Alternative construction methods to rock hammering and blasting (Condition E35)

Project: Sydney Metro City & Southwest – TSE Works

Document No: SMCSTSE-JCG-TPW-EN-RPT-097229

DOCUMENT APPROVAL

REVISION	DATE	PREPARED BY	REVIEWED BY	APPROVED BY	REMARKS
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Signature:					

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Glossary

Term/ acronym	Definition
CEMF	Construction Environmental Management Framework (Appendix B of the Submissions and Preferred Infrastructure Report)
CEMP	Construction Environmental Management Plan
DP&E	NSW Department of Planning and Environment
EIS	Environmental Impact Statement for Sydney Metro Chatswood to Sydenham
EPA	Environment Protection Authority
EPL	Environment Protection Licence
EP&A Act	Environmental Planning and Assessment Act 1979
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPBC Act	Environmental Protection and Biodiversity Conservation Act 1999 (Cth)
JHCPBG	John Holland CPB Ghella
POEO Act	Protection of the Environment Operations Act 1997
Project	Sydney Metro City & Southwest
Project Planning Approval	Critical State Significant Infrastructure Sydney Metro & Southwest Chatswood to Sydenham Infrastructure Approval dated 9 January 2017 (Application no. SSI 15_7400)
Relevant Councils	Any or all as relevant, Willoughby, North Sydney, City of Sydney or Inner West
REMM	Revised Environmental Mitigation Measures (Chapter 11 of the Submissions and Preferred Infrastructure Report).
SPIR	Sydney Metro & Southwest Chatswood to Sydenham Submissions and Preferred Infrastructure Report, October 2016
SSI	State Significant Infrastructure
SWTC	Scope of Work and Technical Criteria
TBM	Tunnel Boring Machine
TfNSW	Transport for New South Wales
TSE Works	Tunnels and Station Civil Works for the Sydney Metro City & Southwest Project

1.0 Introduction

1.1 Purpose

John Holland CPB Contractors Ghella (JHCPBG) has been nominated 1st ranked tenderer to be awarded the Design and Construction Contract for the Tunnel and Station Excavation Works (TSE Works) of the Sydney Metro City & Southwest Project (the Project). Transport for NSW (TfNSW) is delivering the Project on behalf of the NSW Government.

The Project was approved by the Minster for Planning on 9 January 2017 subject to a number of Conditions set out in Critical State Significant Infrastructure Sydney Metro & Southwest Chatswood to Sydenham Infrastructure Approval (Application no. SSI 15_7400) (Project Planning Approval).

This report has been prepared to address the requirements of Project Planning Approval Condition E35 and will be provided to the independent Acoustic Advisor for approval in accordance with the requirements of this Condition.

1.2 Background

This report builds on the noise and vibration assessment and analysis undertaken in the EIS and Submissions and Preferred Infrastructure Report. Assessments were undertaken by SLR Consulting Australia Pty Ltd (SLR) as part of the EIS, to determine the impacts of airborne and ground-borne construction noise and vibration and construction traffic. As the EIS included a worst case assessment giving an overly conservative result, it did not accurately present noise levels that receivers would experience during the majority of the construction works. Additional noise and vibration case studies were therefore included in the Submissions and Preferred Infrastructure Report to better describe typical noise and vibration impacts and to demonstrate that they can be managed to acceptable levels.

Project Planning Approval Condition E35 requires that:

> *"The Proponent must review alternative methods to rock hammering and blasting for excavation as part of the detailed construction planning with a view to adopting methods that minimise impacts on sensitive receivers. Construction Noise and Vibration Impact Statements must be updated for each location or activity to adopt the least impact alternative in any given location unless it can be demonstrated, to the satisfaction of the AA, why it should not be adopted."*

The Department of Planning and Environment's (DP&E's) Secretary's Report notes that alternatives to rock breaking and blasting, such as using diamond impregnated wire saws, bursting and splitting, were investigated but discounted as a primary excavation methodology due to their potential limited application, which would require a mix of techniques and plant extending the duration of works. The Secretary also note that the time and noise benefits of blasting over rock breaking are recognised, but it is also noted that rock breaking or similar would still be required for initial excavation until appropriate blasting depth (i.e. until rock is reached with an appropriate safety buffer). The Secretary therefore considers that detailed construction noise planning for excavation should consider all available methods to minimise noise and vibration impacts to receivers, before committing to any particular method.

1.3 JHCPBG's 'Beyond the Game' vision

JHCPBG will implement a clear vision and communicate the values and underpinning behaviours expected of all staff and workforce who participate in the TSE Works.

JHCPBG's 'Beyond the Game' vision is based on our very recent experience in successfully completing the Sydney Metro Northwest Tunnels and Station Civil (TSC) Works. Similarly, the success of the TSC Works was largely attributed to developing a vision lead values based high performance culture 'Beyond the Game' and its guiding values focusses effort towards proactive identification and management of potential issues well ahead of construction. It is a multi-disciplinary and collaborative approach. Our values are:

- One team
  - We work together to deliver the right outcome
  - We listen, we speak up, and we support the final decision
  - We plan for safety and we work safely
- Responsibility
  - I understand what I have to do, when it needs to be done and I own the delivery
  - We always keep each other accountable – the standard we walk past is the standard we accept
  - Our safety is my responsibility
- Integrity
  - We do the right thing, in the right way and for the right reason
  - We act professionally, honestly and fairly at all times
  - We champion safety and challenge any unsafe acts
- Humility
  - We never get too big to do the small things that need to be done
  - We are open to new perspectives and share lessons learnt
  - We empower all team members to focus on continually improving our safety performance

Non-negotiables underpin this vision by establishing safety and environment ground rules to drive expected and required behaviours. JHCPBG's 'Beyond the Game' vision will be communicated to employees and subcontractors as part of interview and procurement processes. Our 'Beyond the Game' vision works to ensure that we get the right people to join our team. By putting health and safety first, being environmentally responsible and supporting our host communities, we will again deliver a world class project.

1.4 Structure of this Report

This report is structured as follows:

- Section 2.0 provides an overview of roles and responsibilities with respect to noise management
- Section 3.0 provides an overview of the TSE Works, construction methodology and scope changes determined and under consideration since the Project Planning Approval was granted.

- Section 4.0 provides an overview of elements of the TSE Works where the use of rock hammers and blasting is being considered
- Consideration of alternative construction methodologies for demolition is set out in Section 5.0
- Consideration of alternative construction methodologies for site establishment is set out Section 6.0
- Consideration of alternative construction methodologies for dive, station and shaft excavation is set out in Section 7.0
- Consideration of alternative construction methodologies for cross passage, nozzle and stub tunnel construction is set out in 8.0
- Restrictions on rock hammering are detailed in Section 9.0
- Conclusions are set out in Section 10.0.

2.0 People and collaboration

2.1 Noise and vibration experts

JHCPBG has engaged Renzo Tonin and Associates Pty Ltd (RT&A) to undertake construction noise and vibration modelling for the TSE Works. Established in 1982, RT&A is a leading engineering consulting firm, dedicated to providing a full range of acoustic services including noise, sound quality, vibration and structural dynamics. A member of the Australian Association of Acoustical Consultants, with offices in Sydney, Melbourne, Brisbane and Kuwait, RT&A's award winning consultancy assists architects, engineers, planners, developers and builders, and services government and private enterprise across a diverse range of projects.

RT&A has undertaken comprehensive noise and vibration modelling in developing our tender offer. This detailed modelling has been a key input to our construction planning and identified the suite of reasonable and feasible noise mitigation measures we will implement when delivering the TSE Works. RT&A have provided detailed input to the preparation and finalisation of this report.

During delivery, RT&A will continue to provide specialist advice and services in the development and implementation of this Plan and associated documents to ensure impacts can be avoided, minimised or appropriately mitigated including:

- Preparing the Construction Noise and Vibration Management Plan (SMCSTSE-JHCPBG-TPW-EN-PLN-002012)
- Preparing Construction Noise and Vibration Impact Statements
- Undertaking noise and vibration monitoring when required
- Assisting in community consultation when required.

2.2 JHCPBG Peer review

JHCPBG has engaged Wilkinson Murray to peer review RT&A's noise and vibration assessment and this Report. Wilkinson Murray is an independent Noise, Vibration & Air quality Consulting firm, established over 50 years ago with offices in Sydney, Orange, Queensland and Hong Kong. The firm has worked on many construction projects particularly for large major infrastructure projects in Sydney and Asia. Wilkinson Murray has developed a high level of expertise and has collected a large amount of noise and vibration data pertaining to tunnelling construction and, in relation to ground-borne noise from tunnelling from TBM and roadheader operations.

John Wassermann, who has conducted this review, is a Director at Wilkinson Murray Pty Ltd and is a Mechanical Engineer with over 25 years' experience in the public and private sectors. John worked in the NSW State Government, initially as the Manager of the Noise Assessments area for the EPA, and subsequently as Manager Transport for the Major Infrastructure Assessment area of the then Department of Planning. He has been at Wilkinson Murray since August 2004. John has considerable experience in NSW environmental, noise and air quality legislation, Environment Planning and Assessment Act (1979) and the POEO Act (1997). While working for Government, John has had substantial involvement in regulation and assessment of transport and energy related state significant projects and major infrastructure. While working as a consultant he has been involved in

some of NSW largest infrastructure projects including Cross City Tunnel, Lane Cove Tunnel and the Epping to Chatswood Rail Link.

Mr Wasserman's peer review of this report is documented in Appendix A.

2.3 Acoustic Advisor

Under Project Planning approval Condition A25, a suitably qualified and experienced acoustic advisor who is independent of the design and construction personnel must be nominated by the Proponent and engaged for the duration of construction and for not less than six (6) months following operation of the Project. TfNSW has engaged Dave Anderson, Acoustic Design Studio to be the AA and the Secretary of DP&E approved his appointment.

2.4 Environment Protection Authority

As the JHCPBG Joint Venture is not incorporated, John Holland Pty Ltd will obtain an Environment Protection Licence (EPL) for Rail Systems Activities and Concrete Works as defined under Schedule 1 of the Protection of the Environment Operations Act, 1997 (POEO Act) from the Environment Protection Authority (EPA). The EPA have indicated that demolition works do not require an EPL.

John Holland will apply for an EPL directly following contract award. The EPL will include a number of strict Conditions to regulate emissions including noise and vibration.

2.5 Collaboration with TfNSW, the ER and the JHCPBG team

JHCPBG's relationship with TfNSW, key regulatory stakeholders, the independent Environmental Representative (ER), independent Acoustic Advisor and the Independent Certifier (IC) are shown in Figure 1.

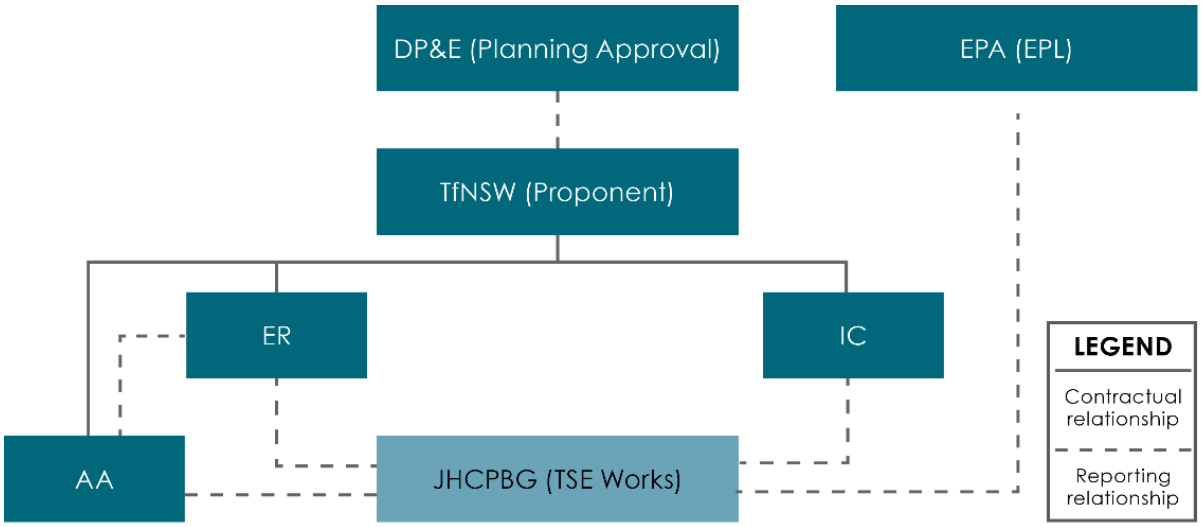

Figure 1: JHCPBG's relationships with key stakeholders

Under the leadership of JHCPBG's Approvals, Environment and Sustainability Manager, we will manage planning approvals, site environmental performance and sustainability together with our design, construction, commercial, quality, safety and community teams. JHCPBG will work collaboratively with environmental stakeholders to ensure all opportunities to minimise impacts will be explored and implemented where reasonable and feasible

3.0 TSE Works Overview

3.1 Approved TSE scope

The TSE Works approved under the Project Planning Approval include design and construction of:

- A northern dive structure approximately 400 metres in length and tunnel portal just north of Mowbray Road, Chatswood
- 15.5 km twin underground upline and downline railway tunnels between Chatswood and Sydenham and 49 cross passages and 8 cross passages with sumps spaced approximately 200 to 240 metres apart
- Excavation and construction of the permanent lining of a shaft at the site of the Artarmon substation (the substation is to be constructed by a follow-on contractor)
- Excavation of stations at Crows Nest, Victoria Cross, Martin Place, Pitt Street and Waterloo
- Excavation of the station and crossover cavern at Barangaroo to allow trains to cross from one track to the other and construction of structures within the Barangaroo station
- Excavation of a temporary access shaft at Blues Point and backfilling and remediation of this site to its existing condition
- A southern dive structure about 400 metres in length and tunnel portal between Sydenham Station and south Bedwin Road, Marrickville
- Establishment and operation of a temporary bespoke precast facility to manufacture the Tunnel Boring Machine (TBM) tunnel lining segments.

3.2 Overview of construction methodology

The construction methodology adopted for the TSE Works entails:

- Demolition works (under both the Demolition Contracts and TSE D&C Deed) to remove existing buildings and structures on TSE Worksites. The extent of demolition works not completed by the two TfNSW Demolition Contractors on award of the TSE D&C Deed will be novated to the TSE Contractor
- Establishment of the precast facility at Marrickville adjacent to the southern dive site to provide segments for the permanent TBM tunnel lining
- Establishment of worksites at Chatswood, Artarmon, Crows Nest, Victoria Cross, Blues Point Barangaroo, Martin Place, Pitt Street, Waterloo and Sydenham
- Local Area (Road) Works, utilities relocation, protection and connection are also required as part of site establishment
- Construction of the station and shaft excavations, the dive structures at Chatswood and Marrickville and the temporary shaft at Blues Point
- Five TBMs will be used to construct the mainline tunnels as follows:
  - Two hard rock TBMs will be launched from Chatswood and tunnel south to Blues Point (a distance of approximately 6 km). It is anticipated that station excavation will

be completed in advance of TBM tunnel construction. The TBMs will be delivered via oversize heavy vehicles at Chatswood and retrieved via road or barge at Blues Point

- Two hard rock TBMs will be launched from Marrickville and tunnel north to Barangaroo (a distance of approximately 8 km). It is anticipated that station excavation will be completed in advance of TBM tunnel construction breaking though and being relaunched from the station excavations. The TBMs will be delivered via oversize heavy vehicles at Marrickville and retrieved via barge at Barangaroo
- Due to different ground conditions, a slurry TBM will be launched from Barangaroo and tunnel north to the temporary Blues Point shaft (a distance of approximately 1 km). The slurry TBM will be retrieved, disassembled and transported back to the Barangaroo worksite via barge and re-assembled and relaunched to complete the second tunnel to Blues Point.

- Cross passages construction will be undertaken closely following the TBMs.

The TSE Works do not include any surface works at Central - the TBMs will pass straight through underground. Surface works including station excavation are to be undertaken by the CSM Contractor.

Tunnelling and associated support activities will be undertaken 24 hours a day and seven days per week.

3.3 Actual and potential scope changes since granting of the Project Planning Approval

TfNSW have determined some scope changes since the Project Planning Approval was granted and are currently investigating a number of additional changes to the Project scope which could impact on the scope of the TSE Works. These potential changes are summarised in Table 1, along with the proposed planning approval pathway.

Table 1: Potential scope changes and proposed planning approval pathway

Scope change	Proposed planning approval pathway	Status
Change to the tunnel alignment between Waterloo and Sydenham	Consistency assessment	Approved by TfNSW 9/5/17
Change to the site area at Barangaroo	Consistency assessment	Approved by TfNSW 9/5/17
Relocation of the Artarmon substation riser to 97 Reserve Road and Relocation of the Victoria Cross North shaft to 50 McLaren Street	Modification to Project Planning Approval (including Project Planning Approval Condition A21)	TfNSW currently preparing the assessment and public exhibition is planned for June 2017
Modifications to Martin Place to incorporate the unsolicited proposal submitted by Macquarie Capital.	Modification to Project Planning Approval	TfNSW currently preparing the assessment and public exhibition is planned for June 2017
Earthworks and culvert installation for the Sydney Metro Trains Stabling Facility (South) once the precast facility at Marrickville has been decommissioned.	Modification to Project Planning Approval	TfNSW currently preparing the assessment and public exhibition is planned for June 2017

TfNSW will determine the appropriate planning approval pathway for these changes. This Report has been prepared to address this changed and additional scope of work. It assumes all these changes will be adopted to avoid the need for later updates.

4.0 Alternatives to rock hammering and blasting

As set out on Section 3.2, the twin rail tunnels (which constitutes the vast majority of the TSE Works) will be excavated using TBMs. Except in the CBD, the rail tunnels are approximately 6 metres apart and between 14 to 48 metres below ground level. In the CBD the running tunnel diverge at stations to minimise long term property impacts. Given their depth and the nature of the cutting process the noise impact from TBMs is limited to regenerated noise which for any given location is very limited in duration, usually affecting a residence or building for no more than two days (one day per TBM pass by). As such, using TBMs will greatly reduce the overall noise and vibration impact of delivering the TSE Works.

In addition, the Artarmon Substation shaft will be excavated with a large diameter piling rig instead of traditional rock hammering method. This will also reduce noise and vibration impacts near these works.

The potential use of rock hammering and blasting to deliver the TSE Works is therefore limited to:

- Demolition of existing buildings and structures to make way for the TSE Works
- Site establishment including utility and local area works
- Dive, station and shaft excavations, including the cross-over cavern at Barangaroo
- Cross passage, nozzle and TBM launch stub excavation

The activities set out above are considered separately taking into account the following:

- The extent and specifications of the required excavation or breaking work
- Geotechnical conditions
- Safety implications
- Program implications

As this report is focused on alternatives to both rock hammering and blasting, further consideration of blasting will be documented in a separate Blast Management Strategy to be prepared only if blasting is adopted. Consideration of non-explosive alternatives to blasting are set out in Section 7.6.

5.0 Alternatives considered for demolition

5.1 Extent of demolition

Demolition will be undertaken at the following TSE worksites and includes the following buildings:

- Martin Place
  - 39-51 Martin Place, Prudential Building (Tiffany & Co.) (DP1103195),
  - Martin Place Shopping Circle (part of)
- Pitt Street South
  - 125 – 129 Bathurst St (DP60293)
  - 131 – 135 Bathurst St (DP59101)
  - 296 – 300 Pitt St (DP436359)
  - 302 Pitt St (DP62668),

As noted in Section 3.2, the extent of demolition works not completed by the two TfNSW Demolition Contractors on award of the TSE D&C Deed will be novated to the TSE Contractor. This includes:

- Chatswood
  - All low level buildings currently occupying the worksite bounded by Pacific Highway, Mowbray Road, Nelson Road and the rail corridor.
- Crows Nest
  - 477 Pacific Highway
  - 479 Pacific Highway
  - 495 Pacific Highway
  - 497 Pacific Highway
  - 501 Pacific Highway
  - 503 Pacific Highway
  - 507 Pacific Highway
  - 511 Pacific Highway
  - 521 Pacific Highway
  - 14 Clarke Street
- Victoria Cross
  - 155-167 Miller Street
  - 181 Miller Street
  - 187-189 Miller Street

- Martin Place
  - 12 Castlereagh Street
  - 55 Hunter Street
  - 5 Elizabeth Street
  - 7 Elizabeth Street
- Pitt Street North
  - 252-254 Pitt Street
  - 256 Pitt Street
  - 40 Park Street
  - 42 Park Street
  - 44 Park Street
  - 46 Park Street
  - 48 Park Street
  - 175-183 Castlereagh Street
- Waterloo
  - 49 Botany Road
  - 59-63 Botany Road
  - 65-67 Botany Road
  - 69-83 Botany Road
  - 85-87 Botany Road
  - 89 Botany Road
  - 93-101 Botany Road
  - 107-117A Botany Road
  - 119-121 Botany Road
  - 122-128 Cope Street
  - 132-134 Cope Street
  - 156-160 Cope Street
  - 170-174 Cope Street
- Marrickville
  - All low level building currently occupying the worksite bounded by Edinburgh Road, Sydney Steel Road, Railway Parade, Bedwin Road and the rail corridor.

5.2 Traditional demolition methodology

The traditional demolition technique used to break down structural reinforced concrete building elements into a size that can be dropped into shutes and/or lift shafts is primarily hammering. The noise created by material dropping down shutes is high impact and when combined with rock hammering adds to the impulsive and tonal characteristics of the noise emission.

Depending on the nature and structure of a building, there are many other methods which may be used including wire cutting, concrete sawing, non-explosive demolition, explosive demolition and demolition pulverisers.

5.3 Alternative methodologies

The use of concrete shear/pulveriser attachments or saw cutting and lifting as the primary demolition method has been adopted across all demolition works for Sydney Metro City & Southwest. Notwithstanding this, there will still be some hammering where there are no other options and this will be dependent on the type and structure of the specific building being demolished.

This method will work to substantially reduce the extent of rock hammering and associated impacts, while also maximising the extent of material reuse from demolition waste streams.

6.0 Alternatives considered for site establishment

6.1 Extent of excavation required

The extent of excavation to be undertaken as part of site establishment works includes:

- Construction of footings for acoustic sheds. These are typically excavations of approximately 1.5m wide by 1m depth by 40m long (depending on size of the shed)
- Trenching for utility works. The dimensions of the trenches will vary depending on the subject service (water, sewer, electricity, and telecommunications) and depths of infrastructure. Deeper services require benching or shoring which occupies a greater plan area than for shallow services. Where these works will result in loss of essential service and/or require road occupancy to complete, they will need to be undertaken in the evening and at night-time
- Local area works including road diversions and modifications. These generally require road occupancy to complete and require works to be completed in the evening and at night-time. Scope would include removal of unsuitable material, replacement of subgrade for road pavements and excavation of landscaping features
- Construction of footings and other civil structures to facilitate installation of tunnelling support equipment, e.g. spoil transfer conveyor structures, retaining walls, water treatment plants

6.2 Traditional excavation methodology

Typically, hammering would be used for excavation during site establishment works. Where confined to areas within the delineated worksite, hammering would proceed within a dedicated excavation zone bounded with a demarked separation distance from adjacent works/access, or within a hard-protected work area in accordance with excavation procedures. Due to noise impacts and the usual case that site establishment excavation is on the surface, work hours are usually reduced to standard day time hours only.

Where the excavation works area extends beyond the actual worksite boundary and into local areas (for example, to construct utility diversions or other local area works), pedestrian and vehicle diversions would be established, protection screens, traffic control and spotters put in place as required, and respite periods would be implemented, to minimise the overall impact of the works.

6.3 Alternative methodologies

Depending on the type and extent of excavation required, alternative methods of construction may include:

- Foundation excavation using a piling rig
- Alternative means of utility diversion via non-buried means
- Footing construction using anchors/tension anchors in combination with smaller reinforced concrete footings
- Mitigating excavation by constructing above ground retaining walls (water treatment plants) and above ground structures (pads).

When determining the excavation methods to be used during site establishment, JHCPBG will consider each case holistically and particularly the benefits of using alternative methods, to reduce the potential noise and vibration.

7.0 Alternatives considered for dive, station and shaft excavations

7.1 Overview

As noted in Section 1.2, the EIS and PIR assessed alternative methods and adopted rock hammering as the preferred excavation methodology for dive, station and shaft excavations. JHCPBG have reviewed the assessment of alternatives presented in the EIS and PIR and provide the following additional information with respect to:

- Bulldozer with ripper
- Xcentric Ripper
- Roadheading
- Rock sawing
- Penetrative cone fracture

Each of these alternatives is addressed below.

7.2 Bulldozer with ripper

- In rock with closer joint spacings, and particularly, shale a bulldozer with a ripper attachment can be used in place of rock hammering.

Approximately 10% of the total spoil for the TSE contract to be excavated is shale, however some of the dives, shafts and station boxes contain significant quantities of shale. An analysis of TSE worksites where bulldozers with rippers could be used is set out in Table 2.

Table 2: JHCPBG review of potential for excavation using a bulldozer with a ripper

TSE Works worksite	Estimated depth of excavation (metres) with potential to be ripped	JHCPBG Comment
Chatswood dive	20m	Can be limited by space constraints
Crows Nest station box	20m	Measured from mid-point of site. Due to the poor quality of the rock there will be a substantial amount of material with potential for ripping.
Victoria Cross North shaft	1-2m	High rock head of good quality sandstone. Joint spacing in rock too large to rip once surface rock removed.
Victoria Cross South shaft	1-2m	High rock head of good quality sandstone. Joint spacing in rock too large to rip once surface rock removed.
Blues Point shaft	2-3m	Small quantity of rock (approx.. 8000m^3)
Barangaroo (Hickson Road) shaft	0m	Rock expected immediately below road surface. Shaft too small to enable alternative methods. Small quantity of rock only (approx.. 5100m^3)
Barangaroo station box	7m	Rock head is sloping towards harbour, average given. Excavation predominantly undertaken by roadheaders.
Martin Place North shaft	4m	Very large shaft. Depending on fault zones there will likely be a larger volume of rock with potential for ripping.

TSE Works worksite	Estimated depth of excavation (metres) with potential to be ripped	JHCPBG Comment
Martin Place South shaft	10m	Significant constraints at this site. Space restrictions will dictate the majority of the rock at this site will be hammered.
Pitt Street North shaft	6m	Excavation undertaken in dual stages with existing basement providing working faces.
Pitt Street South shaft	10m	Potential for ripping to extend to a greater depth depending on encountered geotechnical conditions.
Waterloo station box	18m	There will be a substantial amount of material with potential for ripping.
Marrickville dive	18m	Can be limited by space constraints.

Noise generated by a bulldozer with a ripper attachment is approximately half the intensity of noise generated by rock hammering. In addition, the noise is not impulsive or tonal in nature, making it less annoying to receivers. Using a bulldozer with ripper attachment also greatly reduces vibration (less than half) compared to rock hammering and associated ground-borne noise.

JHCPBG will use bulldozers with rippers where possible to reduce the extent of rock hammering.

7.3 Xcentric Ripper

JHCPBG have previously investigated the feasibility of using vibrating rippers (Xcentric XR30, XR40 or XR50s) in conjunction with rock hammers. We have found that eccentric rippers can be substituted for a rock hammer within a very limited range of rock types, this is generally in weak rock (Shale Class IV) with favourable bedding planes. The eccentric ripper does not offer the same accuracy for trimming activities as a hammer.

Space constraints also limit the deployment of Xcentric rippers. They are not able to be used at shaft sites, due to the short length available in front of the excavator. Where there are longer runs in front of the excavator (such as a station box), ripping with a dozer is usually chosen ahead of an Xcentric rippers due to the higher production rate and reduced noise and vibration impact.

Measurements of Xcentric Rippers excavating sandstone undertaken by RT&A found that noise levels are approximately 10 dB(A) lower than rock hammers and that there are no annoying characteristics to the noise (i.e. noise is not low frequency, impulsive or tonal), so no annoyance penalty need be applied. Where rock hammers can be replaced by vibrating rippers, the extent and magnitude of ‘highly noise affected’ receivers will be reduced. Notwithstanding, Xcentric rippers do produce a significant volume of fine dust which is difficult to minimise.

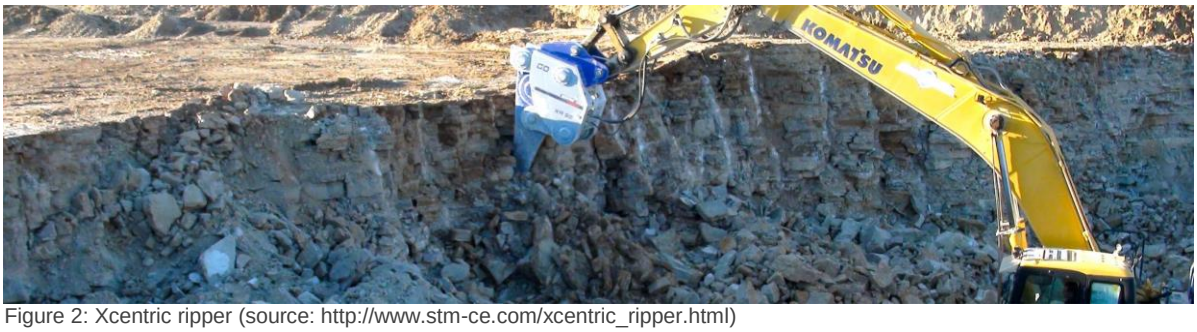

Figure 2: Xcentric ripper (source: http://www.stm-ce.com/xcentric_ripper.html)

Xcentric rippers were used in delivering the Sydney Metro Northwest TSC Works at the Cherrybrook, Norwest and Bella Vista worksites. Performance was monitored and it was noted that:

- Xcentric rippers could not excavate through harder rock
- Production rates and noise and vibration impacts varied depending in the skill and experience of the operator.

There may be an opportunity to use an Xcentric ripper on the TSE works at the Chatswood Worksite. A trial will be undertaken to test suitability prior to confirming further use of the Xcentric ripper.

7.4 Roadheader Excavation

The construction methodology set out in the EIS set out two preferred methodologies for excavating stations:

1. Open top down excavation using excavators with rock hammers –this applied to Crows Nest, Barangaroo and Waterloo station sites, the Chatswood and Marrickville dive sites and the temporary shaft at Blues Point.
2. Excavation of shafts at either end of the station using excavators with rock hammers and use of roadheaders to mine between the shafts- applies to Victoria Cross, Pitt Street and Martin Place.

Figure 3: A roadheader excavating an underground cavern (Airport Link, Brisbane)

The use of roadheaders to mine between the shafts for the stations listed in item 2 substantially reduces the noise and vibration impacts compared to open box excavation. Ground-borne noise from roadheader excavation will generally be below 45 dB(A), except where receivers are within 20m of the excavation area. Where the direct distance between the roadheader and the receiver (slant distance) is 40 m, ground-borne noise levels in sandstone would be approximately 35 dB(A). This compares to 50 dB(A) for rock hammering using a 30-tonne excavator.

The station excavation methodology at Barangaroo provides for an acoustic cover to allow 24 hour excavation with roadheaders, once the upper shoring has been installed and the weaker “Other Than Rock” (OTR) material will be removed using conventional excavation methods. For this reason, the majority of the hard rock component at Barangaroo station box will be excavated using roadheader.

7.5 Rock sawing

Excavation with saw cuts is a methodology to reduce the impacts of rock hammering. Lifts vary depending on blade size and can be up to 1.25m. The attachments can be configured with single or multiple blades mounted to a 45T excavator (or similar).

Figure 5: Use of an excavator mounted rock saw (single blade)

Airborne noise from rock sawing is comparable to rock hammering. However, rock sawing reduces ground-borne noise and vibration compared to standard rock hammering. Note that with rock sawing there is still a need for some rock hammering to break out the blocks. The usual spoil loading techniques and associated noise impacts are also required.

In order to meet the shaft excavation program, the required production rates are in the range of 150 to 350 BCM/day depending on location, geology and shaft footprint. The station boxes and dives require 350 to 700 BCM/day. The method is typically associated with removing intact sandstone blocks rather than a methodology needed to achieve the production required to meet the TSE program. Therefore depending on the specific shaft or station box the rock sawing method would add significantly to the overall excavation program compared to standard rock hammering.

Potential program impacts for each site are variable depending on the total volume of excavation and the space constraints. Overall saw cutting can add 6 – 12 months to a station box or shaft excavation (depending on rock hardness).

7.6 Non-explosive techniques

Non-explosive excavation techniques such as Cardox, Nonox and Penetrating Cone Fracture (PCF) are alternatives to blasting which use a gas expansion (smokeless propellant) that, when ignited, produces gas that fractures rock or concrete. Rock breaks in a spherical fracture that propagates 45 degrees from the base corner of the drill hole.

Figure 4: Use of Cardox to remove tunnel rock (source: http://www.cardox.net)

Relative to blasting, these techniques minimise peak vibration levels as a much smaller energy input is required. This is because rock requires less energy to break in tension than compression. It is an innovative technology, but it has limited and highly specialised applications that include breaking up boulders and removing mine overburden in hard rock in conjunction with other excavation techniques such as blasting. Like blasting, these techniques still require rock hammering to establish sites and break up rock not fractured by the gas expansion.

PCF was trialled at the Harbour Street portal site during the construction of the Cross City Tunnel but was discontinued as the propellant was absorbed by existing natural rock microfractures and therefore fractures in the rock itself did not propagate. JHCPBG has reviewed the geotechnical profile of the TSE Works with sandstone close to the surface (Victoria Cross, Blues Point, Pitt Street and Martin Place) and notes that it is very similar to the rock encountered during the unsuccessful Cross City Tunnel trial and, on this basis, these non-explosive techniques will not be pursued for the TSE Works.

7.7 Adopted excavation methodologies for dives, stations and shaft excavations

JHCPBG will use a combination of methods to minimise high noise impacts. The feasibility of the alternative methods discussed above has been considered based on:

- The specifications of the excavation – there needs to be sufficient space for the required plant and equipment
- Geotechnical conditions
- Program implications – alternative excavation methods can add significantly to the program and the overall duration of noise generating works. It is also essential to note that excavation of station boxes and shafts is a time critical element of the TSE Works. Excavation of the stations needs to be completed in advance of TBM tunnelling in order to meet the construction program. If station and shaft excavations are not completed in advance of TBMs, this delay would necessitate extensive additional rock hammering to remove tunnel segments from the base of the station and shaft excavations prolonging

the handover of the completed TSE works. This additional hammering would consist of detailed, slow excavation around the installed tunnel lining rings, in order to manage the safety risks associated with this scenario. This would have the potential to delay handover of each respective site by three months. Given the density of the concrete segments and the sensitivity of the excavation around the excavated tunnels, rock hammering would be the only suitable removal method.

Based on the above analysis, the adopted excavation method for the station boxes, shafts is a combination of bulldozers with rippers, rock hammers, roadheaders and potentially blasting. At this stage, the feasibility of blasting is still under consideration and has not yet been confirmed for any of the worksites. An overview of construction activities and adopted excavation methods is set out in Table 3.

Table 3: Overview of excavation methodologies adopted for dives, stations and shafts

TSE Works worksite	Adopted excavation methods
Chatswood Dive site	TBM tunnelling support and temporary spoil storage, including temporary and permanent dive construction. Excavation of the dive structure using rippers and rock hammers. Trial of Xcentric ripper to confirm potential for further use
Artarmon Substation	Excavation of vertical shaft via large diameter piling rig
Crows Nest	Station box excavation using rippers and rock hammers and floor preparation with rock saws and hammers
Victoria Cross	Shaft and station cavern excavation with rock hammers and roadheaders Blasting has not been ruled out as the primary excavation method for Victoria Cross North shaft site however please refer to JHCPBG's response to QID 9643.1 for the updated construction methodology.
Blues Point	Temporary shaft for TBM extraction excavated using rock hammers
Barangaroo	Station box and cavern excavation and under harbour TBM tunnelling support Station box with excavators, rock hammers and roadheaders Cavern excavation using rock hammers and roadheader
Martin Place	Shaft and station cavern excavation with rock hammers and roadheaders
Pitt Street	Shaft and station cavern excavation with rock hammers and roadheaders
Waterloo	Station box excavation using rippers and rock hammer and floor preparation with rock saws
Marrickville Dive site	TBM tunnelling support site including temporary spoil storage, including temporary and permanent dive construction Excavation of the dive structure using rippers and rock hammers

8.0 Alternative methods for cross passage, nozzles and stub tunnel construction

8.1 Cross Passages

As noted in Section 3.2, cross passages are spaced at approximately 200-240 metres along the twin tunnels, which are each approximately 15 kilometres in length. There are 57 cross passages to be excavated which are all generally located in hard rock.

Cross passages will be used as a primary fire and life safety measure during both construction and operation. This allows for secondary egress for people to evacuate and access for Emergency Services in the event of an incident. It is essential that the cross passage construction program closely follows the progress of the TBMs, as any delay in cross passage construction can have significant adverse consequences for fire and life safety of construction personnel. The TBMs have rescue chambers fitted on them with capability for the personnel working on the TBMs, which may be used in the event of an incident. However, this primary fire and life safety measure still relies on being able to obtain quick and efficient access to the location of the incident using the closest cross passage. The alternative of providing rescue chambers along the tunnels was considered, but will not be implemented as they would restrict movement and access in the tunnel and could pose a safety hazard.

Our tender option to delete four cross passages and use the base of the Blues Point shaft as a cross passage (to delete excavation of a further cross passage) if taken up by TfNSW will avoid five (5) cross passage excavations. This equates to over 4500t reduction in spoil generation. Assuming these options are adopted in the D&C Deed, approximately 50 cumulative days of rock hammering would be saved from the construction works.

Our tender option to reduce the size of the equipment and non-equipment cross passages if taken up by TfNSW will avoid the excavation of over 27,000 tonnes of spoil. Assuming these options are adopted in the D&C Deed, approximately 270 cumulative days of rock hammering would be saved from the construction works.

Construction options are limited for excavation of the running tunnel cross passages due to safety and accessibility constraints. Typically, small rock hammers are used in order to negotiate the tight working areas available. Previously, non-explosive alternatives have been considered (e.g., PCF at Epping Chatswood Rail Line) however these methods have been discounted due to the relative ineffectiveness of this method in Sydney Sandstone geology. This is due to the existence of microfractures within the natural formation of the rock which “absorb” the energy released in the process. When space constraints can be minimised, for example at cross passages with greater length, road headers may be considered. This method was recently adopted on the Sydney Metro Northwest project for its “long” approximately 50m cross passage nearby Epping Station.

For the reasons outlined above, in the most part, small rock hammers will be used for the construction of the cross passages. Where longer cross passages exist through the CBD, roadheaders are being considered however the reduced cross sectional profile of these cross passages may preclude the ability of roadheaders to operate effectively.

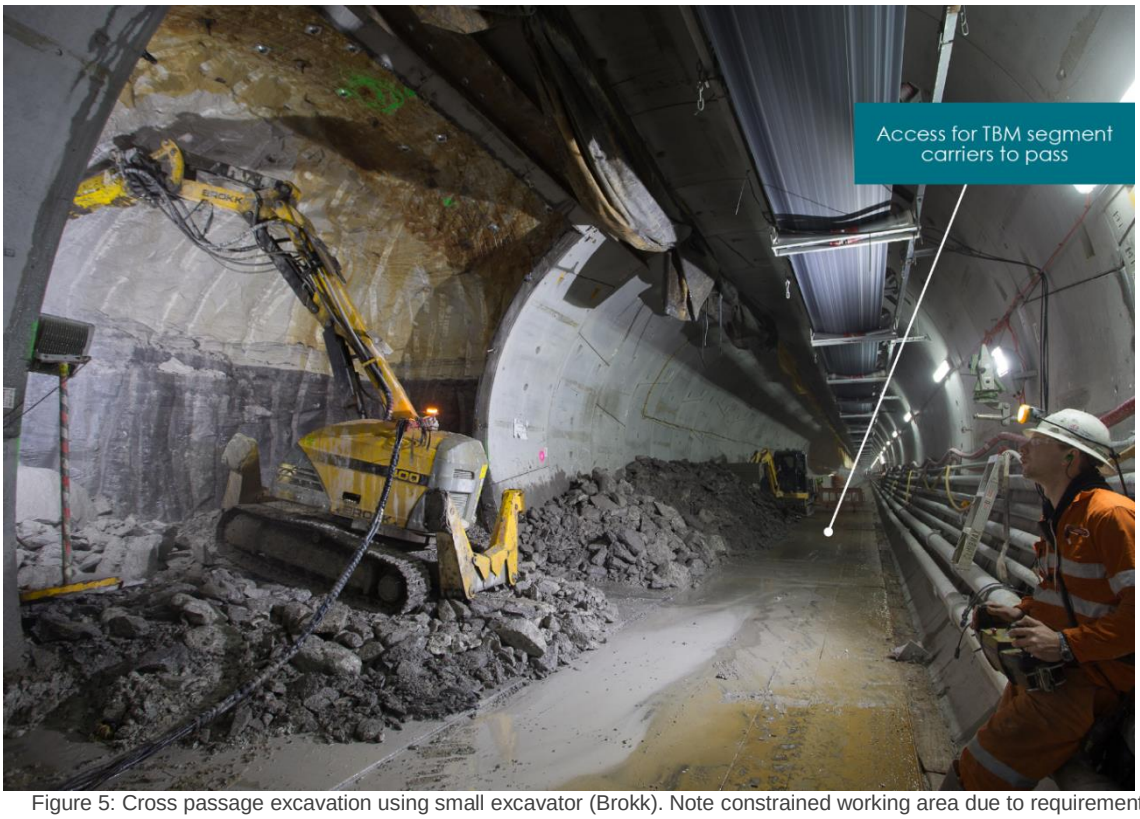

Figure 5: Cross passage excavation using small excavator (Brokk). Note constrained working area due to requirement to maintain through traffic.

Figure 7: Roadheader as used for construction of cross passage on recently completed Sydney Metro Northwest project. Note additional working room required in comparison to small excavator (Brokk).

Ground-borne noise from excavation using the small Brokk excavator is typically 6 dB lower than larger 20-30 tonne excavators. Verification noise monitoring during the use of Brokk excavators during cross passage excavation on the Sydney Metro Northwest TSC Works found that the reduced ground-borne noise generated allowed the extension of cross passage excavation into the out-of-hours work period, while still maintaining compliance with the noise management levels for ground-borne noise.

8.2 Nozzles and stub tunnel construction

There are nozzles and TBM re-launch stubs at each of the station sites across the TSE Works, each with various configurations and in different ground conditions. To maximise the benefits of non-rock hammer excavation methods in rock, road headers are planned for use where the rock is hard. Table 5 shows site by site the respective ground conditions and planned excavation plant. In the event that rock encountered is harder or softer than expected, it is possible that excavation plant specifications will be adjusted to match the revised operating constraints. Figure 6 shows a set of nozzles and stubs from the recently completed Sydney Metro Northwest project, approaching readiness for TBM re-launch.

Table 3: Summary of Nozzle / Stub locations, plant and ground conditions

Location	Configuration	Planned primary excavation plant	Expected Ground Conditions
Pitt St	Stub (2x12m)	Road header	Class 1-2 Sandstone
Martin Place	Stub (2x12m)	Road header	Class 1-2 Sandstone
Barangaroo Cavern	Stub (2x12m)	Road header	Class 1-2 Sandstone
Victoria Cross	Nozzle (2x16m) / Stub (2x12m)	Road header	Class 1-2 Sandstone
Waterloo Station Box	Nozzle (2x16m) / Stub (2x12m)	Excavator	Class 2-4 Shale / Sandstone
Crows Nest Station Box	Nozzle (2x16m) / Stub (2x12m)	Excavator	Class 3-5 Shale / Sandstone

Figure 8: Nozzle and stub tunnel – prior to TBM re-launch

9.0 Restrictions on rock hammering

The Project Planning Approval imposes conditions on rock hammering which are far stricter than any of the recent tunnel project approval in Sydney. Traditionally, daytime rock hammering is managed under EPLs using the following standard condition:

> High noise impact works and activities must only be undertaken:
> a) between the hours of 8:00am to 6:00pm Monday to Friday;
> b) between the hours of 8:00am to 1:00pm Saturday; and
> c) in continuous blocks not exceeding 3 hours each with a minimum respite from those activities and works of not less than 1 hour between each block except as expressly permitted by Condition L4.4 and L4.5 or another condition of this licence.
> For the purposes of this condition 'continuous' includes any period during which there is less than a 1hour respite between ceasing and recommencing any of the work that is the subject of this condition.

High noise impact works are defined as:

> means jack hammering, rock breaking or hammering, pile driving, vibratory rolling, cutting of pavement, concrete or steel or other work occurring on the surface that generates noise with impulsive, intermittent, tonal or low frequency characteristics.

This EPL Conditions effectively allows for 8 hours of rock hammering on week days (in two blocks of three hours and one two hour block) and two blocks of rock hammering on Saturday.

The Secretary's Assessment Report States at page 26 *"Stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street and Central….pose significant challenges when considering construction noise and vibration as it is difficult to establish standard management and mitigation measures in areas with a diverse range of receivers."*

Based on our comprehensive noise and vibration modelling, these criteria (GBN exceeds 60dB(A) and/or vibration is perceptible) are exceeded for rock hammering and other high noise impacts at each of the listed TSE Worksites.

Our program is therefore based on high noise impact works and activities, including rock hammering being permitted:

- Between the hours of 8:00 am and 6:00 pm; and,
- In continuous blocks not exceeding 3 hours each with a minimum respite from those activities and works of not less than 1 hour between each block

This assumption is based on the above EPA standard conditions which have been applied to EPLs for over a decade. It is unlikely that the EPA will allow excavation by rock hammering within surface sites (except where there are public interfaces or safety impacts) for longer than three hours without respite or between 7 am and 8 am or 6 pm and 8 pm even though this is permitted under Condition E38.

In this context, the potential to reach any alternative agreement with surrounding land users and the EPA is very unlikely and instead, the most certain strategy is to assume that only the stipulated noise and vibration impacts allowed by this condition and EPA requirements will be permitted.

Given limitations specified in other Conditions of the Project Planning Approval, and considering standard EPA requirements, rock hammering is limited to a maximum of 6.5 hours per day between 8 am and 6 pm in continuous blocks not exceeding 3 hours each with a minimum respite from those activities and works of not less than one (1) hour between each block unless otherwise permitted under Condition E38.

10.0 Conclusion

This report documents JHCPBG's detailed consideration of alternatives to rock hammering and blasting which has been completed in close consultation with RT&A and has been peer reviewed by Wilkinson Murray.

It is important to note that the twin rail tunnels will be excavated using TBMs, avoiding the need for extensive rock hammering.

As noted in Section 1.1, this Report has been prepared to address the requirements of Project Planning Approval Condition E35 and will be provided to the independent Acoustic Advisor for approval in accordance with the requirements of this Condition prior to contract award. It documents JHCPBG's consideration of alternative construction methods to rock hammering and blasting and the following confirms the baseline rock hammering restrictions and alternatives to be adopted by JHCPBG in delivering the TSE Works:

- Rock hammering is limited to a maximum of 6.5 hours per day between 8 am and 6 pm in continuous blocks not exceeding 3 hours each with a minimum respite from those activities and works of not less than one (1) hour between each block unless otherwise permitted under Condition E38
- Rock hammering required for demolition has been significantly reduced through the use of concrete shear/pulveriser attachments or saw cutting and lifting as the primary demolition method
- Rock hammering associated with site establishment works is minimal and ripping will be used where possible. Rock hammering and concrete sawing is required for utility and local area works which require road occupancy or essential service disruption. This work is time critical given the window of time provided to complete works to avoid traffic conduction and/or service disruption.
- Rock hammering for the excavation of dive, station and shaft excavations will be significantly reduced by:
  - Using bulldozers with ripper attachments where possible
  - Using a road headers to mine the station and cavern excavations at Victoria Cross, Barangaroo, Pitt Street and Martin Place. It is noted that the use of a road header to excavate the Barangaroo station box was not detailed in the EIS or Submissions and Preferred Activity Report, but has been included in our revised tender offer and significantly reduces noise and vibration impacts in this precinct.
  - Saw cutting, for dive, station box and shaft excavation walls and floor trimming where practicable
  - Use of the xcentric ripper, subject to further investigation of the potential benefit through implementation of a trial at the Chatswood Worksite.
- Stubs and nozzles will be excavated with roadheaders where geological conditions show that hard rock is predicted. In areas where weaker rock is foreseen, rock hammers will be used. Impacts on nearby receivers will be significantly less in this case.
- If taken up by TfNSW, JHCPBG's reduction in cross passage numbers and sizes will work to avoid rock hammering. The use of Brokks and saw cutting (where practicable) in place of standard rock hammers also ensures the noise and vibration impacts of

these fire and life safety critical works are substantially reduced compared to standard rock hammering.

The TSE Construction Noise and Vibration Management Plan (SMCSTSE-JHCPBG-TPW-EN-PLN-002012) will set out the framework for how JHCPBG will minimise and manage noise and vibration impacts during design and construction of the TSE Works. The Plan will:

- Identify the work areas, site compounds and access points;
- Identify sensitive receivers by means of an updated land use survey
- Establish the relevant construction noise and vibration goals to minimise and manage impacts from the TSE works, including requirements for managing noise intensive activities to satisfy Project Planning Approval Conditions E37, E38 and E46, the Interim Construction Noise Guideline and any EPL requirements
- Provide details of construction activities and identification of key noise and vibration generating activities that form the basis of the noise and vibration mitigation design
- Present the indicative reasonable and feasible noise and vibration mitigation design for each worksite, including in relation to noise intensive construction activities
- Detail the noise and vibration monitoring requirements to validate the modelling used to develop the design and the ongoing monitoring requirements to confirm that the TSE worksites meeting the construction noise and vibration goals.

The noise and vibration impacts of the TSE Works will be modelled in accordance with this Plan to determine the required suite of reasonable and feasible management measures. The results of these noise and vibration modelling and required management will be documented in Construction Noise and Vibration Impact Statements (CNVIS) for worksites and activities. CNVIS will provide detailed construction noise and vibration prediction, assessment, mitigation design outcomes and discussion of management measures to limit impacts to sensitive receivers. Each CNVIS will address:

- Scope of work covered by the CNVIS
- Justification for OOHW (where required)
- Nearest noise and vibration sensitive receivers, based on the updated land use survey
- Construction noise and vibration objectives
- Construction noise and vibration assessment
- Mitigation options and preferred management measures, including site specific requirements in relation to noise intensive activities
- Noise and vibration monitoring requirements for each construction worksite/activity.

Appendix A – Wilkinson Murray Peer Review

WILKINSON MURRAY

5 June 2017

WM Project Number: 16200
Our Ref: SM16200JW05062017

Dr Caitlin Richards
Approvals, Environment and Sustainability Manager
John Holland CPB Ghella JV
Level 9, 50 Bridge Street
SYDNEY NSW 2000

Dear Caitlin

Re: Sydney Metro City & Southwest – Peer Review - Alternative construction methods to rock hammering and blasting Report (SMCSTSE-JCG-TPW-EN-RPT-097229)

Wilkinson Murray has been engaged by John Holland CPB Ghella JV to peer review the Alternative construction methods to rock hammering and blasting Report (SMCSTSE-JCG-TPW-EN-RPT-097229) (Report). The Report has been prepared in response to Condition E35 of the Sydney Metro City & Southwest Project Planning Approval dated 9 January 2017 (Application no. SSI 15_7400). The aim of the peer review is to review the methodology adopted and the technical accuracy of the report with regard to noise and vibration issues.

WILKINSON MURRAY'S EXPERIENCE

Wilkinson Murray is an independent Noise, Vibration & Air quality Consulting firm, established over 50 years ago with offices in Sydney, Newcastle, Wollongong, Orange, Queensland and Hong Kong. The firm has worked on many construction projects particularly for large major infrastructure projects in Sydney and Asia. Wilkinson Murray has developed a high level of expertise and has collected a large amount of noise and vibration data pertaining to tunnelling construction and, in particular in relation to ground-borne noise from tunnelling from TBM and roadheader operations.

Some of the Sydney tunnel construction projects in which Wilkinson Murray has been involved with include:

- Lane Cove Tunnel;
- Cross City Tunnel;
- Epping to Chatswood Rail Link;
- Northside Storage Tunnel;

John Wassermann, who has conducted this review, is a Director at Wilkinson Murray Pty Ltd and is a Mechanical Engineer with over 25 years' experience in the public and private sectors. , John worked in the NSW State Government, initially as the Manager of the Noise Assessments area for the EPA, and subsequently as Manager Transport for the Major Infrastructure Assessment area of the then

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ACOUSTICS AND AIR

Department of Planning. He has been at Wilkinson Murray since August 2004. John has considerable experience in NSW environmental, noise and air quality legislation, Environment Planning and Assessment Act (1979) and the POEO Act (1997). While working for Government, John has had substantial involvement in regulation and assessment of transport and energy related state significant projects and major infrastructure. While working as a consultant he has been involved in some of NSW largest infrastructure projects including Cross City Tunnel, Lane Cove Tunnel and the Epping to Chatswood Rail Link.

CONCLUSIONS

The Report, together with clarifications in discussion, lead me to be satisfied that the report presents a thorough and comprehensive review of alternative construction methods to rock hammering and blasting for the Sydney Metro City & Southwest project with regard to noise and vibration issues.

I trust this information is sufficient. Please contact us if you have any further queries.

Yours faithfully
WILKINSON MURRAY

John Wassermann
Director

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Mr Stuart Hodgson
Principal Manager,
Program Sustainability Environment & Planning
Sydney Metro
Transport for NSW
PO Box 588
NORTH RYDE BC NSW 1670

28 August 2017

Ref:E35 Report

Dear Stuart

RE: Endorsement of TSE E35 Report: Alternative construction methods to rock hammering and blasting - Sydney Metro City & Southwest

Thank you for providing the following document for Environmental Representative (ER) review and endorsement. The document is provided to address the Condition of Approval E35 of the Sydney Metro City & Southwest project (SSI – 15_7400 January 9 2017).

- Alternative construction methods to rock hammering and blasting (Condition E35, Revision 2 dated 6 June 2017).

I note the document includes a statement by Wilkinson Murray as peer reviewer that defines the document as presenting *"a thorough and comprehensive review of alternate construction methods to rock hammering and blasting for the Sydney Metro City and South West project with regards to noise and vibration issues."*

Further, the Acoustic Advisor has endorsed the document on 15 June 2017.
As an approved ER for the Sydney Metro City & Southwest project, I have reviewed the document and, with reference to the AA endorsement, consider that the document responds to the conditions of the DPE Approval. This review has not considered technical aspects of the report, as these have been assumed to be addressed by the Acoustic Advisor.

Yours sincerely

Michael Woolley
Environmental Representative – Sydney Metro – City and South West