Wanda One Sydney Pty Ltd

Australia Sydney 1 Project

Geotechnical Desktop Study

17 June 2015

Pour trust
into your
foundations
and you
can build
anything

Australia Sydney 1 Project

Prepared for
Wanda One Sydney Pty Ltd
Australia Sydney 1 Project

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For and on behalf of Coffey

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1. Introduction

This report presents the results of a geotechnical desk study carried out to support the Stage 1 Development Application for the proposed Australia Sydney One Project, for Wanda One Sydney Pty Ltd.

The objectives of the study are to develop a preliminary geotechnical model in order to provide preliminary assessment of:

- Excavation conditions
- Potential ground movements and impacts on adjacent structures/infrastructure
- Potential impacts on the future rail infrastructure
- Retention system requirements and design parameters
- Suitable footing types and foundation design parameters
- Likely groundwater conditions
- Further geotechnical investigations.

2. The Site and the proposed development

The site is located at the northern extent of Pitt Street, adjacent to the above ground Cahill Expressway and elevated rail line. The site is bounded by George Street, Herald Square and Pitt Street to the west, north and east, respectively. The site includes three lots, currently occupied by the properties of Gold Fields House (1 Alfred Street), Fairfax House (19-31 Pitt Street) and The Registered Club (Registered Place, off 31 Pitt Street). The approximate size of the site is 35,000m^2, presented in the attached Figure 1.

The properties consist of:

- Gold Fields House – 28 levels with two to three levels of basement
- Fairfax House – 16 levels with one basement level
- The Registered Club – 6 levels with no basement

The redevelopment of the site is proposed to involve the construction of two towers of 56 levels (Tower A) and 23 levels (Tower B), with a common six level basement, extending to approximately RL -17mAHD. Where possible, the existing Gold Fields House basement walls are to be retained, and re-used as permanent retention to the new construction.

The heritage listed Tank Stream stormwater drainage tunnel runs underground parallel to and immediately adjacent to the eastern site boundary at this point. It flows through a masonry semi-circular arched tunnel, about 3.5m wide and 1.5m high.

The alignment for the proposed CBD Rail Link runs roughly north-north-west to south-south-east and passes under the intersection of Pitt and Alfred Street (north east corner of site). The proposed cavern crown for Macquarie Place Station will extend under the corner of the site at about RL-15.3m AHD.

3. Desk study information

3.1. Geology

The 1:100,000 Sydney Geological Sheet indicates the site is situated across a boundary between Fill, estuarine alluvium and Hawkesbury Sandstone, described on the geological sheet as follows:

- Fill: dredged estuarine sand and mud, demolition rubble, industrial and household waste.
- Alluvium: silty to peaty quartz sand silt and clay with common shell layers.
- Sandstone: medium to coarse grained with very minor shale and laminite lenses.

A plan of near vertical structural features in the CBD by Pells et al (2004) indicates the site is remote from the mapped structural features such as major fault zones or igneous intrusions. The nearest mapped features are:

- The Pittman LIV dyke (a near vertical structure, often weathered to clay) is mapped approximately 120m to the south of the site, trending generally east to west.
- The GPO Fault Zone (typically highly weathered sandstone with near vertical parallel shear zones, clay infilled joints, with some seepage) is mapped approximately 300m east of the site, trending approximately north-north east to south-south west.

Sandstone bedrock within the Sydney CBD typically follow a dominant NNE trending sub-vertical joint set, with a less dominant joint set observed running perpendicular.

3.2. Site historical background

The site is close to the initial European settlement of Sydney, which occupied the areas close to a freshwater creek, known as the Tank Stream. The Tank Stream originally ran from the site of the present day Hyde Park, parallel to the present day Pitt and George Streets entering Sydney Cove at a location close to Bridge Street. As Sydney grew in the early 19th Century the Tank Stream was progressively covered forming the current stormwater channel, located generally 5m below the existing road pavement.

Ongoing development of the Sydney Cove area through the 19th and 20th Centuries has resulted in significant land reclamation over the estuarine mud flats, creating the present day Alfred Street, Herald Square and Circular Quay.

Based on the available data, the eastern boundary of the site may lie within the margins of the Tank Stream gully. On this basis, alluvium may be encountered in eastern and southern areas of the site. The edge of the Tank Stream structure appears to run immediately adjacent to the eastern boundary of the site and is located immediately underneath the western Pitt Street footpath.

3.3. Geotechnical investigations in the locality

Coffey's local experience includes the following sites:

- 190 George Street, 200 George Street and 4 Dalley Street
- Pitt Street Hotel

- Electricity Substation at 16 Dalley Street

The sandstone encountered at these nearby sites generally has sub-horizontal bedding with dips of up to 10˚, with some cross bedding within the sandstone units of about 5˚ to 30˚. Defects in more competent rock (Class I and II sandstone) are typically spaced at 0.3m to 1.0m, except where shear zones/crushed zones are present. Clay seams may be encountered but are typically less than 10 to 15mm.

The following photograph presents bedrock conditions within Unit 5 material at a construction site near to the Sydney 1 project.

Photograph 1 – Excavation in Unit 5 bedrock

The “Foundation Plan & Details” drawing from the construction of Gold Fields House indicates pad footings founded between approximate RL -4.5m and RL -6.2m, “designed for a minimum bearing pressure of 30 tons/sq ft on sandstone”. Based on Ordnance No 70 from the Local Government Act 1919 (revised in 1988), the existing footings appear to have been designed based on the presence of “hard sandstone”, for which certain limits used to apply. The foundation condition descriptions presented in Ordnance No 70 for an allowable bearing capacity of 3,210kPa (or 30tons/sq ft) are commensurate with Class II or better sandstone

3.4. Other available information

Within our archives the following information is held:

- Geotechnical reports for 33-35 Pitt Street, dated 1981 and 1982
- Engineering borehole logs for 6-8 Underwood St
- Geotechnical engineering information at 19 Pitt Street, dated 1968
- Geotechnical information relating to the Cahill Expressway construction
- As built drawings for Goldfields House and Fairfax House

The above investigations indicate the site to be underlain by a variable thickness of fill overlying sandstone bedrock towards the western site boundary. Alluvial deposits overly the sandstone bedrock towards the Pitt Street boundary.

No survey levels are supplied for the historical information available. Ground levels have, therefore, been assumed from current road pavement levels.

4. Preliminary geotechnical model

Table 1 presents the inferred stratigraphy at the site based on the information noted in Section 3. The units are defined in terms of their origin and rock mass characteristics based on the system presented in Pells et al (1998).

Table 1: Geotechnical Units

Geotechnical Unit	General Description	Estimated Thickness
1. Fill	▪ Fill comprised of variable sand, gravel and boulders, clay and construction materials.	2m to 5m
2. Alluvium/Marine Deposits	▪ Silty and sandy clay; ▪ Typically soft to firm; ▪ Containing occasional shell beds.	3m
3. Residual Soils	▪ Stiff to very clay	<2m or absent altogether
4. Sandstone Class V & IV	▪ Extremely to moderately weathered; ▪ Very low to medium strength but containing clay seams and defects	1 to 2m
5. Sandstone Class II & I	▪ Slightly weathered to fresh; ▪ Medium to high strength. ▪ Moderately to widely spaced defects	>15m

Figure 2 presents an inferred bedrock contour plan, based on information held. We expect bedrock levels across the site to vary between about 3m AHD at the western extent and -4m AHD at the eastern boundary. The bedrock level falls towards the palaeochannel coinciding with the original course of the Tank Stream.

Figures 3 and 4 present inferred geological cross sections showing the stratigraphic units relative to approximate outline of the proposed building.

The lower basement level of Gold Fields House is constructed within sandstone bedrock, assessed to be founded on Unit 5 material. No information exists on the founding conditions at Fairfax House or the Registered Club, however, it is anticipated that both buildings are founded on bedrock, whether on piled or spread footings. Engineering borehole logs and observations of local excavations indicate the bedrock surface is typically highly weathered to moderately weathered sandstone (Unit 4), grading to slightly weathered and fresh sandstone (Unit 5) with depth.

Borehole information from nearby sites indicates that groundwater levels vary between -0.4m AHD and 0.2m AHD. The close proximity of Sydney Cove and the presence of reclamation fill suggest groundwater levels may fluctuate with tides. The ‘as-built” drawing 2564-31 of Gold Fields House retaining wall elevations show a drained basement, with a 150mm thick drainage layer below the sub-basement floor slab. Previous communication with the building manager indicated that the current groundwater flow into the basement is minimal and that the drainage system is performing satisfactorily.

5. Preliminary discussion and recommendations

5.1. Excavation conditions

Proposed bulk excavation for the basement is likely to extend to approximately -17 m AHD. Excavations are likely to penetrate through all the nominated geotechnical units, in some part. Where excavations in Unit 1, Unit 2 and Unit 3 material is required, this should be achievable using an excavator bucket. This material is likely to be encountered below the Fairfax House, the Registered Club and laneways.

The lower Unit 4 materials are likely to require the use of a D8 or D9 bulldozer fitted with a ripper or an excavator assisted by a rock saw and impact hammer.

Excavation below the existing basement at Gold Fields House, and at depth below Fairfax House and the Registered Club, in Unit 5 Sandstone would typically require a rock saw and impact hammer fitted to an excavator, such as was recently adopted for the nearby 200 George Street excavations. Ripping using a large bulldozer (D10 or D11) may be possible, however, ripping may be impracticable due to the space constraints.

If practicable, ripping productivity rates in the high strength sandstone will be low and may produce blocky material. If ripping proves to be impracticable, rock saws, impact hammers and milling machines could be used for all bulk and detailed excavation and trimming works.

The use of hydraulic impact hammers for bulk excavation, trimming excavation sides and detailed excavation, will cause vibrations that could damage vibration sensitive structures and services. Rock saws may be required to reduce risks associated with overbreak, rock hammering and excessive vibrations below the existing basement walls and adjacent to vibration sensitive structures and services.

The proximity of the excavations to the Heritage listed Tank Stream should be taken into consideration when selecting suitable excavation methods. The proximity of the excavations to the Heritage listed Tank Stream should be taken into consideration when selecting suitable excavation methods. Planning for the excavation of the basement is to include mitigation measures to minimise the impact of the project on the Tank Stream, such as those summarised within the Heritage Impact Statement and Archaeological Statement, July 2010, produced by Godden Mackay Logan Pty Ltd.

Rock cores should be obtained prior to commencing excavation and prospective excavation contractors should inspect rock core of a geotechnical investigation to make their own judgement on plant selection and likely productivity or specific plant.

Condition surveys should be carried out on neighbouring buildings and utilities, specifically the Tank Stream structure, prior to commencing excavation and vibration monitoring carried out during excavation to confirm that vibrations are not causing damage to sensitive structures.

5.2. Groundwater

Proposed basement excavations will be below the groundwater table. Anecdotal evidence suggests the current Gold Fields House basement walls perform as a cut off structure to groundwater within the fill and alluvial soils. The southern basement walls are likely to be removed, with new retention structures installed close to the site boundary. It is anticipated that the existing Gold Fields House northern and eastern retaining walls may be retained and extended to the lower basement levels.

Groundwater levels and permeability will be assessed by the installation and monitoring of piezometers as well as in-situ water pressure testing during geotechnical investigations.

Extensive dewatering of the fill and alluvial materials is not desirable as this could lead to consolidation settlement of the soil and may need special permits to discharge off site. Therefore, it is recommended to maintain the integrity of the cut-off provided by The Gold Fields House basement walls to be retained, and carry out appropriate treatment of joints or other defects near the base of the walls that may provide hydraulic connection to the groundwater within the alluvium. It is recommended that retention systems to be installed close to the perimeter of the development are installed as a groundwater cut-off to the underlying bedrock.

Groundwater inflows may occur within the underlying rock mass, either through the mass itself, along defects or at the base of the basement wall. Groundwater flows during excavation within the bedrock may be able to be managed by a drainage system. Where unacceptable groundwater inflows occur in the rock mass, targeted grouting may be able to be used to reduce inflows.

The detailed assessment and design of groundwater management systems will be addressed during the borehole investigation.

5.3. Excavation induced ground movements

Ground movements usually occur as a result of basement excavations. In the soil and rock profiles that require shoring, lateral and vertical ground movements will be dependent on the design and construction of the shoring retention system. Experience and published data suggest that lateral movements of an adequately designed and installed retention system in soil and weathered rock will be between 0.1% and 0.3% of the retained height. The extent of the horizontal movement behind the excavation face typically varies from 1.5 to 3 times the excavated height.

Whilst Class I and II Hawkesbury Sandstone is often self-supporting, it typically has high “locked in” lateral stresses that can be relieved by basement or other excavations, resulting in inwards movements of the rock mass of typically 0.5mm to 2 mm (average about 1mm) per metre depth of excavation. In addition, the lateral stresses can cause shearing movements along seams and bedding planes, resulting in differential movement. The amount and timing of ground movement will be dependent on the depth of excavation, and the location and condition of bedding defects and seams.

Depending on the specific retention system, basement excavation details and the nature of adjacent structures, detailed analysis will be required.

5.4. Excavation support

5.4.1. Underpinning adjacent structures

The depth of footings and basement levels of buildings on the southern boundary are not known. The need for underpinning of the load carrying footings of adjacent structures will need to be assessed in future investigations.

5.4.2. Retaining walls

Presently, the existing basement retaining walls of Gold Fields House are braced by the basement and ground floors slabs. When the existing structure is demolished this support will be removed and alternative temporary support will be required during construction. Along the retained northern and western boundaries, and partial southern boundary, it may be feasible to anchor the existing retaining walls (depending on the presence of basements or underground assets). It is anticipated that anchors would be extended to bedrock, where possible. The construction of new retaining structures along the southern boundary will be dictated by the presence of services or basements of neighbouring structures, which are currently unknown.

Along the eastern boundary, the presence of the Tank Stream tunnel will most likely preclude the possibility of external anchoring above about RL -1m AHD. Possible internal support, using strutting, bracing or a cantilever piled solution may be required.

Where the excavation extends beneath the toe of the existing basement walls, it may be necessary to:

- Install toe anchors to provide lateral support and reduce wall movements.
- Install support such as rock bolts and shotcrete below the base of the existing retention system.

Adequate support below the toe of the new and retained basement walls is critical to the continuing performance of the existing walls and to reduce groundwater inflows and minimise potential movement of adjacent structures and services.

Based on the preliminary geotechnical model for the site, it is expected that newly constructed retaining walls will be required where Unit 1 Fill and/or Unit 2 Alluvial soils are present, along the southern and partially along the eastern boundaries.

Depending on project requirements for a sufficiently watertight and/or stiff retention system, the following options could be considered:

- Driven sheet piles
- Secant pile wall.

For a sheet piled wall, overlapping or interlocking sheets would be vibrated or driven into the ground around the proposed basement perimeter prior to excavation. As the excavation proceeds, the sheet pile wall would require stiffening with horizontal beams, cross struts and/or temporary anchors. The steel sheet piles could be used to provide formwork for the permanent basement walls, but this would preclude their recovery. Sheet piles would likely refuse on the weathered bedrock, and groundwater seepage would be expected to occur through the clutches and toe of the wall.

Secant piling involves drilling “soft” piles using low strength concrete at centres of 1.5 × pile diameter. Normal strength “hard” piles are then drilled between the soft piles, cutting into the soft piles to form a relatively water-tight seal. The secant pile wall would be installed into bedrock around the proposed basement perimeter prior to excavation and would likely require the progressive installation of ground anchors or internal bracing to provide additional lateral stability to the wall as the excavation proceeds. Unless bored carefully, secant piles can deviate from vertical centre during installation, creating gaps between the piles and resulting in groundwater seepage and ground loss.

For the preliminary assessment of existing and new retaining walls, the parameters in Table 2 should be adopted.

Table 2: Preliminary Retaining Wall Design Parameters

Material Type	Bulk Density (kN/m^3)	Coefficient of Active Earth Pressure, K_a	Coefficient of Passive Earth Pressure, K_p
Unit 1 Fill	18	0.4	2.5
Unit 2 Alluvium	18	0.36	2.8
Unit 3 and Unit 4 Residual soil and weathered bedrock	24	0.2	5

Retaining walls should be designed for appropriate hydrostatic and surcharge loads.

Where cantilevered walls are not practicable, lateral stability could be provided by anchors installed progressively as the excavation proceeds. Anchors would need to be installed beneath adjacent properties and would need the permission of adjacent property owners and Council. We recommend that early action on negotiating permission is taken to reduce the likelihood of later delays.

5.4.3. Support of rock excavation

Excavations in rock should be able to be cut vertically provided geotechnical assessment is carried out progressively and support installed. Rock bolt support, possibly supplemented with shotcrete and mesh may be necessary in the upper weathered sections of the rock (Unit 4). In the Unit 5 bedrock, support may be limited to rock bolting of potentially unstable blocks. Particular attention should be paid to the assessment of outward projecting or re-entrant excavation corners. If sub-vertical joints cross such a corner, potentially unstable wedge type blocks can require extensive bolting.

To assess the need for bolting and rock face support, rock faces will be geotechnically assessed at the following stages:

- After the first 1m depth of excavation below retaining walls
- After each 1.5m depth increment of excavation thereafter

Preliminary design of the basement structure indicates an internal wall is to be constructed in front of the bedrock cut face, to provide protection for users. Vertical excavations for basements in the Sydney CBD have typically not required the construction of a wall for geotechnical purposes, and in some cases no protection has been required at all. Where serviceability of the basement requires a wall for aesthetic performance, Coffey recommends the construction of either a shotcrete and mesh or thin panel wall with suitable drainage formed against the rock. Such drainage measures will depend on the likely groundwater inflows, to be determined, however, likely methods may include wick drains, geo-grid ‘egg box’ drainage or free draining pea gravel. Cladding walls to be constructed against the rock face should be well articulated, and should not be constructed until all excavation induced movements have ceased. Waterproofing on the inside face of the cladding is likely to be required to minimise seepage.

5.5. Foundations

Bulk excavations for the redevelopment are expected to expose predominantly Unit 5 sandstone with some possible minor exposure of Unit 4 sandstone towards the eastern site boundary.

It is likely that column loads for the proposed redevelopment may be supported using pad, strip or piled footings founded on Unit 3 sandstone bedrock. Ultimate limit state geotechnical design parameters are provided in Table 3 for various classes of sandstone. Foundation design should be consistent with the limit state design methodology presented in Australian Standards.

Table 3: Preliminary Foundation Design Parameters

Geotechnical Unit	Limit State Design		
	Ultimate End Bearing Capacity (kPa)	Ultimate Shaft Adhesion (kPa)*	Elastic Modulus (MPa)
Unit 4 Sandstone	6,000	350	250
Unit 5 Sandstone	40,000	2,000	1,000

*Shaft adhesion should be ignored for pad footings

The above parameters are applicable only where strict on site assessment of construction methodology is followed, such as pile base cleanliness and wall roughness. For limit state design of pile foundations, a geotechnical reduction factor, ϕ_g, will require assessment in accordance with the Australian Standard AS2159-2009.

All footing excavations should be observed by a geotechnical engineer to assess the foundation conditions. Where serviceability limit state bearing capacities greater than 3,500 kPa are adopted, foundation defects should be assessed by cored boreholes or spoon testing in jackhammer holes and/or observation of rock exposures in lift wells (if available). The number of tests for verification will depend on the number and layout of footings, and the number of existing cored boreholes.

5.6. Planning for the future railway

5.6.1. The CBD Rail Link

The future CBD Rail Link tunnels and caverns will be in relatively close proximity to the proposed basement structure. Preliminary drawings were previously prepared by RailCorp (now Sydney Trains), during the previous Development Application phase, showing exclusion zones with restricted loading surrounding the proposed underground assets.

During the interim, the planning and control of the CBD Rail Link has been transferred from RailCorp to Transport for NSW (TfNSW), and specifically the Sydney Metro program. Recent experience of developments close to the CBD Rail Link indicates that the former exclusion zones are unlikely to be adopted for determination of developments that may impact on the rail tunnels. A recent approach has been adopted by TfNSW to require Finite Element (FE) modelling to assess the impact of the development on future constructability of rail tunnels and stations. Furthermore, the impact of the future tunnel construction on the development will require assessment.

The FE assessment has been used largely to assess whether the design of developments will impact or impede the construction of the tunnels and stations, based on standard tunnelling methods, including:

- Foundations and structural loading.
- Potential ground movement.
- Water tightness and groundwater control.

It must be noted that no information is available for the likely tunnel construction method or station layout for the Sydney Metro development, which is planned to replace the CBD Rail Link, with smaller tunnels and single decker trains. Therefore, alignment configurations may change, and thus the impacts of the development may change, however, we cannot assess the impacts of these changes as part of our desk study.

5.6.2. Foundations and structural loading

The maximum proposed bulk excavation for the basement will extend to approximately RL -17 m AHD, which is a similar level to the crown level of the CBD Rail Link tunnels and station cavern. Based on the assessment of likely ground levels, it is anticipated that the lower basement level will be in Unit 5 sandstone. It is also inferred that the proposed CBD Rail Link tunnels will be constructed in Unit 5 sandstone.

Shallow footings at the base of the proposed level basements will be located outside of the TfNSW typical protection zones and will not apply additional loading to CBD Rail Link. Footings should be designed to allow for the effects of removal of rock mass in the assumed tunnel zones.

5.6.3. Potential ground movement

The construction of tunnels induces ground movements to the sides and in front of the advancing tunnel face. The magnitudes of the ground movement is dependent on several factors, including tunnelling method, the quality of workmanship, ground and groundwater conditions and geotechnical properties. The CBD Rail Link tunnels in the vicinity of the development will be constructed within high strength sandstone; therefore the majority of the ground movement induced by tunnel construction will be a result of stress redistribution within the rock mass.

The construction of the basement will result in stress redistribution and potential stress relief within the bedrock. This stress redistribution may result in opening of existing bedding planes and rock defects, and also movements along these features. Furthermore, the construction of the rail tunnels is likely to cause further stress redistribution, which may result in ground movements which effect the basement structure.

In our experience, surface ground movements immediately above the tunnels associated with the construction of two tunnels of similar size, depth and location to the CBD Rail Link relative to the proposed development may be less than 5 mm. However, ground movements, both vertically and laterally, at depth may be significantly greater. Therefore, ground movements induced by the tunnel construction will need to be analysed and designed for. The development will then be designed to tolerate the anticipated tunnelling induced ground movements associated with the construction of the CBD Rail Link.

The methodology for the prediction of tunnelling induced ground movements will be as follows:

- Complete the site investigation
- Develop a geotechnical model and associated design parameters
- Conduct numerical analysis for the basement and tunnel construction, including a sensitivity assessment of the various input parameters.
- Calibrate the analysis results against measured movements for tunnels constructed in similar conditions.
- Develop instrumentation and monitoring plan to measure actual movements with those predicted.

In addition, the detailed design of the basement adjacent to the proposed tunnels would need to consider the potential impacts of the future rail construction works, including:

- Low pressure conditions during tunnel construction
- Impacts of tunnel grouting operations (if required)

- Additional loading on the basement due to tunnelling.

5.6.4. Water tightness and groundwater control

The proposed basement excavations will be predominantly within Unit 5 bedrock below the groundwater table. No groundwater inflow assessments are possible at this stage of development, however the existing two level basement is understood to be operating adequately, suggesting manageable groundwater inflows through bedrock at RL -4m AHD.

Geotechnical investigations will be performed to assess the rock mass permeability to the Basement 5 level. This information will assist in the design of a drained or tanked basement structure. Where groundwater inflows are high a method of ground improvement may be adopted to attempt to limit volumes to a drained basement. Where such improvement does not result in a level of inflow reduction, a tanked basement design may be adopted. As such, the proposed development is unlikely to result in changes to groundwater levels within the areas around the tunnels.

5.6.5. Impact of project construction on the CBD Rail Link

The findings in this report indicate that the development is not located in an area of known major structural features such as major fault zones or igneous intrusions. It is inferred that the existing basement floor is underlain by Unit 5 bedrock. It is likely that the majority of the proposed basement will be constructed within Unit 5 sandstone. Similarly, the CBD Rail Link tunnels in the vicinity of the development are likely to be constructed within Unit 5 sandstone.

At detailed design stage a ground investigation including borehole drilling will be carried out to provide information on the ground conditions at the site, including the presence and nature of the rock jointing. A detailed geotechnical model will be developed for the basement excavation which will include the findings of the ground investigation together with borehole information from nearby sites. The impact of any identified adversely oriented joints will be considered in the basement excavation design.

Appropriate excavation procedures will be developed to reduce risks of deterioration of the surrounding rock mass quality. These may include limiting over-excavation and vibration damage by rock sawing on excavation boundaries adjacent to the proposed CBD Rail Link.

Excavation in rock should be progressed with geotechnical assessment being carried out progressively and rock support measures installed as required. If rock bolts are required to be installed, they will be designed to be outside the CBD Rail Link excavation zone. They will be isolated from stray currents, or alternatively fibreglass bolts may be considered.

At detailed design stage of the basement an assessment of the impacts, if any, on the future tunnel works will be assessed. This would include assessment of:

- Any additional loading on the tunnel lining
- Impacts on tunnelling rates
- Relaxation of the ground which may result in ravelling and ground loss
- Future monitoring requirements.

Based on our understanding of the site conditions Coffey assess that the presence of the proposed basement may be of risk to the future CBD Rail Link tunnels on the nominated alignments. This assessment is based on construction of the basement may result in a change to stress distribution within the areas around the tunnels. However:

- The basement construction methodology is not anticipated to affect the zone which would be tunnelled.

- Construction of the basement will not result in significant adverse change to groundwater levels within the areas around the tunnels.
- There is no evidence of major faulting in the vicinity of the basement or tunnels.
- No additional loads on the CBD Rail Link tunnels are anticipated resulting from groundwater inflow to the basement.

A more detailed assessment of potential impacts on the CBD Rail Link tunnels will be undertaken at detailed design stage of the basement.

5.7. Recommended monitoring measures

A geotechnical monitoring programme should be implemented during the construction phase as a check of design assumptions and to enable excavation support to be installed progressively as required by the revealed conditions. The programme should include, as a minimum, the following components:

- Monitoring of surface survey points located on existing structures, on any retaining wall, and on the ground surface at lateral distance from the excavation. Survey monitoring should be undertaken on a weekly basis during construction. Monitoring points should provide for accurate recording of both vertical and horizontal movements
- Undertake regular geotechnical assessments of exposed rock faces. Installation of rock face support as required
- Vibration monitoring on vibration sensitive structures located close to the excavation, such as the adjacent buildings and the Tank Stream structure.

6. Conclusions

Coffey has assessed the proposed redevelopment scheme in the context of the existing geotechnical conditions at the site and conclude that the site is suitable for its intended use.

Coffey is satisfied that the geotechnical challenges posed by the site conditions, including the high/perched groundwater water and potential impact of ground movements due to excavation on adjacent sensitive structures, can be adequately addressed through the utilisation of industry-standard design and construction techniques and practices.

7. Limitations and further geotechnical involvement

The preliminary geotechnical assessment and recommendations presented in this report are based on a desk study limited to boreholes located outside of the site boundaries. Ground conditions can vary over relatively short distances and site specific investigation and construction stage geotechnical assessments should be considered to manage geotechnical risk.

We recommend that a minimum of six cored boreholes, both vertical and inclined, be drilled on site to approximately 20 to 25 m below ground level, with an assessment of the rock mass permeability to be undertaken by insitu testing in at least 2 locations.

Furthermore, a FE model assessment of the potential impacts on the CBD Rail Link will be performed as part of the detailed design phase.

The attached document entitled “Important information about your Coffey report” forms an integral part of this report and presents additional information about its uses and limitations.

8. References

Pells PJN, Mostyn G & Walker BF (1998) “Foundations on Sandstone Shale in the Sydney Region” Aust. Geomech. Jnl, Dec 1998.

Pells PJN, Braybrooke J & Och D (2004) Map and Selected Details of Near Vertical Structural Features in the Sydney CBD

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.

Important information about your **Coffey** Report

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

drawn	MG / AW	coffey	client:	WANDA ONE SYDNEY PTY LTD			
approved	MG		project:	AUSTRALIA SYDNEY 1 PROJECT CIRCULAR QUAY, SYDNEY, NSW			
date	05 / 06 / 15		title:	SITE LOCATION PLAN			
scale	AS SHOWN						
original size	A4		project no:	GEOTLCOV24001AD	figure no: FIGURE 1	rev:	A

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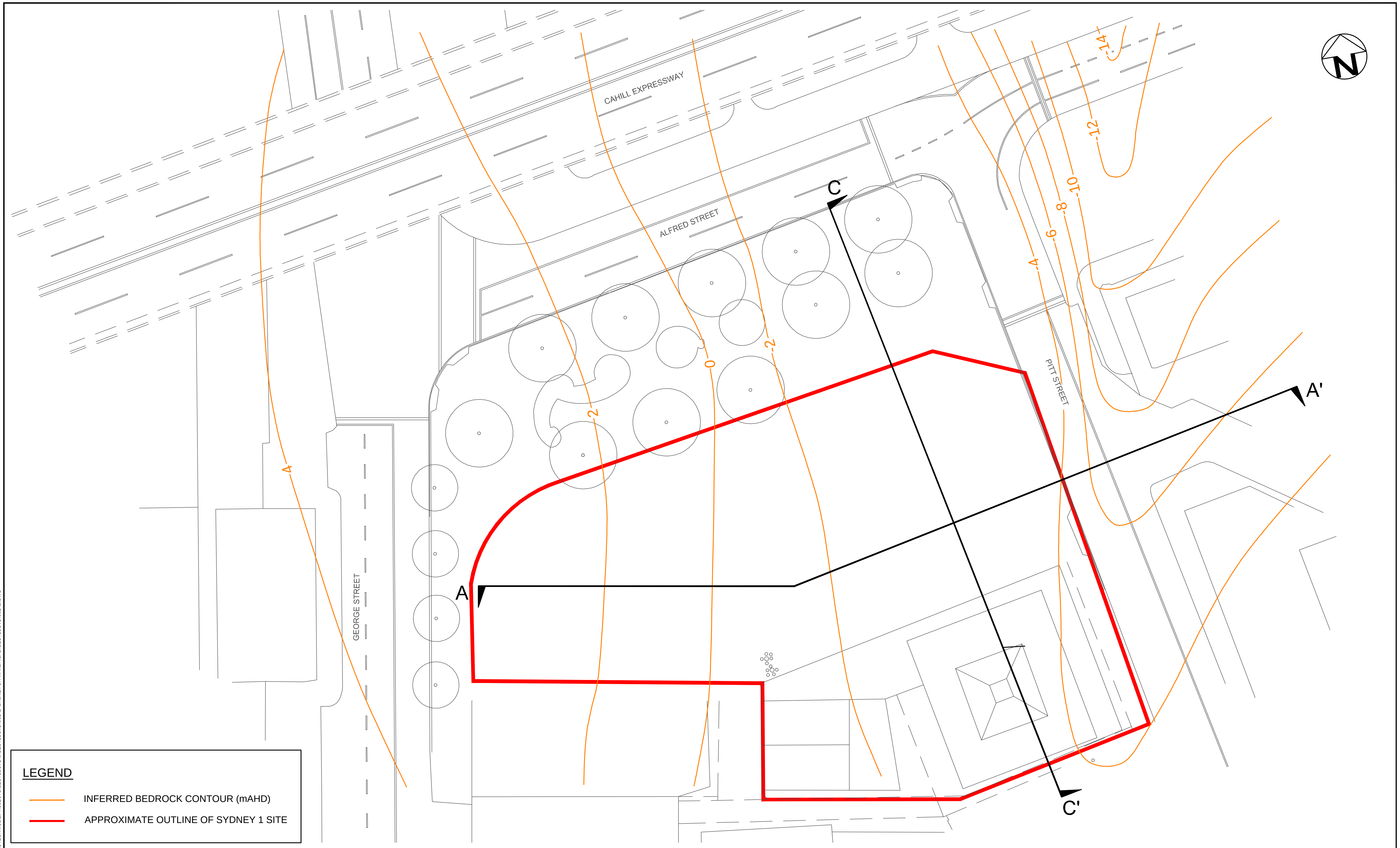

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revision

no.	description	drawn	approved	date
A	ORIGINAL ISSUE	MG	MG	05/06/2015

drawn	MG / AW
approved	MG
date	05 / 06 / 15
scale	AS SHOWN
original size	A3

coffey

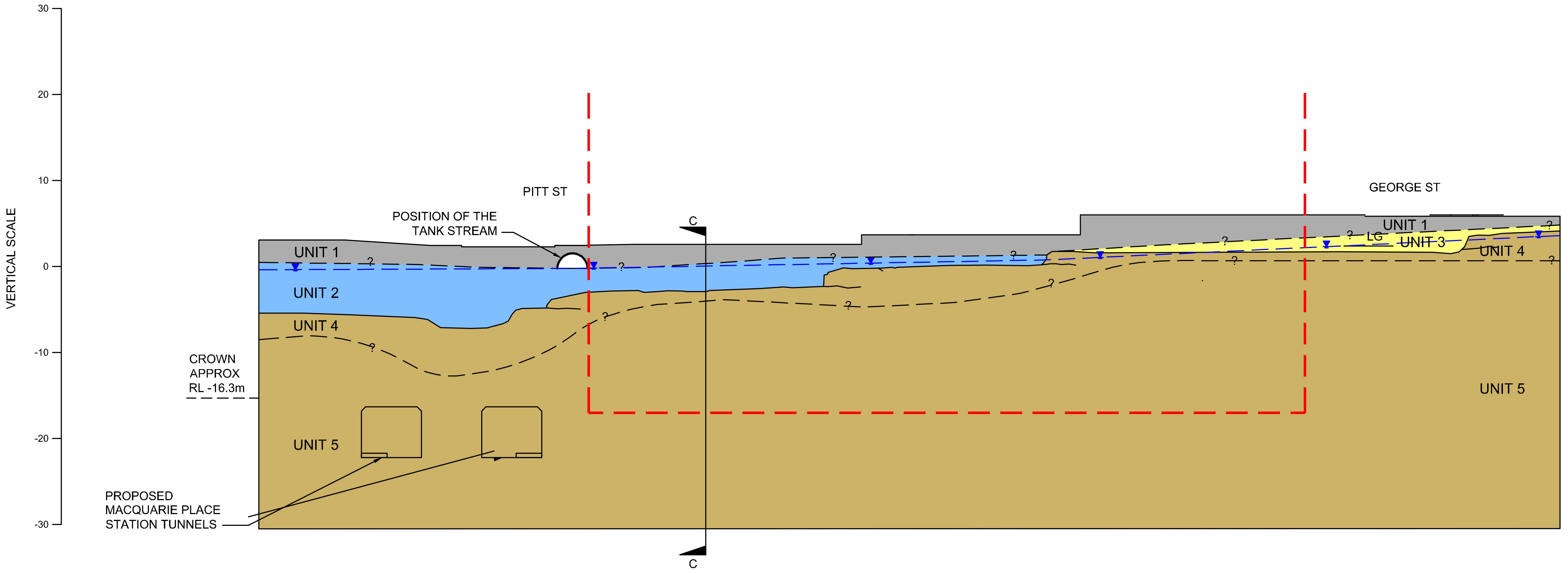
client:	WANDA ONE SYDNEY PTY LTD
project:	AUSTRALIA SYDNEY 1 PROJECT CIRCULAR QUAY, SYDNEY, NSW
title:	INFERRED BEDROCK CONTOUR PLAN
project no:	GEOTLCOV24001AD
figure no:	FIGURE 2
rev:	A

NOTES:

1. LOCATIONS OF THE TANK STREAM AND MACQUARIE PLACE STATION ARE INDICATIVE ONLY AND SHOULD NOT BE RELIED UPON FOR OTHER PURPOSES.
2. LOCATION AND EXTENT OF STRATIGRAPHICAL UNITS IS INFERRED AND BASED ON BOREHOLES DRILLED AT NEARBY SITES. ACTUAL CONDITIONS MAY VARY FROM THOSE SHOWN.

LEGEND:

- APPROXIMATE POSITION OF AUSTRALIA SYDNEY 1 PROJECT
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUNDWATER LEVEL
- UNIT 1 - FILL
- UNIT 2 - ALLUVIUM / MARINE DEPOSITS
- UNIT 3 - RESIDUAL SOIL
- UNIT 4 / UNIT 5 - SANDSTONE



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Scale (metres) 1:500

no.	description	drawn	approved	date
A	ORIGINAL ISSUE	MG	MG	05/06/2015

revision

drawn	MG / AW
approved	MG
date	05 / 06 / 15
scale	AS SHOWN
original size	A3

coffey

client: WANDA ONE SYDNEY PTY LTD

project: AUSTRALIA SYDNEY 1 PROJECT
CIRCULAR QUAY, SYDNEY, NSW

title: SECTION A-A' INFERRED GEOLOGICAL CONDITIONS

project no: GEOTLCOV24001AD | figure no: FIGURE 3 | rev: A

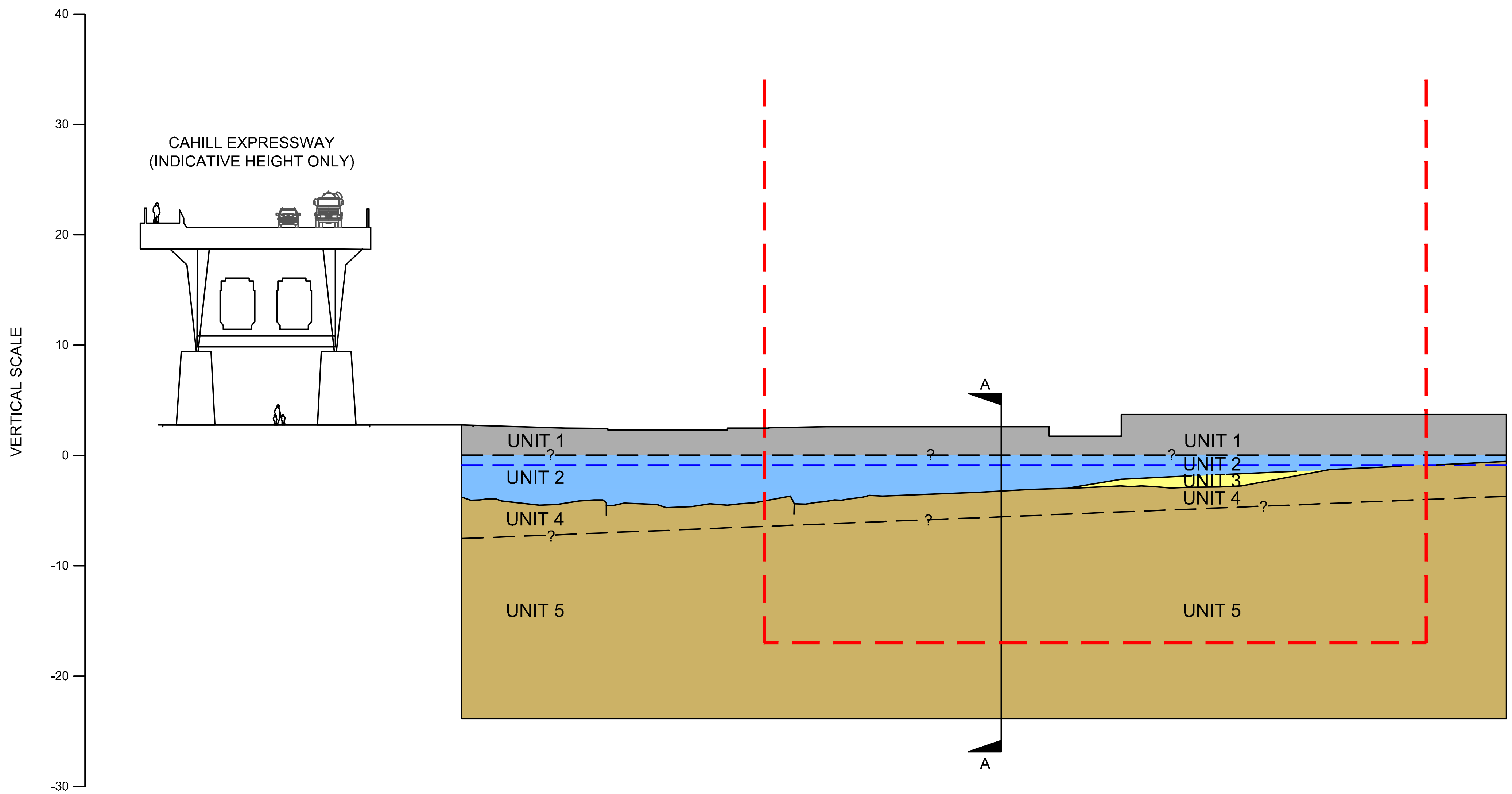
PLOT DATE: 5/06/2015 3:49:27 PM DWG FILE: F:\GEOTECHNICS\1.PROJECTS\GEOTLCOV240\GEOTLCOV24001AD CRONE FOR WANDA\CAD\GEOTLCOV24001AD.DWG

NOTES:

1. LOCATION AND EXTENT OF STRATIGRAPHICAL UNITS IS INFERRED AND BASED ON BOREHOLES DRILLED AT NEARBY SITES. ACTUAL CONDITIONS MAY VARY FROM THOSE SHOWN.

LEGEND:

- APPROXIMATE POSITION OF AUSTRALIA SYDNEY 1 PROJECT
- —?— INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUNDWATER LEVEL
- UNIT 1 - FILL
- UNIT 2 - ALLUVIUM / MARINE DEPOSITS
- UNIT 3 - RESIDUAL SOIL
- UNIT 4 / UNIT 5 - SANDSTONE



revision	no.	description	drawn	approved	date
	A	ORIGINAL ISSUE	MG	MG	05/06/2015

5 0 5 15 25

Scale (metres) 1:500

drawn	MG / AW
approved	MG
date	05 / 06 / 15
scale	AS SHOWN
original size	A3

coffey

client:	WANDA ONE SYDNEY PTY LTD
project:	AUSTRALIA SYDNEY 1 PROJECT CIRCULAR QUAY, SYDNEY, NSW
title:	SECTION C-C' INFERRED GEOLOGICAL CONDITIONS
project no:	GEOTLCOV24001AD
figure no:	FIGURE 4
rev:	A