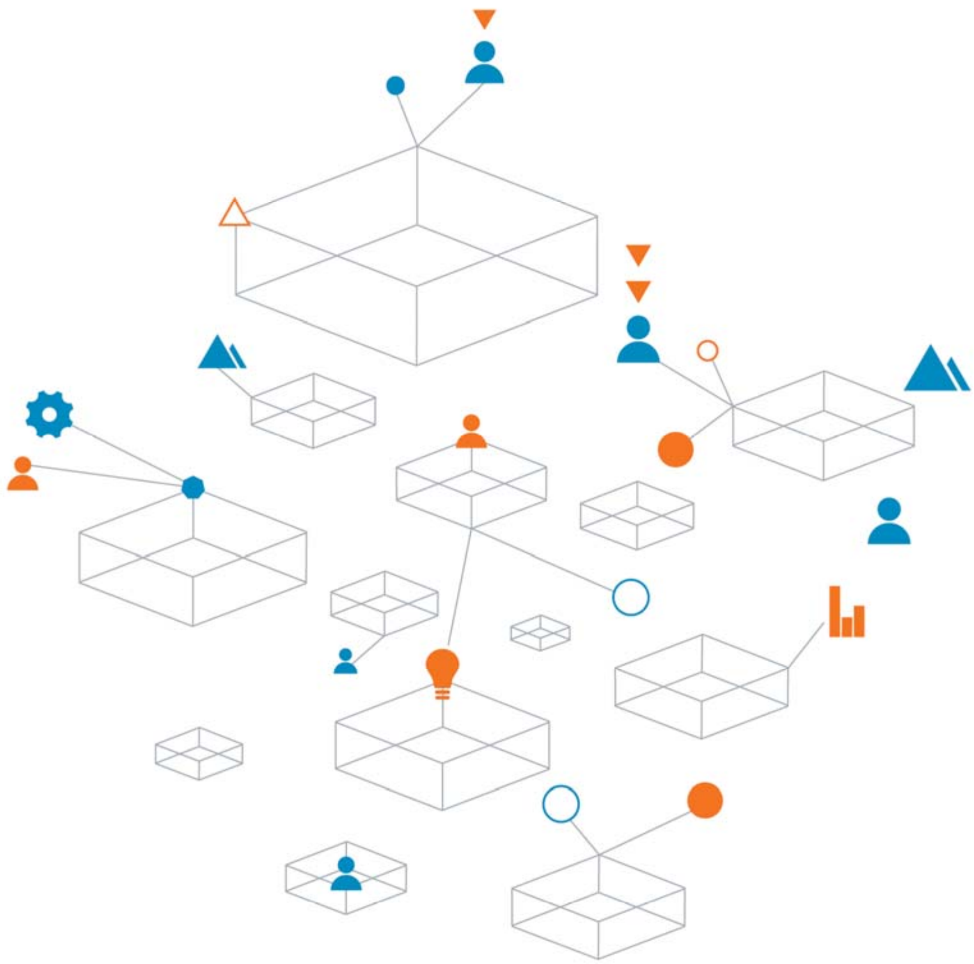
Sydney Harbour Foreshore Authority

Cockle Bay Marine Structures

Geotechnical and Geophysical Report

27 March 2015



Trust is the
cornerstone
of all our
projects

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Cockle Bay Marine Structures

Prepared for
Sydney Harbour Foreshore Authority
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27 March 2015

Document authorisation

Our ref: GEOTLCOV25293AA-AD

For and on behalf of Coffey

Russell Copeman
Geotechnical Engineer

Quality information

Revision history

Revision	Description	Date	Author	Reviewer	Signatory
v1		6/03/2015	RC	PKW	RC

Distribution

Report Status	No. of copies	Format	Distributed to	Date
v1	2	PDF	Katy Johnson and Glenda Munro	6/03/2015

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1. Introduction

Sydney Harbour Foreshore Authority (the Authority) has a vision “to make unique places in Sydney that the world talks about”. To further this vision the Authority will be upgrading the existing wharf structures within Cockle Bay that are nearing the end of their useful life. The upgrade project is called the Cockle Bay Marine Structures project and involves staged demolition of the existing wharf and jetty structures and construction of new low lying floating pontoons. The pontoons will connect to the existing reinforced concrete deck with ramps at several locations around the bay and will be tied to piles at regular intervals for lateral restraint. Concept drawings showing locations of the proposed structures have been provided to us by Mott Macdonald and are outlined on Figures 4 and 5.

Coffey has been engaged by the Authority under contract no. 101100489 to provide a geophysical investigation and geotechnical report to support the design development and tender documentation for the marine structures upgrade. We have carried out the works in general accordance with the alternative scope in our tender (Ref GEOTLCOV25293AA-AA, dated 20 January 2015) and Variation Direction 1 for three additional geophysical lines.

The objective of the desk study was to collate existing geotechnical information in the area to provide a geotechnical model including the requested parameters for pile design. The objective of the geophysical investigation was to supplement the existing geotechnical information by mapping top of rock levels near the proposed marine structure locations. .

2. Method

2.1. Desk study

To make use of existing geotechnical information we carried out a desk study of information held in our archives. We used borehole data from the references listed in Table 1 to assess the geological/ geotechnical conditions at the proposed maritime structure locations. This includes site investigations carried out by us as well as information gathered by others for previous projects.

Table 1: Previous investigations used in preparation of this report

Ref No.	Description of Previous Project
R1	Department of Main Roads, “North Western Expressway Project”, 1971
R2	Coffey & Partners Pty Ltd, “ Darling Harbour Development Maritime Structures Geotechnical Investigation Zones 1 to 6” May 1985 (S7559/1-AE)*****
R3	Coffey & Partners Pty Ltd, “ Darling Harbour Development Project Convention Centre – Geotechnical Investigation” June 1985 (S7559/3-AD)
R4	Arup Geotechnics, “ Darling Harbour Development Western Boulevard – Site Investigation Report”, December 1985
R5	Coffey & Partners Pty Ltd, “ Darling Harbour Light Monorail Geotechnical Investigation”, May 1986 (S7769/1-AG)
R6	Coffey Geosciences Pty Ltd, “Proposed Convention and Exhibition Centre”, May 2003
R7	Coffey Geotechnics Pty Ltd, “Proposed Sydney International Convention, Exhibition and Entertainment Precinct (SICEEP)”, 25 May 2013 (GEOTLCOV24303AC-AD)

R8	Coffey Geotechnics Pty Ltd, "Geotechnical Investigation Report for SSDA6, Sydney International Exhibition and Entertainment Precinct - ICC Hotel", 26 August 2013 (GEOTLCOV24303AH-AH Rev 1)
R9	Coffey Geosciences Pty Ltd, "Matilda Cruises Redevelopment, Pier 26, Darling Harbour", 31 January 2000, (S20330/1-AH)

2.2. Geophysical investigation

To supplement the archived geotechnical information we carried out a geophysical investigation.

2.2.1. Fieldwork operations and OH&S

Geophysical fieldwork was conducted from 24 to 27 February, and applied static Underwater Seismic Refraction (sUSR).

The sUSR operation involved the deployment of a seismic array with 2 or 5 metre detector intervals on the seabed and used a 20 cu in. Bolt® Air Gun energy source to create seismic energy on the seabed at various positions along the bottom-placed hydrophone array. The seismic source was fired at nominal 8 to 10 metre intervals within the seismic array and additional offset shots, where possible, either side of the array. At some locations a small vessel was used to place the seismic array and seismic energy source.

The sUSR data was recorded with two 24 Channel GEODE digital seismographs.

The start and end of the sUSR line locations were positioned by our field geophysicist using a differential GPS. The position data was collected using a Navcom GPS which has a reported manufacturer's accuracy of better than ± 50 cm horizontal position accuracy for eastings and northings.

Table 2 provides the start and end coordinates of each sUSR line.

Table 2: sUSR line co-ordinates

Static sUSR Line	Start (m)		End (m)	
	Easting	Northing	Easting	Northing
sUSR 1	333684	6250554	333709	6250697
sUSR 2	333438	6250695	333441	6250750
sUSR 3	333470	6250586	333475	6250671
sUSR 4	333514	6250504	333477	6250569

Datum and Map grid system: GDA94 / MGA Zone 56

Figure 1 shows the site plan with the location of the static Underwater Seismic Refraction (sUSR) lines.

During the fieldwork relative levels of the seafloor were measured by lowering a tape measure from the water surface along each sUSR section to create a topographic profile of the seafloor for use in data post-processing. Tide variation was measured during the survey and the appropriate corrections were applied to the depth measurements during data processing to reduce all levels to mAHD.

The geophysical fieldwork was completed in accordance with industry practice and Coffey's Quality System (ISO 9001 accredited). Field operations were supported by approved Environmental and Safe Work Method Statements and Operational Health and Safety Plans.

All reasonable measures were taken to ensure the acquisition of good quality data that were adequate for analysis. In general, these measures included:

- Daily monitories and assessment of weather forecasts;
- Adherence to QA procedures and QC checks on all acquired geophysical data; and
- Completion of daily toolbox meetings.

No reportable Health, Safety, Security & Environment (HSSE) incidents occurred during the geophysical fieldwork.

2.2.2. Data processing and analysis

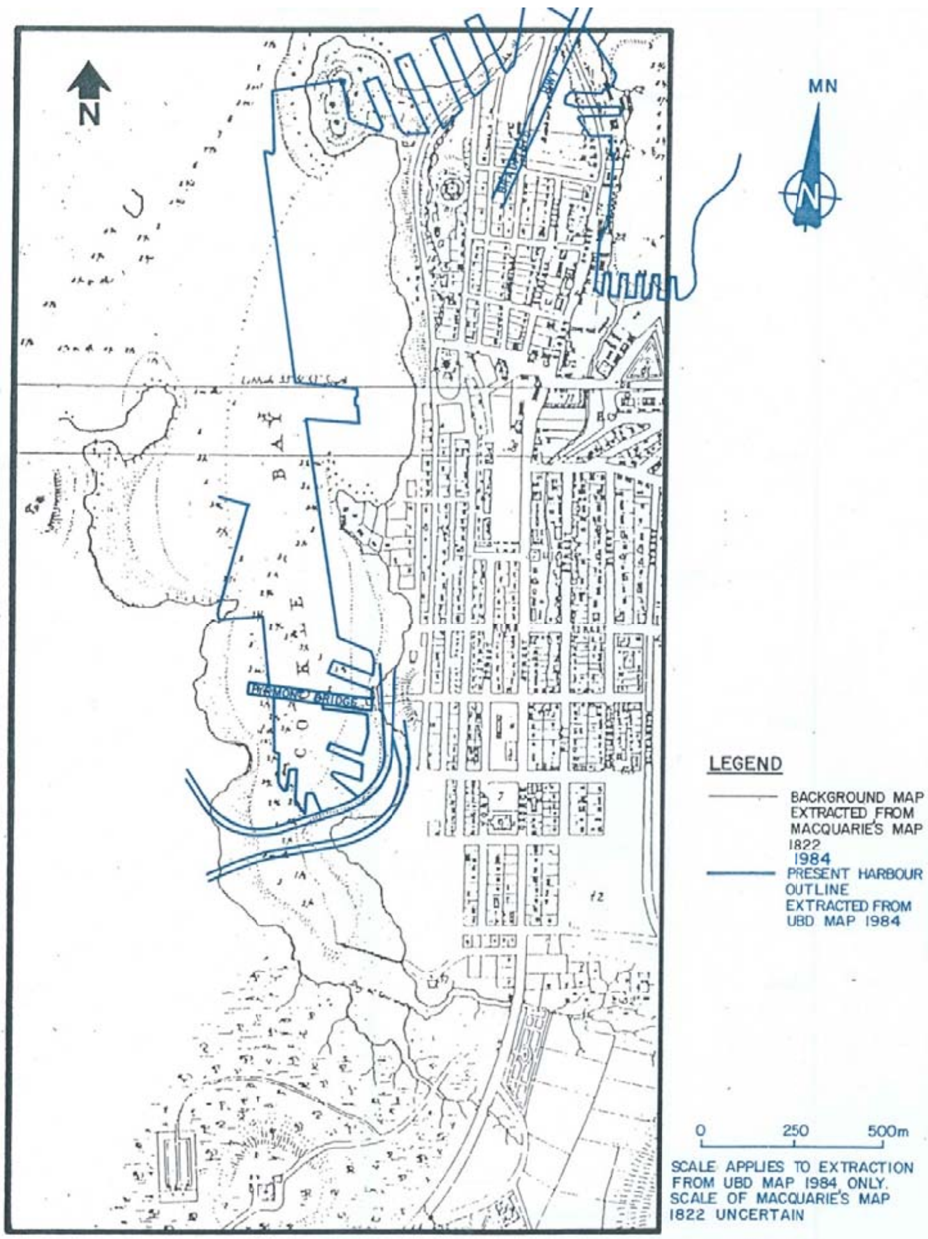
The following procedures were used to process and analyse the sUSR data and are in accordance with accepted practice:

- The digital refraction data was examined and first arrivals were picked and timed using IXSeg2SegY software or the first break picking module in RAYFRACT© (ver. 3.23) software. Only clearly observed first arrivals were timed;
- The seismic refraction data was inverted using wavefront eikonal tomography with a smoothed initial model and RAYFRACT© software; and
- Interpreted seismic velocities and measured elevations were used to create seismic sections.

3. Results

3.1. Geological setting

The proposed marine structures are located within Cockle Bay at the south end of darling harbour, to the west of the Sydney CBD. Drawing 1 shows the1984 Cockle Bay outline and western distributor location overlaid on Governor Macquarie's map of 1822. It shows that Cockle bay formerly extended as far south as Hay Street in Haymarket and has been progressively in-filled since the 1820's to the current sea wall locations. In 1985, the finger wharfs were demolished and the current concrete decking was built on piles extending past the sea walls over the bay.



Drawing 1: 1984 Cockle Bay outline and western distributor location overlaid on Macquarie's map of 1822

The Sydney 1:100 000 scale geology map indicates quaternary alluvium of Holocene age infilling the cockle bay channel underlain by Hawkesbury Sandstone bedrock. The alluvium is described as silty to peaty sand, silt and clay with ferruginous and humic cementation in places and common shell layers. These river sediments and back swamp deposits would be expected to have been deposited predominantly in a north south direction, consistent with the shape of the bay. The underlying sandstone bedrock is described as medium to very coarse grained quartz sandstone, with very minor shale and laminate lenses.

3.2. Geophysical investigation results

The results of the sUSR survey are presented as interpreted seismic sections on Figure 2 and Figure 3. Simplified borehole logs for boreholes within about 10m of the sUSR lines have also been plotted on these seismic sections. These boreholes have been used for correlation of the interpreted seismic sections.

Two dominant layers have been interpreted and are summarised in Table 3 below.

Table 3: Subsurface geophysical interpretation

Material / Origin	Depth to Top of Unit (m)	Thickness of Unit (m)	Elevation at Top of Unit (mAHD)	P-wave Velocity (m/s)
Clayey silt/ clayey sand/ fill/ sand/ clay	0	1 to 21m	1 to -6	1500-1950
EW to HW Sandstone	1 to 20	>1	-6 to -26	>1950

We have interpreted the top of extremely weathered rock to coincide with the 1950m/s seismic velocity contour. The 1950m/s seismic velocity contour is plotted as a bold dashed line on Figures 2 and 3.

Along the eastern side of cockle bay the geophysics interpreted top of extremely weathered rock levels as low at RL -26m depth. The nearest boreholes to the northern half of USR 1 are approximately 30m to the west (R2-W2 and R2-C2). These boreholes both show top of highly weathered rock at about RL -19.5m. 30m to the east, at R2-L4, top of highly weathered rock is at RL -17.4m.

Some reasons for this discrepancy may be the presence of one or more incised channels deep into the rock or complete weathering of the rock at this location due to localised features such as faults or dykes within the rock. Whatever the cause, the level of competent rock appears deeper than the level inferred from the boreholes, although it is possible that the top of weathered rock may occur at higher levels in this area.

3.3. Geotechnical model

The previous data has been compiled along with the results of the geophysical investigation to create the geotechnical model for the proposed marine structures project. Six cross sections of the site (A-A' to F-F') are presented as Figures 6 to 11. The locations of the sections are shown on the site plans (Figures 1, 4 and 5).

Some aspects of the model are discussed in the following sections.

3.3.1. Subsurface soils

The soil profile at the site is variable and complex, resulting from a series of deposition, erosion and re-deposition of alluvial and colluvial materials. While the predominant direction of deposition is probably in the north south direction, deposition may have been influenced by the gullies to the east and south west of the site and by colluvial materials from the cliffs and slopes of the old valley.

The typical characteristics of the soil deposits are as follows:

- A lower sequence (Unit 3), consisting of sandy clay, peaty clay and clayey sand. The peaty material is often interbedded within other materials in the sequence, and was probably formed at varying tidal zones where mangroves and other swamp vegetation once grew.
- An upper sequence (Unit 2), consisting of fine clay materials (Unit 2C) which have been carried further offshore, and coarser sandy materials (Unit 2B) settling out nearer to the shore in the sedimentation process. This resulted in the interlayering of sands and clays at the boundary of Units 2B and 2C. This sequence is capped by a fine clayey silt layer (Unit 2A) which forms the present sea bed and may represent very recent siltation form storm drain runoff. The recent bathymetry shows that in some areas the current sea bed is higher than when the boreholes were drilled in 1985.
- Man-made fill (Unit 1), comprising rock fill mixed in with the Unit 2A materials near the sea wall on the western side of the bay.

3.3.2. Bedrock levels

Inferred bedrock levels are shown as contours of the top of highly weathered bedrock on Figure 5. The contours, in reduced levels relative to AHD have been interpreted from the borehole locations and geophysical investigations. As discussed in Section 3.2, some uncertainties exist in the top of weathered rock level between existing boreholes along the geophysics investigation line USR1, and judgement, taking into account of nearby borehole results, has been applied in the inferred rock levels shown in Figure 5. Within the footprint of the proposed structures on the eastern side of the bay, the bedrock levels are interpreted to vary from -17m AHD to -24 m AHD. On the western side of the bay bedrock levels vary from -2m AHD at the northern end to -16m AHD at the southern end.

The contours confirm that the main north-south trending in-filled channel has a similar shape to the old Cockle Bay shown in Drawing 1. It must be noted that the contours are indicative of the general trend in rock levels. It is likely that actual top of rock levels change in a series of steps and benches rather than smooth slopes.

3.3.3. Geotechnical units and parameters

Table 4 shows the generalised geotechnical units encountered within the site footprint. Table 5 follows showing the requested geotechnical parameters for each unit.

Table 4: Generalised stratigraphic units are shown

Unit no	Material origin	Description	Condition	Area of occurrence	RL of top of unit (m)	Thickness (m)
1	Fill	Heterogeneous material comprising mixtures of gravel, sand, clay, sandstone, bricks, concrete and timber	Variable; loose to dense	Behind existing sea walls and mixed into estuarine deposits near the western sea wall	2.5	
2A	Estuarine deposits	Clayey Silt, high liquid limit, dark grey and black, some organic material	very loose	whole site except at R2-W6 where fill is mixed with the estuarine deposits	sea bed - refer to figure 4	nil to 5; generally 3
2B	Alluvium and colluvium	Silty sand and clayey silt, fine to medium grained, light grey to dark grey	very loose to dense	eastern and western sides along the slopes of the old valley	-7 to -10	nil to 6 m
2C	Alluvium	Clay, high plasticity, grey, brown and red brown, trace of sandstone and ironstone gravel	stiff to very stiff	towards centre of channel	-8 to -11	3 to 9
3A	Alluvium	Sandy clay, low plasticity, grey and brown, fine to medium grained sand.	stiff	towards centre of channel, lower elevation	-15 to -17	1 to 4
3B	Alluvium	Peaty (organic) clay, high plastic black	firm	towards centre of channel, lower elevation	-19	nil to 4
4A	Residual soil and bedrock	Clayey sand and Sandstone (class V or worse), extremely to highly weathered, fine to coarse grained, brown.	dense to very low strength	entire site,	-6 to -26	absent towards centre of channel to 5.5 (at R2-W6)
4B	Bedrock	Sandstone (Class IV and III), highly to moderately weathered, fine to coarse grained, brown to grey brown.	medium to high strength	entire site	Refer to figure 5	about 1.0
4C	Bedrock	Sandstone (class II or better), slightly weathered to fresh, fine to medium grained, light grey	high strength	entire site	Refer to figure 5 and generally subtract 1m in reduced level	unknown

Table 5: Generalised geotechnical design parameters for each relevant material

Unit	Consistency/ Relative density/ rock mass classification	Unit weight (KN/m^3)	Undrained parameters				Drained parameters				Foundation parameters		
			Undrained cohesion, cu (kPa)	Undrained Young's modulus, Eu (MPa)	Lateral yield pressure, py (kPa)	Modulus of subgrade reaction[2] (MPa/m)	Drained cohesion, c' (kPa)	Drained friction angle, ϕ' (deg)	Poisson's ratio, v'	Drained Young's modulus, E' (MPa)	Ultimate end bearing (kPa)	Ultimate shaft adhesion (kPa)	Serviceability end bearing (kPa)
2A Estuarine deposits[1]	very loose or very soft	15	-	-	-	-	-	-	-		-	-	-
2B Alluvium and colluvium	very loose to dense	17	-	3	45	4.2	0	25	0.3	3	450 (driven piles only)	12	150 (driven piles only)
2C Alluvium	stiff to very stiff	20	100	20	900	28	5	27	0.4	14	900	35	300
3A Alluvium	Stiff sandy clay	20	70	14	630	20	5	27	0.4	10	630	25	210
3B Alluvium	firm	16	30	6	270	8.4	0	20	0.3	3	270	15	90
4A Residual soil and bedrock	Class V or worse	21	-	50	900	70	30	35	0.3	50	2000	100	800
4B Bedrock	Class VI/III	22	-	400	4,000	560	-	-	0.25	400	15000	700	2500
4C Bedrock	Class II or better	22	-	1200	20,000	1700	-	-	0.2	1200	60000	1600	8000

Notes:

1) Strength and deformation parameters for Unit 2A not provided due to potential for this unit to be eroded and scoured due to wave and boat movements.
2) The modulus of subgrade reaction values are based on the elastic modulus for transient short term loading and assume a pile diameter of 0.45m.

4. Discussion and recommendations

4.1. Geotechnical parameters

The parameters given in Table 5 have been presented separately for drained and conditions. Where loading is short term or transient the undrained parameters should be used. For long term, sustained loading the drained parameters should be used.

The modulus of subgrade reaction values are based on the horizontal elastic modulus for transient short term loading and assume a pile diameter of 0.45m. For other pile diameters, d, the values may be adjusted by multiplying by a factor 0.45/d.

4.2. Soil spring stiffness values

To obtain a spring stiffness values, the modulus of subgrade reaction should be multiplied by the tributary area of the spring. For laterally loaded piles, the tributary area of the spring would be the product of the diameter of the pile and spring spacing.

The moduli of subgrade reaction values given in Table 5 assume conditions within the soil remain elastic. If the lateral pressures developed near the pile head exceed the ultimate lateral pile-soil yield pressure (p_y, given in Table 5), this will cause yielding of the soil. In this case, the soil spring should be replaced by an equivalent lateral resisting load equal to the ultimate lateral pile-soil pressure (p_y) multiplied by the area of the yielded element.

4.3. Piling

We do not expect that piles for floating pontoons will experience significant vertical loads. It is therefore likely that the lateral load case will govern the pile design.

Piles required for ramps and deck structures (tying into the existing concrete decks) may experience more vertical load. These piles may need to be uniformly founded on bedrock to limit differential settlements.

On the east side of the bay, the thickness of soil above bedrock ranges from about 10m to 17m. Piles for the proposed floating marina should have sufficient lateral capacity from the soils and not require founding or socketing into bedrock. As discussed in Section 3.2, there is a discrepancy between the geophysical results along the northern part of cockle bay wharf and the interpretation of top of rock levels from the nearby boreholes. As we expect that the piles for the proposed floating marina in this area will not need to extend to bedrock, this discrepancy should not impact on the design and construction of the proposed structures. However, if this is found to be not the case during preliminary pile design, and more certainty on top of rock levels is required in this area, further investigation may be required.

Where pontoon structures are proposed on the west side, thicknesses of soil overlying bedrock range from about 1m to 10m. Minimal capacity will be obtained from the Unit 1 and Unit 2A soils. We recommend that these are ignored in design. It is likely that piles along the western side of cockle bay will need to be socketed into underlying bedrock for lateral capacity. The exception to this may be at the south end of the proposed wharf, where there is about a 5m thickness of Unit 2B soils.

Where a socket is required into bedrock the piles may need to be cased within the alluvium and bored into rock to obtain the required socket length.

In terms of constructability, driven piles would likely penetrate through units 2, 3 and 4A and refuse a short distance into either Unit 4B or Unit 4C. Some rubble fill was observed on the exposed sea bed, on the western side of the bay. We recommend probing through the fill prior to piling to check for oversize fill material that may cause refusal and/or slow the progress of piling works.

4.4. Corrosion of buried steel and concrete

The results of previous chemical analyses on four sediment samples indicate that the foundation environment is highly aggressive in terms of corrosion at the splash zone (near the fluctuating sea level) and mud zone (near sea bed level).

A previous report on corrosion of steel piles concluded corrosion rates between 0.02mm/year and 0.03mm/year at depths where oxygen level is limited. In the splash zone, a value of 0.1mm/year should be allowed unless corrosion protection such as cathodic protection is provided. Corrosion protection can also take the form of epoxy coatings or protective paint.

5. Limitations

The geotechnical model and parameters provided in this report are based on geophysical testing at specific locations and archived borehole data originally collected by Coffey and others. The engineering logs we reviewed describe subsurface conditions only at the specific borehole locations. Subsurface conditions can change over relatively short distances. We recommend that a geotechnical engineer be engaged during construction to confirm that subsurface conditions are consistent with design assumptions.

The attached document entitled “Important Information About Your Coffey Report” presents additional information on the uses and limitations of this report.

Important information about your Coffey Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples.

These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

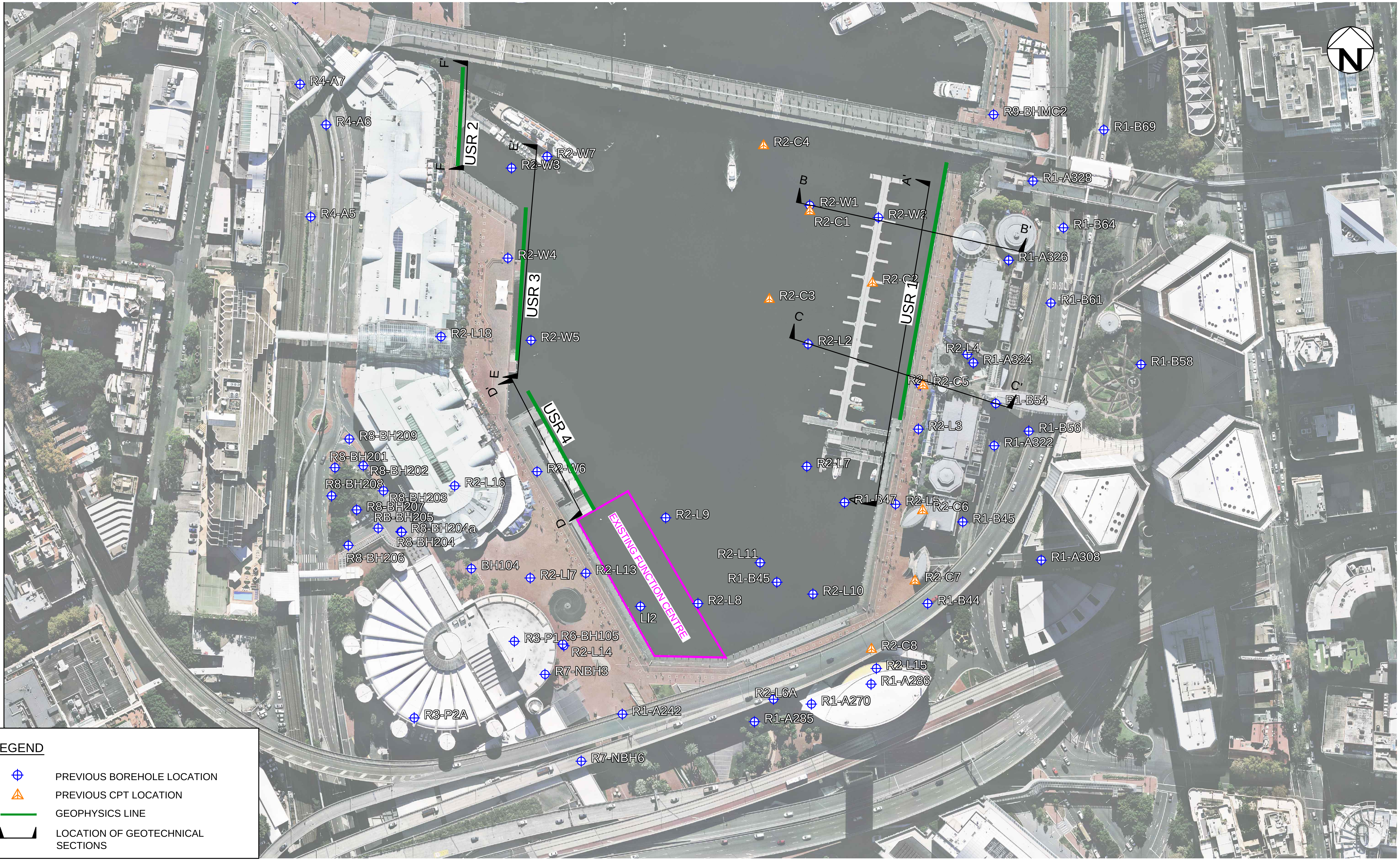
Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

Figures



no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

revision

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Scale (metres) 1:2000

drawn	JP
approved	-
date	16 / 03 / 15
scale	1:2000
original size	A3

coffey

client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES
DARLING HARBOUR, SYDNEY, NSW

title: GEOPHYSICAL INVESTIGATION AND BOREHOLE LOCATION PLAN

project no: GEOTLCOV25293AA-AD | figure no: FIGURE 1 | rev: A

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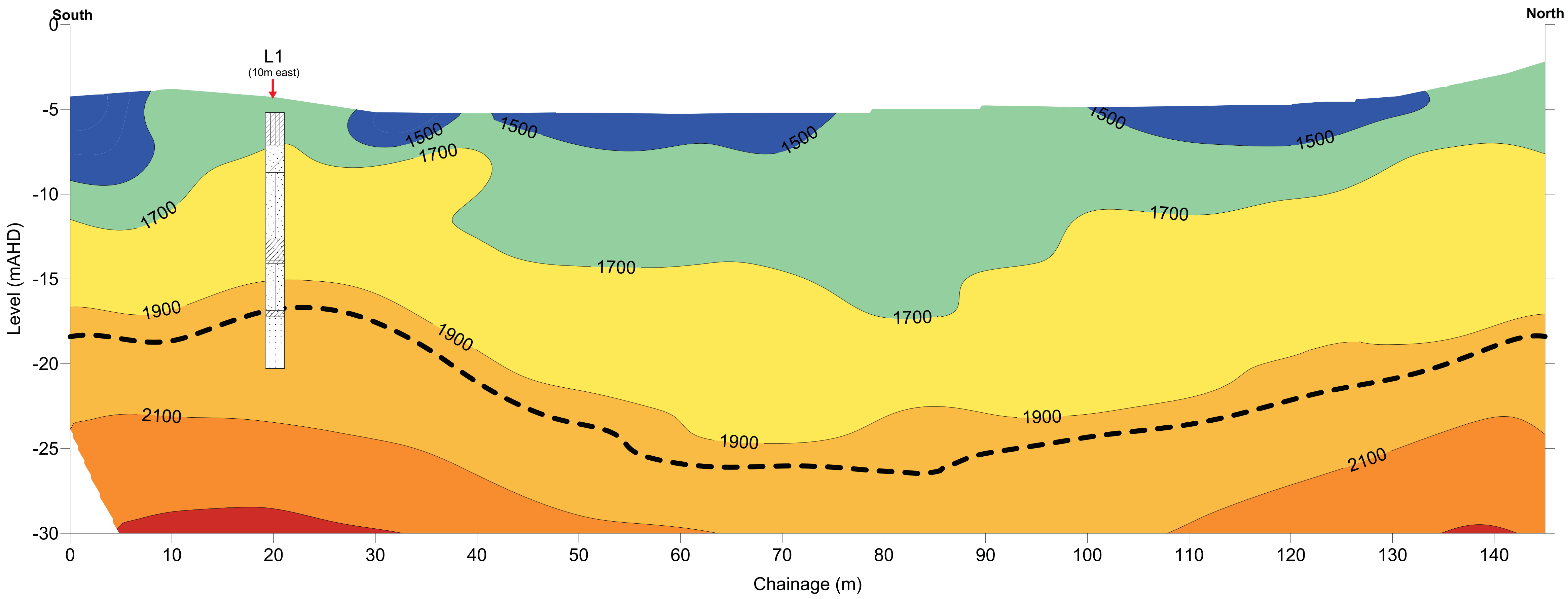
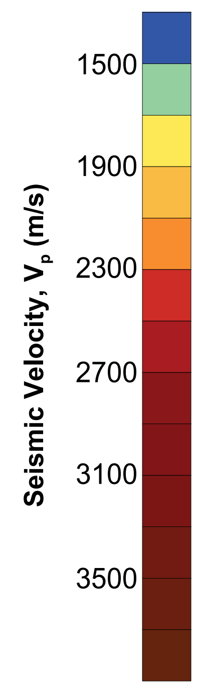
sUSR 1



GEOTECHNICAL LEGEND

- CLAYEY SILT
- CLAYEY SAND
- SILTY SAND
- SANDY CLAY
- CLAY
- SANDSTONE
- NO CORE
- FLY-ASH



Interpreted top of EW rock

VERTICAL CONTROL:
All levels are in meters reduced to AHD (Australian Height Datum)

GEODETIC PARAMETERS:

Coordinate System:	Map Grid of Australia 94 Zone 56 (MGA94 Z56)
Geodetic Datum:	GDA 94
Semi Major Axis:	6378137.0m
Inverse Flattening (1/f):	298.257222101
Projection:	Universal Transverse Mercator (South)
UTM Zone:	Zone 56 South
Central Meridian:	153° East
Reference Latitude:	0° North
Scale Factor at CM:	0.9996
False Easting:	500,000.0m
False Northing:	10,000,000.0m
Ellipsoid:	GRS 1980

revision

no.	description	drawn	approved	date
A	Final	PH	RJW	16/3/2015

Vertical Scale 1:300

Horizontal Scale 1:500

drawn	PH
approved	RJW
date	13/3/2015
scale	AS SHOWN
original size	A3

coffey

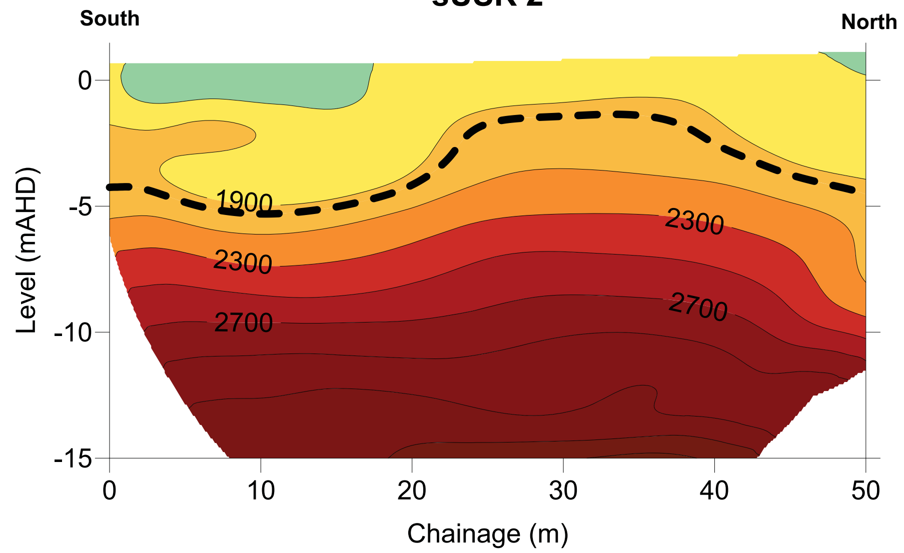
client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES

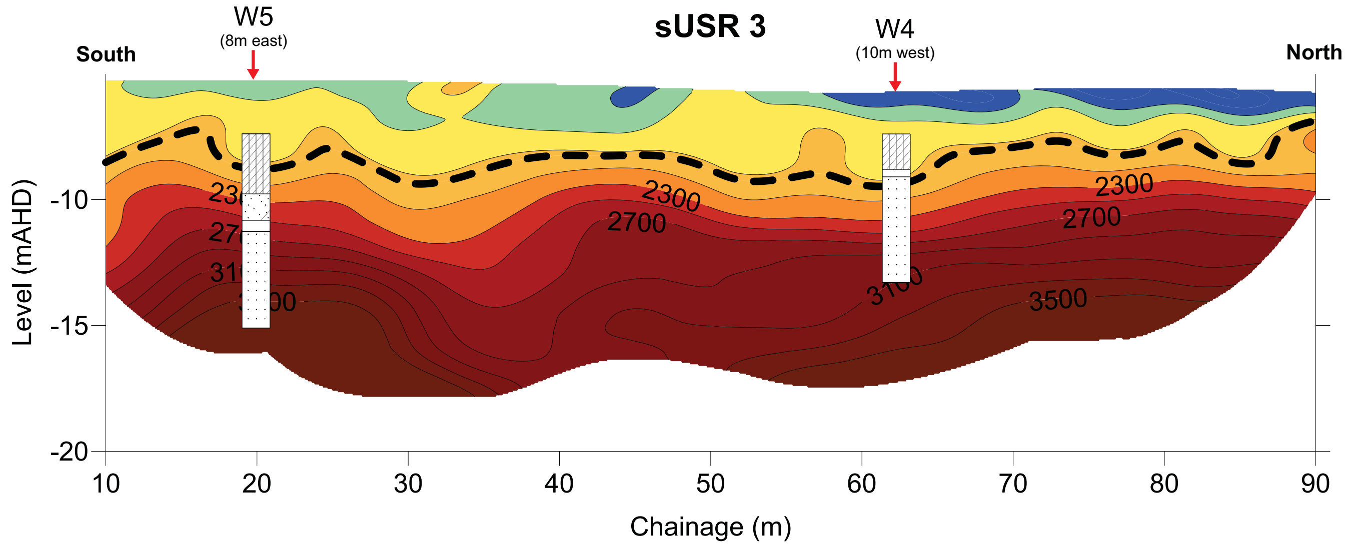
title: Static Underwater Seismic Refraction Line 1

project no: GEOTLCOV25293AA | figure no: FIGURE 2 | rev: A

sUSR 2



sUSR 3



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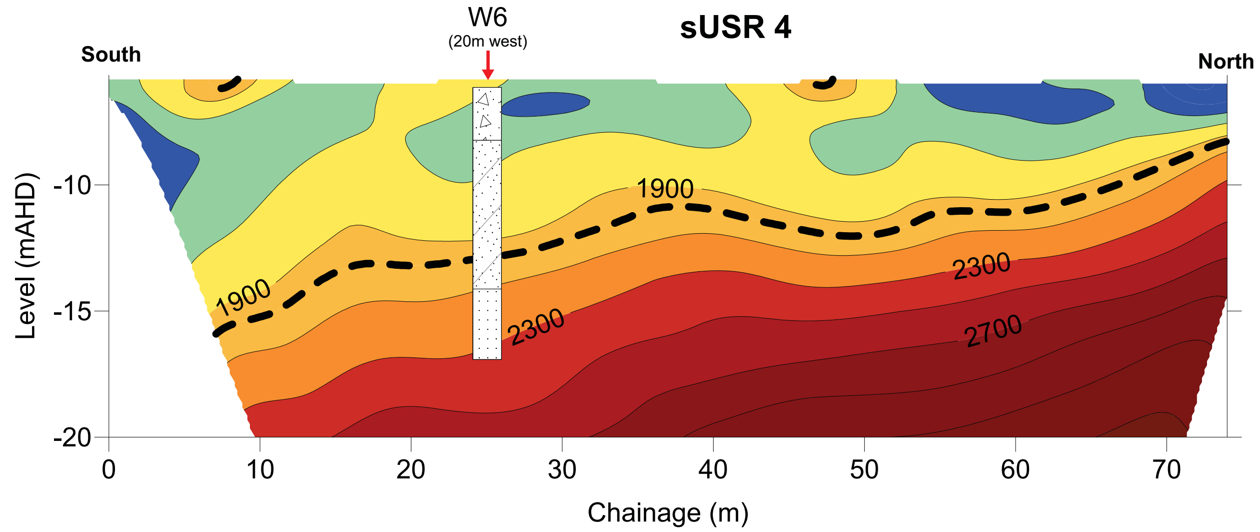
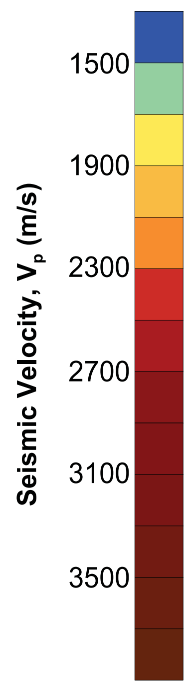


GEOTECHNICAL LEGEND

- CLAYEY SILT
- CLAYEY SAND
- SILTY SAND
- SANDY CLAY
- CLAY
- SANDSTONE
- NO CORE
- FLY-ASH



— — — Interpreted top of EW rock

VERTICAL CONTROL:
All levels are in meters reduced to AHD (Australian Height Datum)

GEODETIC PARAMETERS:

Coordinate System:	Map Grid of Australia 94 Zone 56 (MGA94 Z56)
Geodetic Datum:	GDA 94
Semi Major Axis:	6378137.0m
Inverse Flattening (1/f):	298.257222101
Projection:	Universal Transverse Mercator (South)
UTM Zone:	Zone 56 South
Central Meridian:	153° East
Reference Latitude:	0° North
Scale Factor at CM:	0.9996
False Easting:	500,000.0m
False Northing:	10,000,000.0m
Ellipsoid:	GRS 1980

revision no.	description	drawn	approved	date
A	Final	PH	RJW	16/3/2015

Vertical Scale 1:300

Horizontal Scale 1:500

drawn	PH
approved	RJW
date	13/3/2015
scale	AS SHOWN
original size	A3

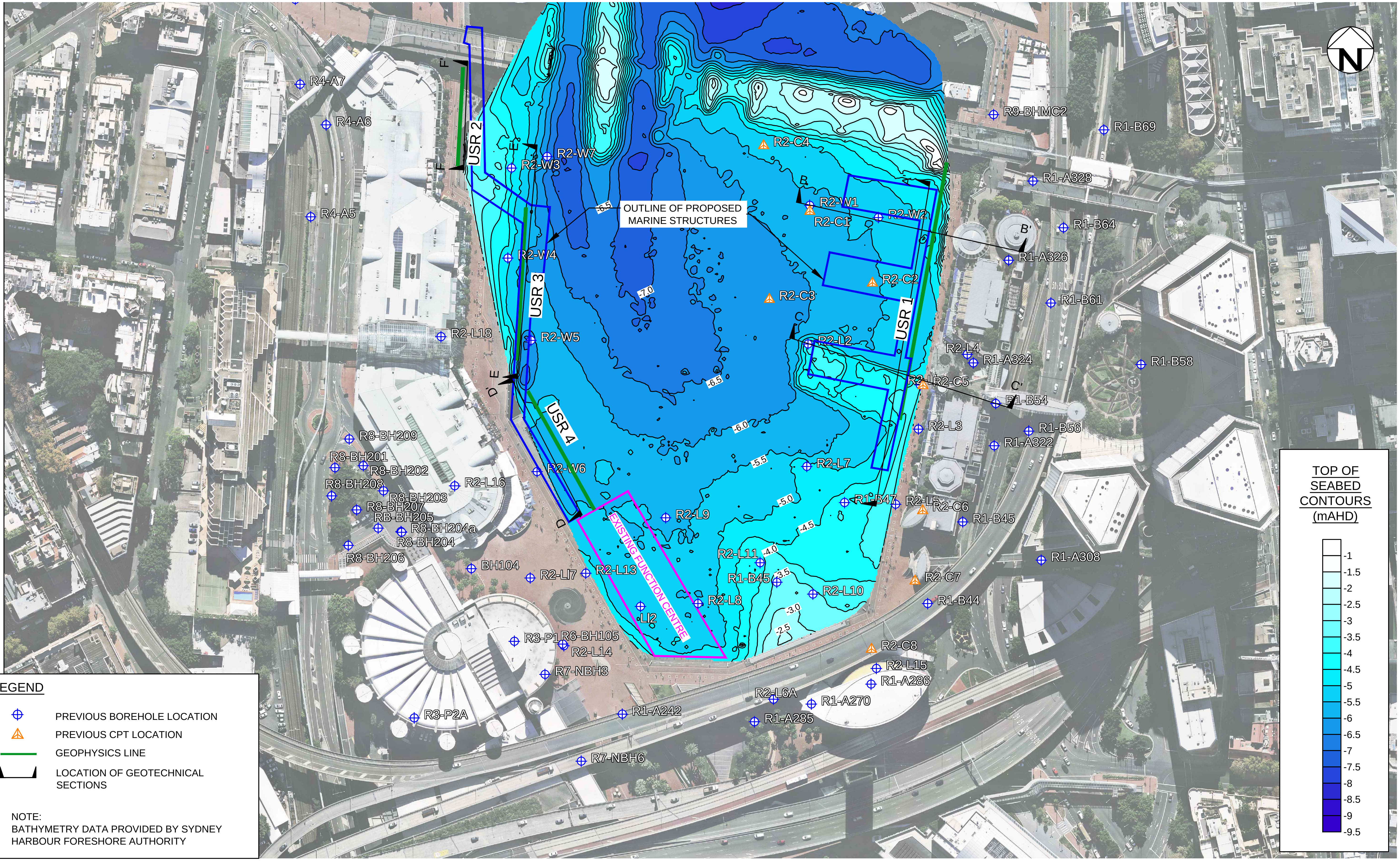
coffey

client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES

title: Static Underwater Seismic Refraction Lines 2 to 4

project no: GEOTLCOV25293AA | figure no: FIGURE 3 | rev: A



no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

revision

Scale (metres) 1:2000 (20 0 20 40 60 80 100)

drawn	JP
approved	-
date	16 / 03 / 15
scale	1:2000
original size	A3

coffey

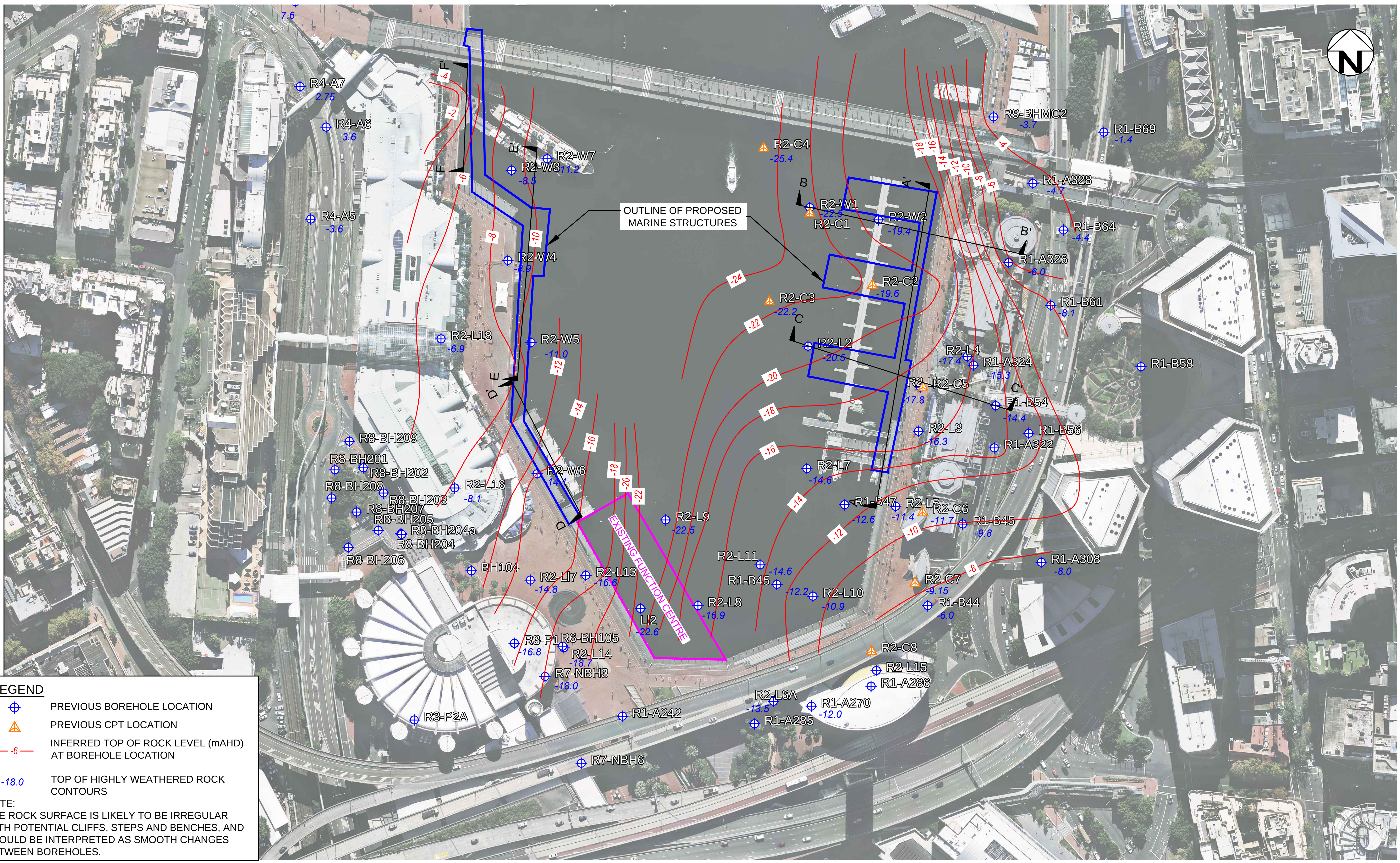
client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES
DARLING HARBOUR, SYDNEY, NSW

title: BATHYMETRY

project no: GEOTLCOV25293AA-AD | figure no: FIGURE 4 | rev: A

PLOT DATE: 26/03/2015 4:03:39 PM DWG FILE: F:\GEOTECHNICS\1 PROJECTS\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG



LEGEND

- PREVIOUS BOREHOLE LOCATION
- PREVIOUS CPT LOCATION
- —-6— INFERRED TOP OF ROCK LEVEL (mAHD) AT BOREHOLE LOCATION
- -18.0 TOP OF HIGHLY WEATHERED ROCK CONTOURS

NOTE:
THE ROCK SURFACE IS LIKELY TO BE IRREGULAR WITH POTENTIAL CLIFFS, STEPS AND BENCHES, AND SHOULD BE INTERPRETED AS SMOOTH CHANGES BETWEEN BOREHOLES.

PLOT DATE: 26/03/2015 4:15:31 PM DWG FILE: F:\GEOTECHNICS\1 PROJECTS\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG

revision no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

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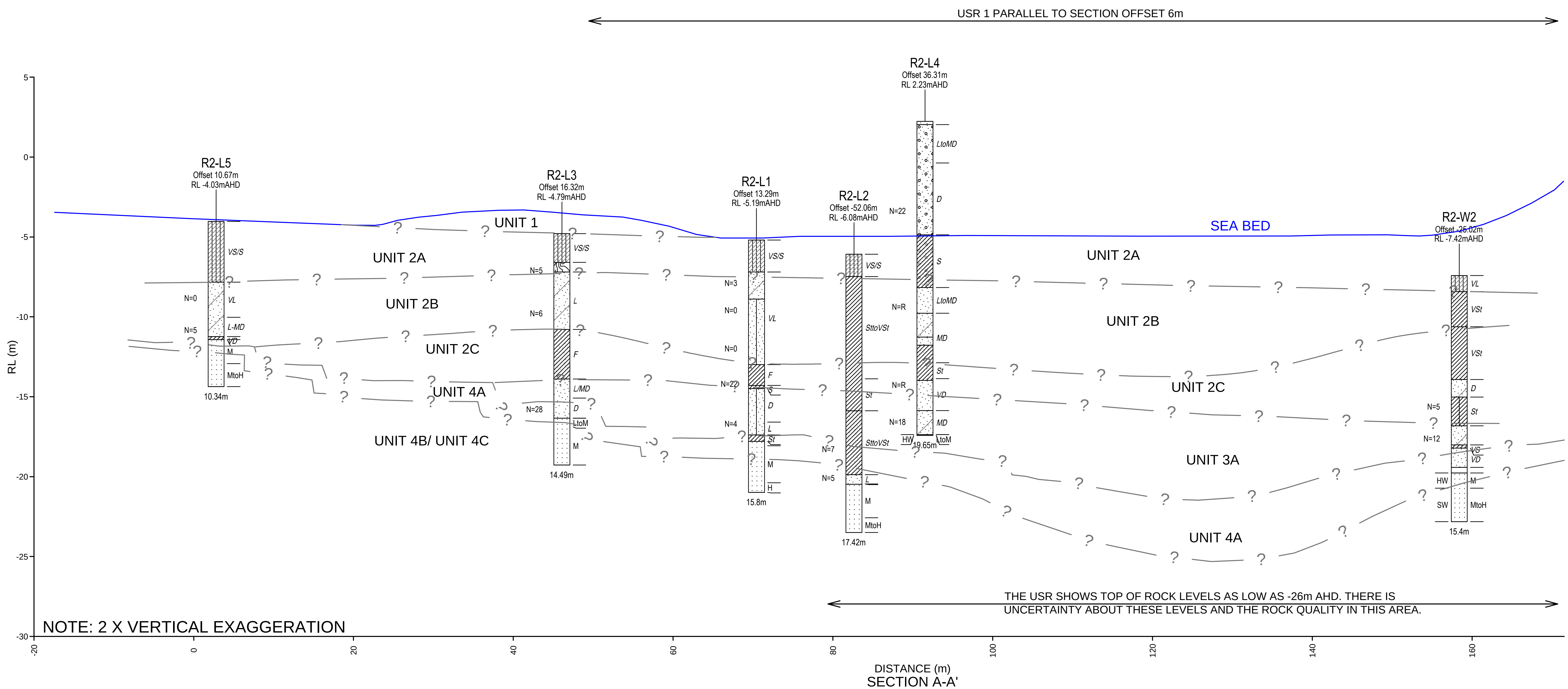
Scale (metres) 1:2000

drawn	JP
approved	-
date	16 / 03 / 15
scale	1:2000
original size	A3

coffey

client:	SYDNEY HARBOUR FORESHORE AUTHORITY
project:	COCKLE BAY MARINE STRUCTURES DARLING HARBOUR, SYDNEY, NSW
title:	TOP OF ROCK CONTOUR PLAN
project no:	GEOTLCOV25293AA-AD
figure no:	FIGURE 5
rev:	A



SECTION A-A'

MATERIAL GRAPHIC

SANDY CLAY
SILTY CLAY
SANDSTONE
GRAVELLY SAND
SAND
CONCRETE
CLAY
CLAYEY SAND
NO CORE
SHALE
SANDY GRAVEL
CLAYEY SILT
SILTY SAND
CLAYEY SILTY SAND
PYROCLASTIC (VOLCANIC ASH)
SILTY CLAYEY SAND
GRAVELLY CLAYEY SAND
WOOD
GRAVELLY SANDY CLAY

KEY TO SYMBOLS

WATER LEVEL
N*=17 STANDARD PENETRATION TEST RESULT
— ? — INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1	- FILL
UNIT 2A	- ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B	- ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C	- ALLUVIUM (CLAY)
UNIT 3A	- ALLUVIUM (SANDY CLAY)
UNIT 3B	- ALLUVIUM (PEATY CLAY)
UNIT 4A	- RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B	- HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C	- SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

PLOT DATE: 26/03/2015 4:52:30 PM DWG FILE: F:\GEOTECHNICS\1 PROJECTS\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG

revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

Horizontal Scale (metres) 1:500

Vertical Scale (metres) 1:250

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

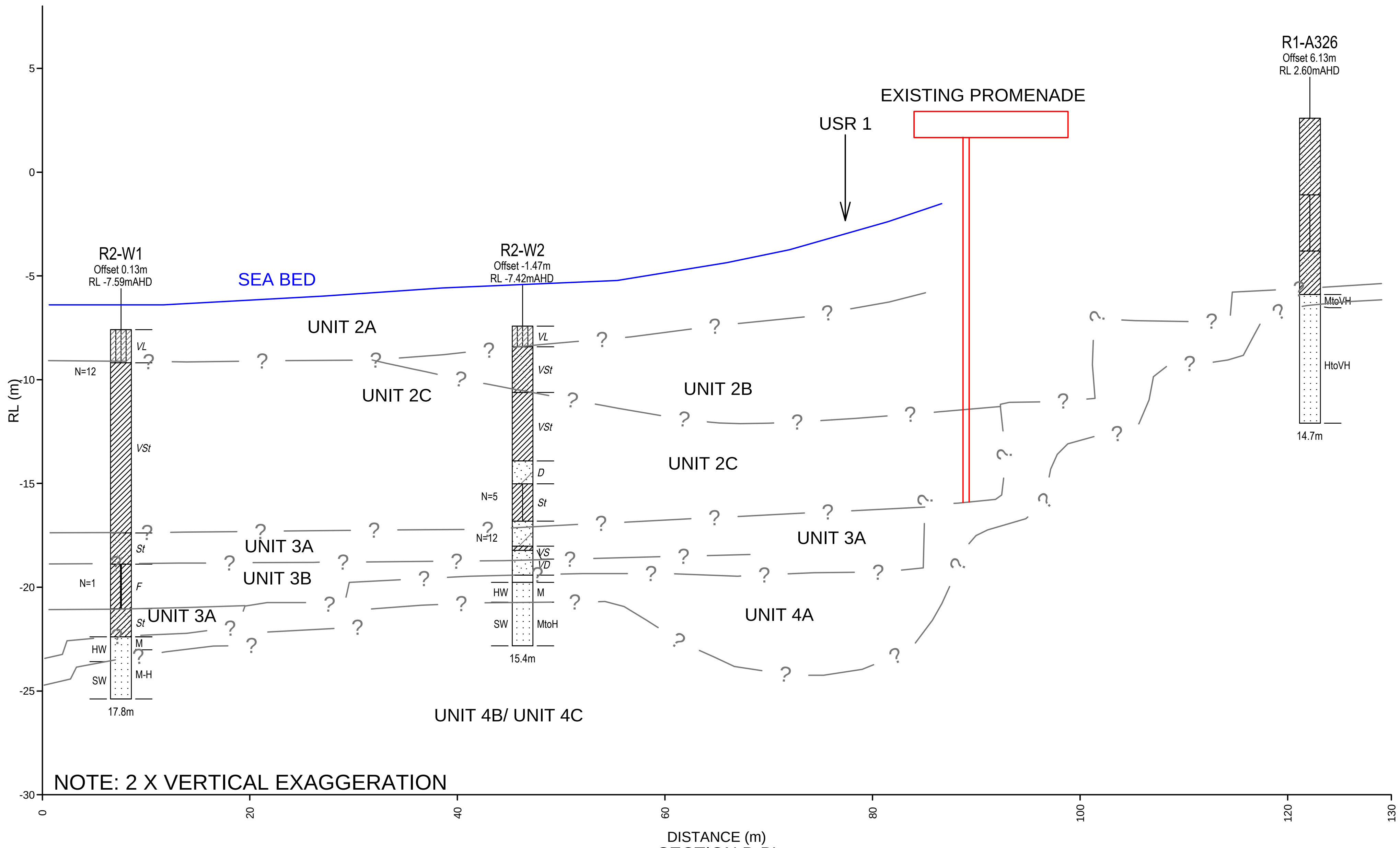
coffey

client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES
DARLING HARBOUR, SYDNEY, NSW

title: GEOTECHNICAL SECTION A-A'

project no: GEOTLCOV25293AA-AD | figure no: FIGURE 6 | rev: A



SECTION B-B'

MATERIAL GRAPHIC

- SANDY CLAY
- SILTY CLAY
- SANDSTONE
- GRAVELLY SAND
- SAND
- CONCRETE
- CLAY
- CLAYEY SAND
- NO CORE
- SHALE
- SANDY GRAVEL
- CLAYEY SILT
- SILTY SAND
- CLAYEY SILTY SAND
- PYROCLASTIC (VOLCANIC ASH)
- SILTY CLAYEY SAND
- GRAVELLY CLAYEY SAND
- WOOD
- GRAVELLY SANDY CLAY

KEY TO SYMBOLS

- WATER LEVEL
- N*=17 STANDARD PENETRATION TEST RESULT
- —— ? —— INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1	- FILL
UNIT 2A	- ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B	- ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C	- ALLUVIUM (CLAY)
UNIT 3A	- ALLUVIUM (SANDY CLAY)
UNIT 3B	- ALLUVIUM (PEATY CLAY)
UNIT 4A	- RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B	- HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C	- SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

revision

Horizontal Scale (metres) 1:500

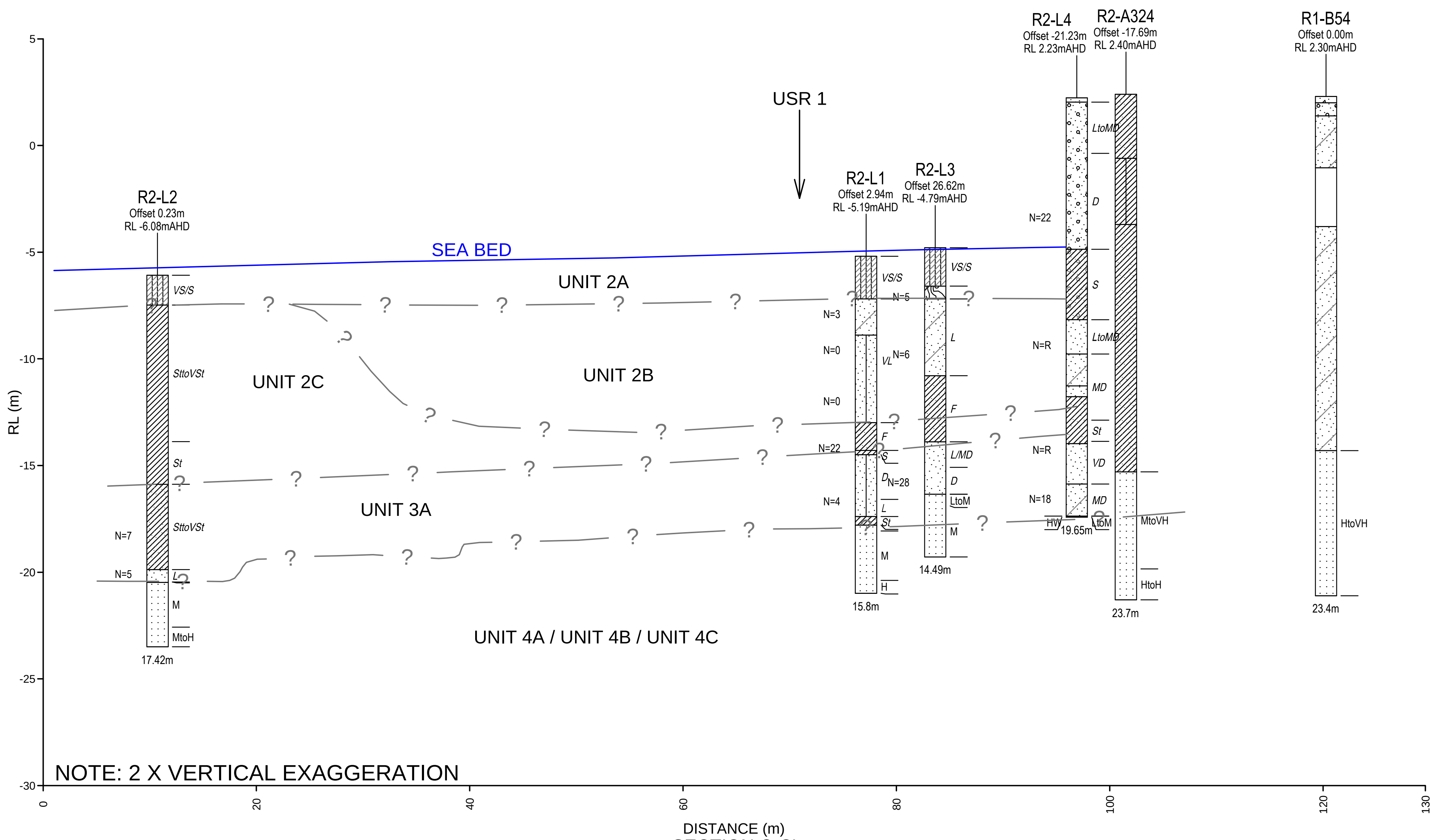
Vertical Scale (metres) 1:250

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

coffey

client:	SYDNEY HARBOUR FORESHORE AUTHORITY
project:	COCKLE BAY MARINE STRUCTURES DARLING HARBOUR, SYDNEY, NSW
title:	GEOTECHNICAL SECTION B-B'
project no:	GEOTLCOV25293AA-AD
figure no:	FIGURE 7
rev:	A

PLOT DATE: 26/03/2015 4:55:04 PM DWG FILE: F:\GEOTECHNICS\1.PROJECTS\GEOTLCOV252\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG



SECTION C-C'

MATERIAL GRAPHIC

- SANDY CLAY
- SILTY CLAY
- SANDSTONE
- GRAVELLY SAND
- SAND
- CONCRETE
- CLAY
- CLAYEY SAND
- NO CORE
- SHALE
- SANDY GRAVEL
- CLAYEY SILT
- SILTY SAND
- CLAYEY SILTY SAND
- PYROCLASTIC (VOLCANIC ASH)
- SILTY CLAYEY SAND
- GRAVELLY CLAYEY SAND
- WOOD
- GRAVELLY SANDY CLAY

KEY TO SYMBOLS

- WATER LEVEL
- N*=17 STANDARD PENETRATION TEST RESULT
- — ? — INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1	- FILL
UNIT 2A	- ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B	- ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C	- ALLUVIUM (CLAY)
UNIT 3A	- ALLUVIUM (SANDY CLAY)
UNIT 3B	- ALLUVIUM (PEATY CLAY)
UNIT 4A	- RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B	- HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C	- SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

revision

Horizontal Scale (metres) 1:500

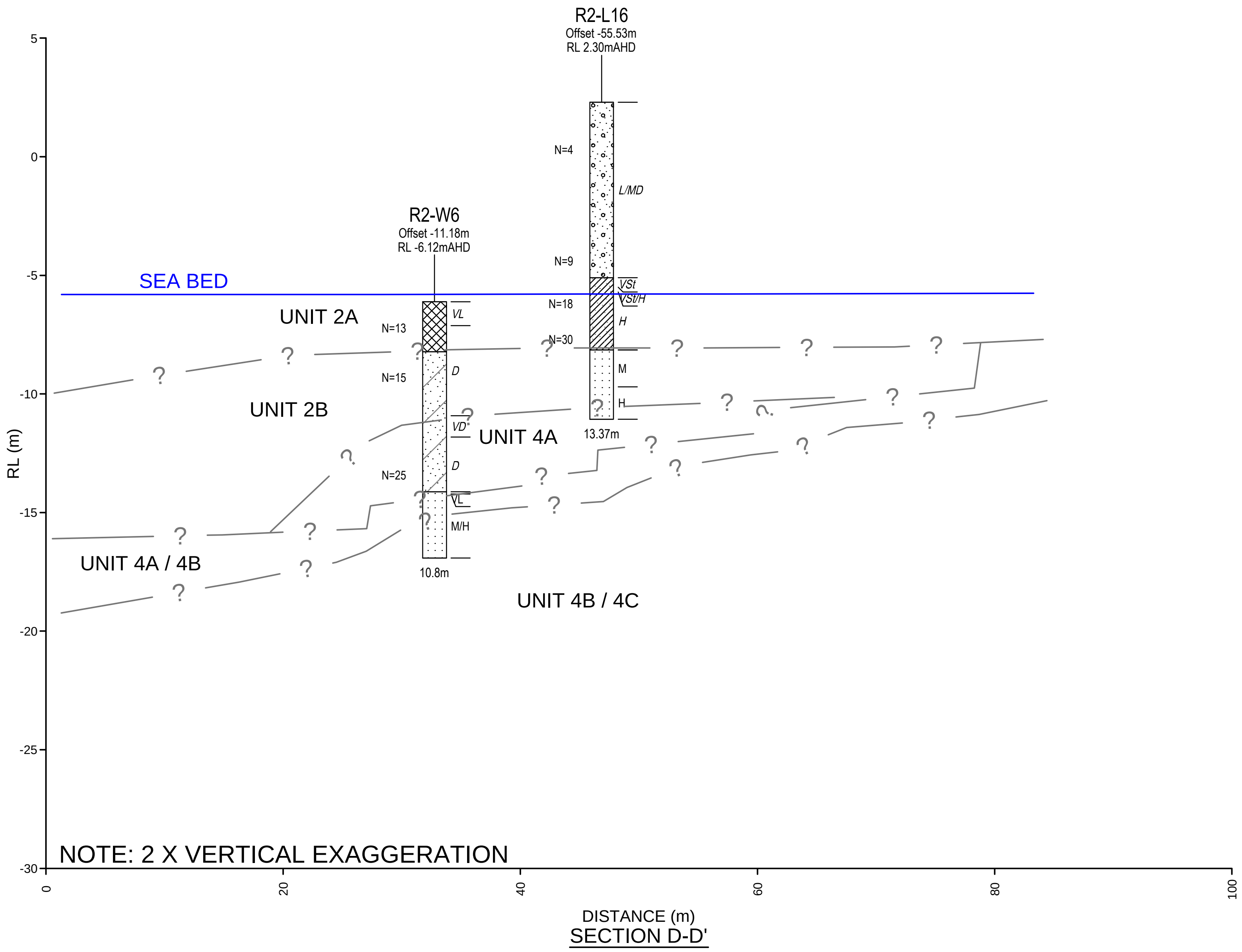
Vertical Scale (metres) 1:250

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

coffey

client:	SYDNEY HARBOUR FORESHORE AUTHORITY
project:	COCKLE BAY MARINE STRUCTURES DARLING HARBOUR, SYDNEY, NSW
title:	GEOTECHNICAL SECTION C-C'
project no:	GEOTLCOV25293AA-AD
figure no:	FIGURE 8
rev:	A

PLOT DATE: 26/03/2015 4:57:31 PM DWG FILE: F:\GEOTECHNICS\1 PROJECTS\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG



MATERIAL GRAPHIC

- SANDY CLAY
- SILTY CLAY
- SANDSTONE
- GRAVELLY SAND
- SAND
- CONCRETE
- CLAY
- CLAYEY SAND
- NO CORE
- SHALE
- SANDY GRAVEL
- CLAYEY SILT
- SILTY SAND
- CLAYEY SILTY SAND
- PYROCLASTIC (VOLCANIC ASH)
- SILTY CLAYEY SAND
- GRAVELLY CLAYEY SAND
- WOOD
- GRAVELLY SANDY CLAY

KEY TO SYMBOLS

- WATER LEVEL
- N*=17 STANDARD PENETRATION TEST RESULT
- ? INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1	- FILL
UNIT 2A	- ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B	- ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C	- ALLUVIUM (CLAY)
UNIT 3A	- ALLUVIUM (SANDY CLAY)
UNIT 3B	- ALLUVIUM (PEATY CLAY)
UNIT 4A	- RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B	- HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C	- SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

Horizontal Scale (metres) 1:500 (5 0 5 15 25)

Vertical Scale (metres) 1:250 (2.5 0 5 10)

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

coffey

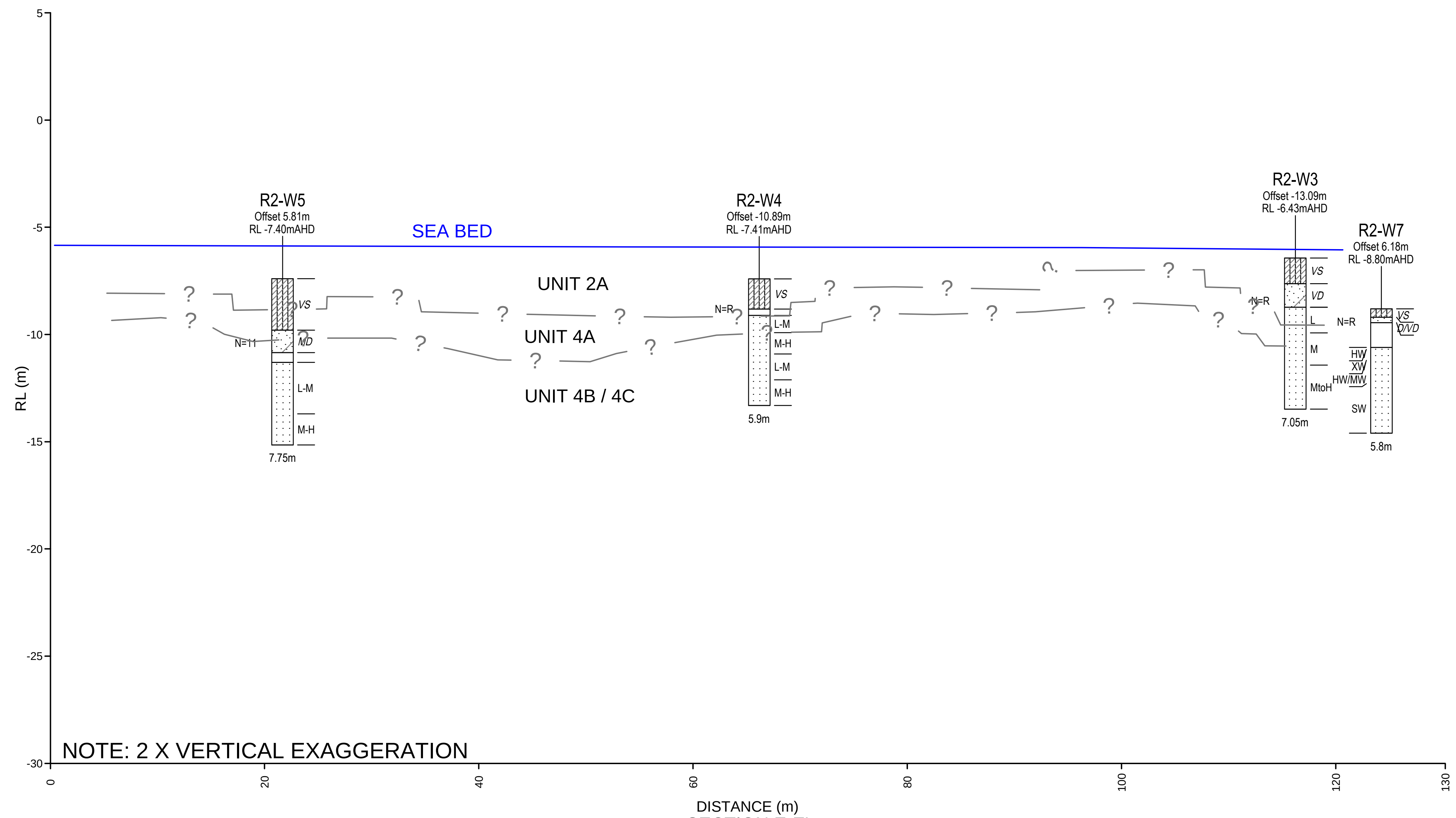
client: SYDNEY HARBOUR FORESHORE AUTHORITY

project: COCKLE BAY MARINE STRUCTURES
DARLING HARBOUR, SYDNEY, NSW

title: GEOTECHNICAL SECTION D-D'

project no: GEOTLCOV25293AA-AD | figure no: FIGURE 9 | rev: A

PLOT DATE: 26/03/2015 4:58:18 PM DWG FILE: F:\GEOTECHNICS\1.PROJECTS\GEOTLCOV252\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG



SECTION E-E'

MATERIAL GRAPHIC

- SANDY CLAY
- SILTY CLAY
- SANDSTONE
- GRAVELLY SAND
- SAND
- CONCRETE
- CLAY
- CLAYEY SAND
- NO CORE
- SHALE
- SANDY GRAVEL
- CLAYEY SILT
- SILTY SAND
- CLAYEY SILTY SAND
- PYROCLASTIC (VOLCANIC ASH)
- SILTY CLAYEY SAND
- GRAVELLY CLAYEY SAND
- WOOD
- GRAVELLY SANDY CLAY

KEY TO SYMBOLS

- WATER LEVEL
- N*=17 STANDARD PENETRATION TEST RESULT
- — ? — INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1	- FILL
UNIT 2A	- ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B	- ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C	- ALLUVIUM (CLAY)
UNIT 3A	- ALLUVIUM (SANDY CLAY)
UNIT 3B	- ALLUVIUM (PEATY CLAY)
UNIT 4A	- RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B	- HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C	- SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

PLOT DATE: 26/03/2015 4:58:51 PM DWG FILE: F:\GEOTECHNICS\1.PROJECTS\GEOTLCOV252\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG

revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

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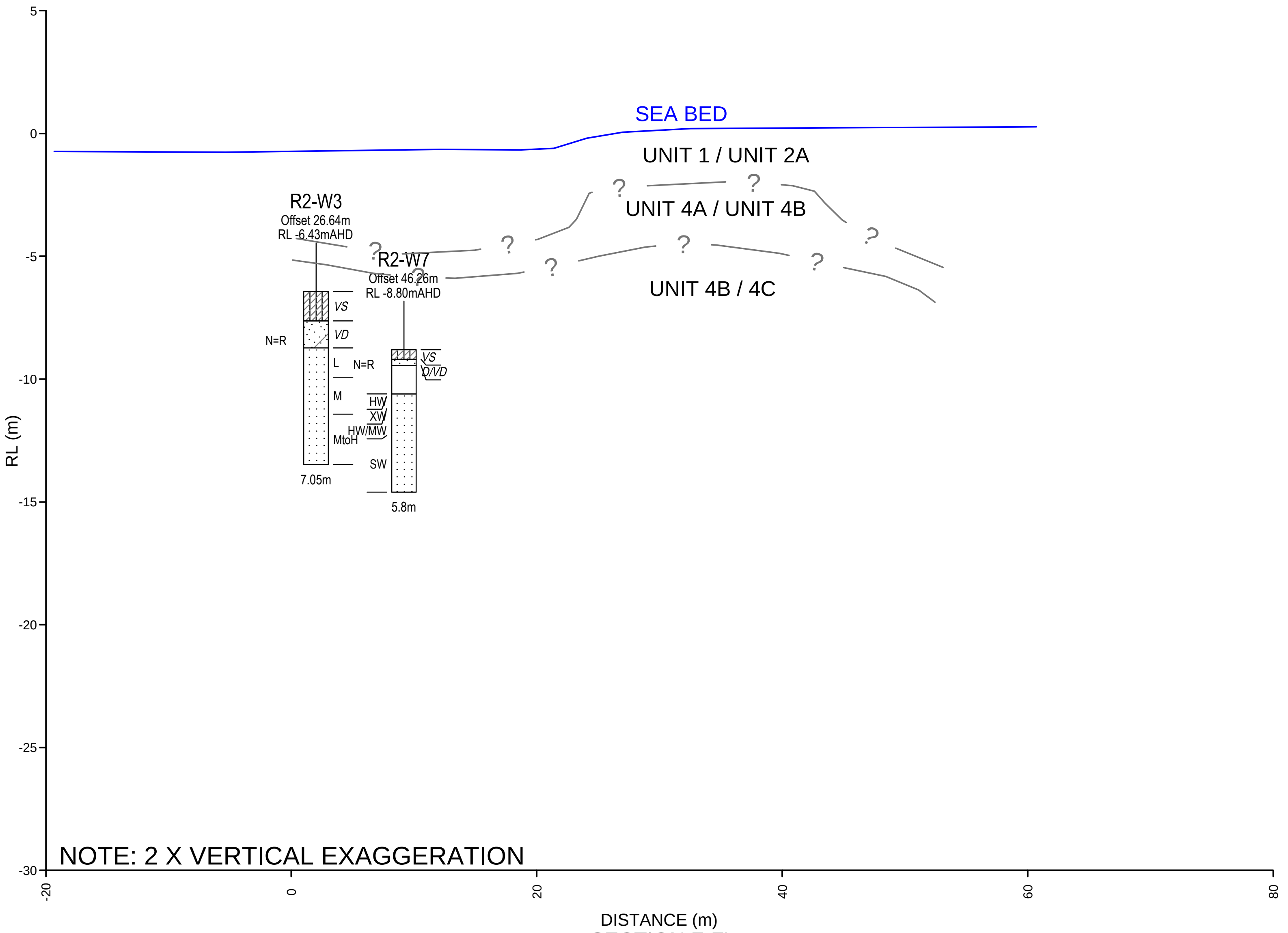
Vertical Scale (metres) 1:250 (2.5, 0, 5, 10)

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

coffey

client:	SYDNEY HARBOUR FORESHORE AUTHORITY
project:	COCKLE BAY MARINE STRUCTURES DARLING HARBOUR, SYDNEY, NSW
title:	GEOTECHNICAL SECTION E-E'
project no:	GEOTLCOV25293AA-AD
figure no:	FIGURE 10
rev:	A



SECTION F-F'

MATERIAL GRAPHIC

- SANDY CLAY
- SILTY CLAY
- SANDSTONE
- GRAVELLY SAND
- SAND
- CONCRETE
- CLAY
- CLAYEY SAND
- NO CORE
- SHALE
- SANDY GRAVEL
- CLAYEY SILT
- SILTY SAND
- CLAYEY SILTY SAND
- PYROCLASTIC (VOLCANIC ASH)
- SILTY CLAYEY SAND
- GRAVELLY CLAYEY SAND
- WOOD
- GRAVELLY SANDY CLAY

KEY TO SYMBOLS

- WATER LEVEL
- N*=17 STANDARD PENETRATION TEST RESULT
- —— ? —— INFERRED GEOLOGICAL BOUNDARY

GEOLOGICAL UNITS

UNIT 1 - FILL
UNIT 2A - ESTUARINE DEPOSITS (CLAYEY SILT)
UNIT 2B - ALLUVIUM AND COLLUVIUM (SILTY SAND AND CLAYEY SILT)
UNIT 2C - ALLUVIUM (CLAY)
UNIT 3A - ALLUVIUM (SANDY CLAY)
UNIT 3B - ALLUVIUM (PEATY CLAY)
UNIT 4A - RESIDUAL SOIL AND EXTREMELY WEATHERED SANDSTONE BEDROCK
UNIT 4B - HIGHLY TO MODERATELY WEATHERED SANDSTONE BEDROCK
UNIT 4C - SLIGHTLY WEATHERED TO FRESH SANDSTONE BEDROCK

revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE			

Horizontal Scale (metres) 1:500

Vertical Scale (metres) 1:250

drawn	JP
approved	-
date	16 / 03 / 15
scale	AS SHOWN
original size	A3

coffey

client:	SYDNEY HARBOUR FORESHORE AUTHORITY
project:	COCKLE BAY MARINE STRUCTURES DARLING HARBOUR, SYDNEY, NSW
title:	GEOTECHNICAL SECTION F-F'
project no:	GEOTLCOV25293AA-AD
figure no:	FIGURE 11
rev:	A

PLOT DATE: 26/03/2015 4:59:19 PM DWG FILE: F:\GEOTECHNICS\1 PROJECTS\GEOTLCOV25293AA COCKLE BAY MARINE STRUCTURES\CAD\GEOTLCOV25293AA-AD.DWG

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