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New Intercity Fleet - Ten Tunnels Deviation Modifications

Noise and Vibration Impact Assessment

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Client: Transport for NSW
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4	22-Jan-2018	Final for TfNSW	Richard Farmer Project Manager	

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Executive summary

AECOM Australia Pty Ltd (AECOM) has been commissioned by Transport for NSW (TfNSW) to undertake a Noise and Vibration Impact Assessment for the New Intercity Fleet - Ten Tunnels Deviation Modifications (the Project). Nearby noise and vibration sensitive receivers were identified and unattended noise measurements were completed to characterise the existing noise environment. The measured noise levels were used to establish construction noise management levels. As operational noise levels are expected to remain largely unchanged with the introduction of the new fleet, no quantitative modelling of operational noise impacts was undertaken.

Construction activity noise

A construction scenario consisting of a number of construction activities has been developed in consultation with TfNSW, and used in a computer-based noise model to determine the potential changes to noise levels as a result of the Project. Construction noise impacts were then assessed at five representative residential receivers at locations along the length of the rail line between the eastern portal of Tunnel 1 (Sydney end) to the western portal of Tunnel 10 (Lithgow end).

The modelling results show that noise levels at the five representative receivers are not predicted to exceed the identified noise management levels (NMLs) during daytime work (i.e. during standard construction hours and during out of standard construction hours in daytime).

For the proposed evening and night-time works, noise levels at three of the representative residential receivers are predicted to exceed NMLs by up to one decibel (dB). This is not considered a significant increase in noise and may not be noticeable. The sleep disturbance assessment results show the noise levels at all representative receivers are not predicted to exceed the sleep disturbance screening criteria or the sleep awakening criteria.

Mitigation measures have been recommended in line with TfNSW's *Construction Noise Strategy.* The implementation of these mitigation measures where reasonable and feasible would minimise and manage noise impacts.

Construction vibration

No significant vibration impacts to structures outside of the rail corridor are considered likely as a result of the Project.

The Project includes modification to the tunnel linings of the heritage listed Ten Tunnels Deviation using a road header. It is recommended that a structural engineer oversee these activities, including undertaking regular inspections, to monitor for potential impacts to the integrity of the brickwork surrounding the working area.

Operational impacts

Environmental noise emissions from the operation of the tunnels are not expected to change significantly as a result of the Project, as such an assessment under the *NSW Noise Policy for Industry* (EPA, 2017) is not required. It is noted that the *Noise Policy for Industry* has replaced the previous *Industrial Noise Policy* (EPA, 2000).

The New Intercity Fleet is expected to be quieter than the existing intercity trains, in particular wheel squeal and engine noise is likely to be lower. The Project modifications will only affect the interior of the tunnels by a maximum of 127 millimetres, therefore operational noise from rail movements through the tunnels is expected to remain largely the same or be reduced from the current situation. Therefore, an assessment under the *Rail Infrastructure Noise Guideline* (EPA, 2003) is not required.

1 Introduction

AECOM Australia Pty Ltd (AECOM) has been commissioned by Transport for New South Wales (TfNSW) to undertake a Noise and Vibration Impact Assessment of the construction of the Ten Tunnels Deviation Modifications (the Project).

The Project would involve tunnel modification works between the eastern portal of Tunnel 1 (Sydney end) to the western portal of Tunnel 10 (Lithgow end) (the Project site) to facilitate the safe and reliable operation of the New Intercity Fleet through the Ten Tunnels Deviation on the Blue Mountains Line. The New Intercity Fleet would provide a better experience for public transport customers by delivering an accessible, modern, safe and comfortable travel experience.

Subject to approval, construction is expected to commence in 2018 and take around two years to complete.

Construction work would need to be undertaken during pre-existing and scheduled rail possessions (typically 48 hours over a weekend where no trains are permitted to operate, and would involve out of hours works) and extended shutdowns (typically the five days either side of a weekend possession).

The shutdown periods would generally take place between the hours of 9:45am and 6:15pm in order to allow diesel passenger trains (such as the XPT and regional services) and freight services to operate outside of these times. Replacement buses would be provided for intercity customers during weekend possessions and extended shutdown periods.

It is anticipated that the Project would utilise the following types of rail possessions and shutdown periods for the works:

- Scheduled weekend routine rail possession and scheduled five-day shutdown on either side (extending for 12 days in total)
- Scheduled weekend routine rail possession and scheduled five-day shutdown on either side with an additional three-day shutdown arranged at the end (extending for 15 days in total)
- Scheduled weekend routine rail possession with an additional shutdown period for five days either side (i.e. additional five-day shutdowns on either side of scheduled weekend possessions would be arranged to allow construction teams to undertake works more efficiently)
- Scheduled weekend routine rail possessions
- Scheduled four or five day possessions.

A combination of six to eight of these types of possessions would be utilised to undertake the works. The final possession and extended shutdown requirements are still being developed (in consultation with Sydney Trains, NSW TrainLink and relevant industry stakeholders), and are also subject to detailed design and development of the contractor's construction methodology.

Approval from TfNSW would be required for the out of hours work and the affected community would be notified as outlined in TfNSW's *Construction Noise Strategy* (TfNSW, 2016).

1.1 Background information

This Noise and Vibration Impact Assessment has been prepared in support of a Review of Environmental Factors report, which has been prepared to assess the environmental impacts associated with the construction and operation of the Project under the provisions of Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The following policies and guidelines are relevant for this assessment:

- *Interim Construction Noise Guideline* (ICNG), Department of Environment and Climate Change (DECC), 2009
- *Assessing Vibration: A Technical Guideline* (AVATG), Department of Environment and Conservation (DEC), 2006
- *NSW Road Noise Policy* (RNP), Department of Environment, Climate Change and Water (DECCW), 2011
- *Rail Infrastructure Noise Guideline* (RING), NSW Environmental Protection Authority (EPA), 2013
- *NSW Industrial Noise Policy*, EPA, 2000
- *NSW Noise Policy for Industry,* EPA, 2017
- *Construction Noise Strategy* (CNS), TfNSW, 2016
- DIN Standard 4150: *Part 3 1999 Structural Vibration in Buildings - Effects on Structures*, 1999
- British Standard 6472: Part 1 2008 *Evaluation of Human Exposure to Vibration in Buildings*, 2008
- Australian Standard AS 2436-2010, *Guide to noise and vibration control on construction, demolition and maintenance sites*, 2010
- Australian Standard AS 1055.1-1997 – *Acoustics – Description and measurement of environmental noise, Part 1: General procedures*, 1997
- *Update of noise database for prediction of noise on construction and open sites*, UK Department for Environment, Food and Rural Affairs (DEFRA), 2006.

Definitions for acoustic terminology used within this report can be found in Appendix A.

1.2 Scope

The scope of this Noise and Vibration Impact Assessment is to:

- establish the existing background noise levels in the vicinity of the Project site
- establish construction noise management levels and vibration limits which would apply to the Project
- predict construction noise and vibration levels at nearby residential and other sensitive receivers due to the Project
- predict noise impacts from additional off-site construction traffic generated by the Project
- recommend mitigation measures where necessary to reduce and manage noise and vibration impacts from the Project
- consider operational noise levels at nearby residential and other sensitive receivers due to the Project.

1.3 Proposed works

The Project comprises minor modifications to sections of the lining of eight tunnels in the Ten Tunnels Deviation and minor modifications to ancillary infrastructure to accommodate the operation of the New Intercity Fleet which is wider and longer than the existing trains.

The Project would include the following key elements:

- modifications to the tunnel lining in Tunnel 1, Tunnel 2, Tunnel 3, Tunnel 6, Tunnel 7, Tunnel 8, Tunnel 9 and Tunnel 10
- modifications to tunnel portals at Tunnel 1 (both ends), Tunnel 2 (both ends), Tunnel 3 (Sydney end) Tunnel 6 (Lithgow end), Tunnel 7 (both ends), Tunnel 8 (both ends) and Tunnel 10 (both ends)
- replacement of an existing cable tray with a new cable tray in Tunnel 3
- replacement of light shields in Tunnel 1 and Tunnel 10.

1.4 Site description

The Project site is located between Newnes Junction Station and Zig Zag Station along the Blue Mountains Line and consists of a series of ten tunnels, known as the Ten Tunnels Deviation. The town of Clarence lies to the north of the Project site, with noise sensitive receivers within Clarence being primarily rural residences. The area surrounding the remaining areas of the Project site is primarily bushland with some open space.

Chifley Road, Clarence serves as the main access road between Newnes Junction and Lithgow and is considered to be an arterial road, in accordance with the categories within the EPA's *NSW Road Noise Policy*.

1.5 Receivers

1.5.1 Representative receivers

In order to simplify the assessment methodology, five representative residential receivers, listed in Table 1, were selected to describe the predicted noise impacts. These residential receivers are expected to be the most impacted by noise from the Project. Receiver locations are presented in Figure 1. No non-residential receivers are expected to be impacted as the nearest non-residential receiver identified was more than one kilometre from the Project site.

Table 1 Representative receivers - Residential

Receiver ID	Receiver address	Distance to Project site (metres)
R1	133 Donald Road, Clarence	388
R2	29 Donald Road, Clarence	446
R3	31 Donald Road, Clarence	426
R4	25 Donald Road, Clarence	409
R5	9 Donald Road, Clarence	293

1.5.2 Heritage items

The Ten Tunnels Deviation is listed on the State Heritage Register, RailCorp S170 Heritage and Conservation Register and under Schedule 5 of the *Lithgow Local Environment Plan 2014*. There are no other heritage structures in the vicinity of the Project site.

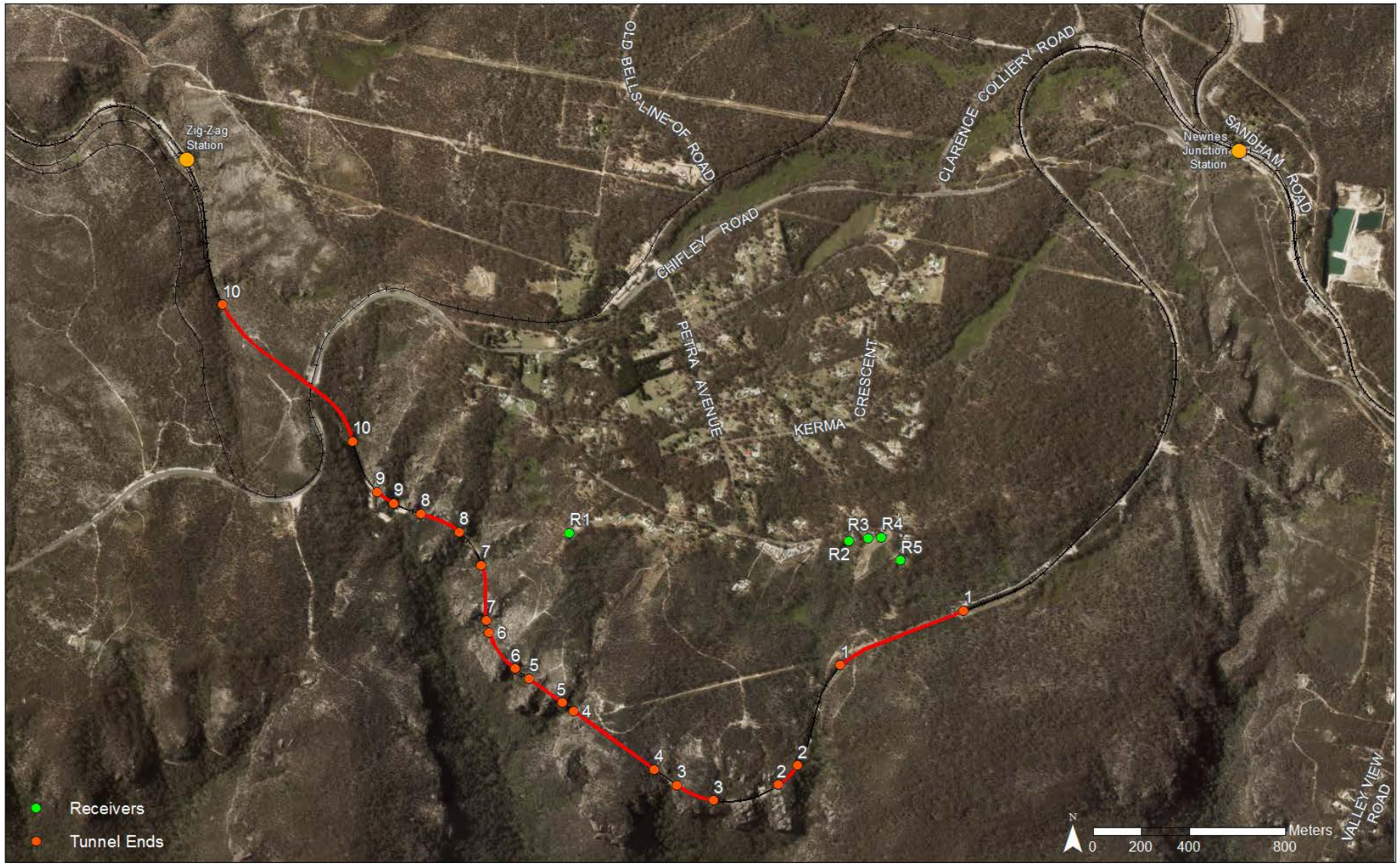


Figure 1 Regional context, nearest residential receivers and tunnel ends

2 Existing acoustic environment

Long-term unattended measurements were undertaken to establish the existing ambient and background noise environment at potentially affected receivers in the vicinity of the Project site.

2.1 Noise measurement methodology

Long-term unattended noise monitoring was conducted between 31 March 2017 and 10 April 2017. A noise logger was placed at a representative location as shown in Appendix B. The noise logger was calibrated prior to and after the monitoring period with a drift in calibration not exceeding ± 0.5 dB(A) (refer to Appendix A for terminology and definitions). The details of the unattended noise monitoring conducted can be found in Table 2.

All of the acoustic instrumentation employed during the noise measurements comply with the requirements of *AS IEC 61672.1-2004 Electroacoustics - Sound level meters - Specifications* and were within their current National Association of Testing Authorities, Australia (NATA) certified in-calibration period (i.e. calibration in the last two years).

The noise environment at each of the rural residential receivers in Clarence is considered to have a similar noise environment to the unattended monitoring location. As such each of these residential receivers was assigned the same background noise level.

In accordance with the EPA's *NSW Noise Policy for Industry* (NPI), noise monitoring affected by adverse weather conditions or extraneous noise events was excluded from the monitoring data. The NPI advises that data may be affected where adverse weather, such as wind speeds higher than five metres per second or rain, occurs. Weather data were acquired from the Bureau of Meteorology's Mount Boyce weather station (station ID 063292).

2.2 Unattended noise measurements

The logger measured the noise levels over the sample period and then determined L_{A1}, L_{A10}, L_{A90}, and L_{Aeq} levels of the noise environment. The $L_{A1,}$ L_{A10} and L_{A90} noise levels are the levels exceeded for 1 per cent, 10 per cent and 90 per cent of the measurement period respectively. The L_{A90} is taken as the background level. The L_{A1} is indicative of the maximum noise levels due to individual noise events such as the pass-by of a heavy vehicle. The L_{Aeq} level is the equivalent continuous sound level and has the same sound energy over the sample period as the actual noise environment with fluctuating sound levels.

The L_{A90} noise levels were analysed to determine a single assessment background level (ABL) for each day, evening and night period in accordance with the NPI for each monitoring location. The ABL is established by determining the lowest ten-percentile level of the L_{A90} noise data acquired over each period of interest.

Table 2 presents individual ABLs for each day's assessment periods. The background noise level or rating background level (RBL) representing the day, evening and night-time assessment periods is based on the median of individual ABLs determined over the entire monitoring period.

Table 2 also presents the existing L_{Aeq} ambient noise level selected for each day, evening and night-time period, in accordance with the NPI. An overall representative L_{Aeq} noise level is determined by logarithmically averaging each assessment period for the entire monitoring period.

Table 2 Unattended noise measurement results in dB(A)

Measurement date (2017)	Background noise levels L_{A90} dB(A)			Ambient noise levels L_{Aeq} dB(A)		
	Day[1]	Evening[1]	Night[1]	Day[1]	Evening[1]	Night[1]
Friday 31 March	-	26	17	-	46	45
Saturday 01 April	32	28	22	45	44	41
Sunday 02 April	36	29	-	46	45	-
Monday 03 April	-	30	27	-	46	43
Tuesday 04 April	33	-	-	44	-	-
Wednesday 05 April	31	24	17	45	44	41
Thursday 06 April	27	26	17	43	41	41
Friday 07 April	30	26	17	46	44	42
Saturday 08 April	29	25	22	45	43	43
Sunday 09 April	-	-	-	-	-	-
Monday 10 April	-	-	-	-	-	-
Log Average				**45**	**44**	**43**
RBL	**35**	**30[2]**	**30[2]**			

Notes:
1. Day is defined as 7:00 am to 6:00 pm, Monday to Saturday and 8:00 am to 6:00 pm Sundays & Public Holidays. Evening is defined as 6:00 pm to 10:00 pm, Monday to Sunday & Public Holidays. Night is defined as 10:00 pm to 7:00 am, Monday to Saturday and 10:00 pm to 8:00 am Sundays & Public Holidays.
2. Where the rating background noise level is found to be less than 35 dB(A) during the day or 30dB(A) during the evening or night, the RBL is set to 35dB(A) during the day or 30 dB(A) during the evening or night in accordance with the NPI.

2.3 Existing noise environment summary

The acoustic environment of the noise logging location and modelled area is characterised mainly by natural sounds with some distant highway noise. Train noise was also heard during the installation of the noise loggers and contributes to the acoustic environment. Night-time noise levels are very quiet, typical of a rural environment.

3 Construction noise and vibration criteria

3.1 Construction activity noise criteria

3.1.1 Interim Construction Noise Guideline

The *Interim Construction Noise Guideline* (ICNG) is the principal guideline for the assessment and management of construction noise in NSW. The ICNG recommends that a quantitative assessment is carried out for all *'major construction projects that are typically subject to the Environmental Impact Assessment (EIA) process'*. Noise levels due to construction activities are predicted at nearby receivers using environmental noise modelling software and compared to the levels provided in Section 4 of the ICNG.

Where an exceedance of the management levels is predicted, the ICNG advises that receivers can be considered 'noise affected' and the proponent should apply all feasible and reasonable work practices to minimise the noise impact. The proponent should also inform all potentially impacted residents of the nature of the works to be carried out, the expected noise level and duration, as well as contact details.

Where construction noise levels reach 75 dB(A) residential receivers can be considered as 'highly noise affected' and the proponent should, in consultation with the community, consider restricting hours to provide respite periods.

The ICNG defines what is considered to be feasible and reasonable as follows:

> Feasible - A work practice or abatement measure is feasible if it is capable of being put into practice or of being engineered and is practical to build given project constraints such as safety and maintenance requirements.
>
> Reasonable - Selecting reasonable measures from those that are feasible involves making a judgment to determine whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the measure.

The construction noise management levels (NML) for the residential receivers are detailed in Table 3 and Table 4.

Table 3 ICNG residential noise management levels

Time of day	NML, L_{Aeq},15min, dB(A)[1]	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level • the proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.

Time of day	NML, L_{Aeq},15min, dB(A)[1]	How to apply
	Highly noise affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• a strong justification would typically be required for works outside the recommended standard hours • the proponent should apply all feasible and reasonable work practices to meet the noise affected level • where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community • for guidance on negotiating agreements see Section 7.2.2 of the ICNG.

Notes:
1. Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 4 presents the NMLs applicable to residential receivers nearby to the Project.

Table 4 Construction noise management levels

Period	RBL, L_{A90} dB(A)	Standard hours noise management levels, $L_{Aeq,15min}$, dB(A)	Out-of-hours noise management levels, $L_{Aeq,15min}$, dB(A)
Day	35	45	40
Evening	30	-	35
Night	30	-	35

3.1.2 Sleep disturbance criteria

The ICNG requires a sleep disturbance analysis where construction works are planned to extend over more than two consecutive nights. On the basis of the ambient noise environment during the night-time period, the predicted L_{A1} noise levels and number of expected L_{A1} noise events should be predicted in order to determine the likelihood of potential sleep disturbance. The ICNG makes reference to the NSW *Environment Criteria for Road Traffic Noise* (ECRTN), now superseded by the *Road Noise Policy* (RNP), for guidance in assessing the potential for sleep disturbance.

The guidance provided in the RNP for assessing the potential for sleep disturbance recommends that to minimise the risk of sleep disturbance during the night-time period (10.00 pm to 7.00 am), the $L_{A1(1\ min)}$, noise level outside a bedroom window should not exceed the $L_{A90\ (15\ minute)}$ background noise level by more than 15 dB. The EPA considers it appropriate to use this metric as a screening criterion to assess the likelihood of sleep disturbance. If this screening criterion is exceeded, a more detailed analysis must be undertaken and include the

extent that the maximum noise level exceeds the background noise level and the number of times this is likely to happen during the night-time period.

The RNP contains a review of research into sleep disturbance which represents NSW EPA advice on the subject of sleep disturbance due to noise events. It concludes that having considered the results of research to date that, *'Maximum internal noise levels below 50 to 55 dB(A) are unlikely to cause awakening reactions'*. Therefore, given that an open window provides around 10 dB in noise attenuation from outside to inside, external noise levels of 60 to 65 dB(A) are unlikely to result in awakening reactions.

Based on the measured background noise levels during the night, the sleep disturbance criteria for the nearest noise sensitive residential receivers are presented in Table 5.

Table 5 Sleep disturbance criteria

Background noise level (L_{A90}), dB(A)	Sleep disturbance criteria, dB(A)	$L_{A1(1\ minute)}$, dB(A)
	Screening level	Awakening reaction
30	45	65

3.2 Construction traffic noise criteria

Noise from construction traffic on public roads is not covered by the ICNG. However, the ICNG does refer to the ECRTN, now superseded by the RNP, for the assessment of noise arising from construction traffic on public roads.

To assess noise impacts from construction traffic, an initial screening test should be undertaken by evaluating whether existing road traffic noise levels will increase by more than 2 dB(A). Where the predicted noise increase is 2 dB(A) or less, then no further assessment is required. However, where the predicted noise level increase is equal to or greater than 2 dB(A), and the predicted road traffic noise level exceeds the road category specific criterion then noise mitigation should be considered for those receivers affected. A screening test for noise impacts resulting from construction traffic has been undertaken in Section 4.5.

3.3 Construction vibration criteria

The relevant standards and guidelines for the assessment of construction vibration are summarised in Table 6.

Table 6 Standards/guidelines used for assessing construction vibration

Item	Standard/guideline
Structural damage	German Standard DIN 4150 – Part 3 – Structural Vibration in Buildings – Effects on Structures (DIN 4150)
Human comfort (tactile vibration)	Assessing Vibration: A Technical Guideline (AVATG)[1]

Notes
1. This document is based upon the guidelines contained in British Standard 6472:1992, 'Evaluation of human exposure to vibration in buildings (1-80 Hz)'. This British Standard was superseded in 2008 with BS 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings – Part 1: Vibration sources other than blasting" and the 1992 version of the Standard was withdrawn. Although a new version of BS 6472 has been published, the Environment Protection Authority still requires vibration to be assessed in accordance with the 1992 version of the Standard at this point in time.

Vibration, at high levels, has the potential to cause damage to structures and disrupt human comfort. Vibration and its associated effects are usually classified as continuous, impulsive or intermittent as follows:

- continuous vibration continues uninterrupted for a defined period and includes sources such as machinery and continuous construction activities

- impulsive vibration is a rapid build up to a peak followed by a damped decay. It may consist of several cycles at around the same amplitude, with durations of typically less than two seconds and no more than three occurrences in an assessment period. This may include occasional dropping of heavy equipment or loading activities
- intermittent vibration occurs where there are interrupted periods of continuous vibration, repeated periods of impulsive vibration or continuous vibration that varies significantly in magnitude. This may include intermittent construction activity, impact pile driving, jack hammers.

3.3.1 Structural damage

At present, no Australian Standards exist for the assessment of damage caused by vibration.

The German Standard (DIN 4150) provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are presented in Table 7. DIN 4150 states that buildings exposed to higher levels of vibration than recommended limits would not necessarily result in damage. In this assessment of DIN 4150 limits have been adopted for residential and heritage structures such as the tunnels.

Table 7 Structural damage safe limits (DIN 4150) for building vibration

Group	Type of structure	At foundation – Less than 10 Hz	At foundation - 10 Hz to 50 Hz	At foundation - 50 Hz to 100 Hz[1]	Vibration at the horizontal plane of the highest floor for all frequencies
1	Dwellings and buildings of similar design and/or use	5 mm/s	5 to 15 mm/s	15 to 20 mm/s	15 mm/s
2	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 and have intrinsic value (e.g. buildings that are under a preservation order/heritage listed)	3 mm/s	3 to 8 mm/s	8 to 10 mm/s	8 mm/s

Notes:

1. At frequencies above 100 Hz, the values given in this column may be used as minimum values

3.3.2 Human comfort

The assessment of intermittent vibration outlined in the NSW EPA guideline A*ssessing Vibration: A Technical Guideline* (AVTG) is based on Vibration Dose Values (VDVs). The VDV accumulates the vibration energy received over the daytime and night-time periods.

Maximum and preferred VDVs for intermittent vibration arising from construction activities at residences are listed in Table 8. The VDV criteria are based on the likelihood that a person would comment adversely on the level of vibration over the entire assessment period.

Table 8 Preferred and maximum vibration dose values for intermittent vibration ($m/s^{1.75}$) for daytime (7am – 10pm) and night time (10pm – 7am)

Location	Daytime Preferred	Daytime Max	Night time Preferred	Night time Max
Residences	0.2	0.4	0.13	0.26

4 Construction noise and vibration assessment

4.1 Construction activities and scheduling

To estimate the potential noise impacts from the Project a noise model has been developed in consultation with TfNSW, using a construction scenario consisting of a number of proposed construction activities. These activities would be confirmed by the construction contractor prior to construction commencing and further noise assessment would be undertaken if required. The modelled construction scenario is described in Table 9 which provides the assumed construction activities, and the location and proposed timing of these activities.

It is anticipated that the Project would utilise three scheduled weekend routine rail possessions and scheduled five-day shutdown on either side (extending for 12 days in total) and three scheduled weekend routine rail possessions with additional shutdown periods for five days either side (i.e. it is proposed to arrange for an additional five-day shutdown on either side of three scheduled weekend possessions, to allow construction teams to undertake works more efficiently).

Table 9 Construction noise assessment modelling scenario and scheduling

Stage	Construction activities	Location	Timing
1	• delivery of equipment and materials • establish construction site compounds (offices, temporary facilities, etc.) • vehicle movements within and around the Project site	Tunnels 1, 2, 3, 9 and 10	48 hour or 12 day shutdown periods
2	• notching the tunnel lining at the toe and haunch using a road header • strengthening notches using rock bolts and concrete • remove and replace existing rock bolts where required • reconstructing the tunnel wall (concrete sections only) where required • removal of moss, build-up and other debris as required	Tunnels 1,2, 3,6,7,8,9 and 10	48 hour or 12 day shutdown periods
3	• relocation of cable tray	Tunnel 3	48 hour or 12 day shutdown periods
4	• removal and replacement of lighting moisture protection shields	Tunnel 1 and Tunnel 10	48 hour or 12 day shutdown periods

4.2 Construction noise sources

Construction noise sources and their respective L_{Aeq} sound power levels for the construction scenario are shown in Table 10. These sound power levels are typical values taken from data provided in Australian Standard AS2436-2010, *Guide to noise and vibration control on construction, demolition and maintenance sites* and the UK Department for Environment, Food and Rural Affairs' (DEFRA) *Update of noise database for prediction of noise on construction and open sites* noise database and assume equipment is modern and in good working order.

Table 10 Equipment sound power levels used in the assessment

Equipment	Sound Power Level, dB(A)	
	L_{Aeq}	L_{A1}
Jack hammer	108	116
Non-powered hand tools	94	102
Excavator (road header)	110	118
Water cart	100	108
Generator	93	101
Road rail suction truck	103	111
Rail mounted trolley	100	108
Rail mounted elevated work platform	87	95
Road rail concrete truck	106	114
Road rail excavator	98	106

4.3 Modelling and conditions

In order to assess noise impacts during construction, a noise model was created to represent 'reasonable' worst periods of upgrade works. The construction of the Project has been modelled in SoundPLAN Version 7.3 with the following features included in the noise model:

- ground topography (the level and shape of the surrounding land)
- ground absorption and reflection
- buildings (including shielding of noise)
- residential receivers (as shown in Table 1)
- construction noise sources for the Project (as listed in Table 10).

Noise emissions from the construction locations have been modelled using an implementation of the International Organisation for Standardization 9613-2: *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* algorithm with neutral metrological conditions.

It can be expected that there may be differences between predicted and measured noise levels due to variations in instantaneous operating conditions, plant in operation during the measurement and also the location of the plant equipment. The acoustic shielding calculated in the model due to fixed building structures would also vary as the construction equipment moves around the site.

Construction noise levels at the identified residential receivers have been assessed against the NMLs for standard hours, daytime, evening and night-time out-of-hours (as shown in Table 4). However, the level of impact may change depending on the final construction methodology which would be developed by the contractor, and further assessment would be undertaken if required.

During construction, not all equipment would be operating simultaneously at all times and in the one location (as assumed in the modelling), which would result in a reduction in predicted noise levels.

Mitigation measures for receivers have been specified in Section 4.7. These measures are considered to be feasible and reasonable and would reduce the impact of these exceedances.

Noise results for the tunnel modification works are presented in Appendix C as noise contour layers over aerial maps.

4.4 Construction noise impacts

4.4.1 Noise impacts at residential receivers

Standard working hours

The predicted construction noise levels at residential receivers during standard hours are shown in Table 11. Results show that noise levels at the five representative residential receivers are predicted to be below the NMLs during standard construction hours.

High noise producing activities include the use of road headers and jackhammers. Construction noise sources are predominately associated with the entrances of tunnels where noise would emanate from.

Ground-borne noise (or 'regenerated' noise) is not considered to be a significant issue for this Project due to the relatively large distances from the Project site to the nearest sensitive receivers.

Outside of standard hours

The predicted construction noise levels at residential receivers outside of standard hours are shown during for the daytime, evening and night-time periods in Table 11. The modelling results show that noise levels at the five representative receivers are not predicted to exceed the NMLs during out of standard construction hours in the daytime.

For the proposed evening and night-time works, noise levels at three of the representative residential receivers (R3, R4 and R5) are predicted to exceed NMLs by up to one decibel. An exceedance of the NMLs of one decibel indicates that the construction activities may be audible but are unlikely to be intrusive.

Mitigation measures have been recommended in line with TfNSW's *Construction Noise Strategy.* The implementation of these mitigation measures where reasonable and feasible would minimise and manage noise impacts.

4.4.2 Noise impacts at non-residential receivers

No non-residential receivers are expected to be affected by the tunnel modification works.

Table 11 Predicted noise impacts at representative residential receivers in dB(A)

Receiver ID	Nearest distance to rail alignment (metres)	Noise management levels in dB(A)				Noise modelling results in dB(A)			
		Standard construction hours	Outside of standard hours			Standard construction hours	Outside of standard hours		
		Daytime	Daytime	Evening	Night	Daytime	Daytime	Evening	Night
R1	388	45	40	35	35	35	35	35	35
R2	446	45	40	35	35	35	35	35	35
R3	426	45	40	35	35	36	36	36	36
R4	409	45	40	35	35	36	36	36	36
R5	293	45	40	35	35	36	36	36	36

Notes:
1. Items shaded in GREY indicate predicted noise impact at this receiver during this work stage is above NML

4.4.3 Sleep disturbance assessment

As the tunnel modification works may require night-time works, consideration must also be given to the potential for sleep disturbance to residential receivers during night-time. It is noted however that works have been scheduled to occur during the day between 9:45 and 18:15 in an effort to avoid night works and minimise sleep disturbance.

Table 12 Predicted $L_{A1(1min)}$ noise impacts at representative residential receivers – sleep disturbance – Night-time in dB(A)

Receiver ID	Nearest distance to rail alignment (metres)	Sleep disturbance screening level	Sleep awakening level	Tunnel Modifications
R1	388	45	65	43
R2	446	45	65	43
R3	426	45	65	44
R4	409	45	65	44
R5	293	45	65	44

Sleep disturbance results are based on the predicted night time $L_{A1(1\ minute)}$ dB(A) noise levels for construction equipment. Based on past projects and AECOM's experience; it is assumed to be eight decibels higher than L_{eq} noise levels.

Results show that no representative receivers are predicted to exceed the sleep disturbance screening criteria or the sleep awakening criteria during the tunnel modification works.

4.5 Construction traffic assessment

Construction traffic volumes are anticipated to be up to 20 heavy vehicles supplying plant and equipment at the beginning and end of each possession / shutdown, plus a number of light / medium vehicle movements to service personnel and small equipment / material requirements.

From on-site observations during the deployment of unattended noise measurement equipment, the existing traffic flow is substantially greater than the proposed construction traffic numbers. Based on a review of traffic and transport conditions along Chifley Road, Clarence, including average annual daily traffic, additional construction traffic movements would be less than 10 per cent of the existing total daily movements.

In order for construction traffic to generate an increase in noise levels of greater than two decibels, existing traffic levels along construction traffic routes would need to increase by around 60 per cent. As a result, traffic noise levels would increase by less than two decibels. Therefore, the construction vehicles would have a negligible impact on existing road traffic noise in the area. The traffic generated by the Project is considered to comply with the *Road Noise Policy* criteria.

4.6 Construction vibration assessment

Vibration-intensive works may include the use of the following items of equipment:

- jack hammer
- road header.

The safe working distances of these items of equipment from off-site receivers are shown in Table 13 which is based on recommendations of the TfNSW *Construction Noise Strategy* (CNS) and AECOM's previous project experience. If these safe working distances are complied with, no adverse impacts from vibration intensive works are likely in terms of human response or cosmetic damage.

Based on the indicative construction activities assessed for the Project, it is unlikely that works would occur within the safe working distances for offsite vibration sensitive receivers. If vibration-intensive works are required within these safe working distances, mitigation measures to control excessive vibration would be implemented as outlined in Section 4.7.

Table 13 Safe working distances of vibration intensive equipment to be used during the Project

Plant	Rating/ Description	Cosmetic damage – residential/commercial	Cosmetic damage - heritage	Human response
Jack hammer	Hand-held	1 m (nominal)	1 m (nominal)	Avoid contact with structure
Road header	Excavator mounted	7 m	10 m	25 m

It is likely that works will be undertaken within the safe working distances of the tunnels. The safe working distances for cosmetic damage are generally considered to be conservative and working within them would not necessarily result in damage. However, as factors such as work practices and intervening structures can affect vibration levels, vibration monitoring is recommended within these distances and should be undertaken at the beginning of vibration intensive works in order to refine the safe working distances for site specific conditions.

The tunnels should be demarcated as constraint areas, as far as is practical, during construction to avoid potential impacts from vibration. For vibration-generating activities within the tunnels, it is recommended that attended measurements are undertaken when work commences, to determine site specific safe working distances.

4.7 Construction mitigation measures

4.7.1 Construction Noise and Vibration Management Plan

It has been identified that potential construction noise impacts at three residences within the vicinity of the tunnel modification works may exceed the noise management levels. The exceedance of the noise management levels is minor (1 dB), however standard construction noise mitigation measures, including a Construction Noise and Vibration Management Plan (CNVMP) would be developed and implemented prior to commencement of construction activities.

Table 14 presents the standard mitigation measures contained within the *Construction Noise Strategy* (CNS) which should be considered as mitigation measures as part of the CNVMP.

Table 14 TfNSW's *Construction Noise Strategy* standard mitigation measures

Action required	Safeguard details
Management measures	
Implement any project specific mitigation measures required	In addition to the measures set out in this table, any project specific mitigation measures identified in this report.
Implement community consultation measures	Periodic notification (monthly letterbox drop or equivalent), website, Project Infoline, Construction Response Line, email distribution list.
Site inductions	All employees, contractors and subcontractors are to receive an environmental induction.
Behavioural practices	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height, throwing of metal items and slamming of doors.

Action required	Safeguard details
Noise monitoring	A noise monitoring program is to be carried out for the duration of the works in accordance with the CNVMP and any approval and licence conditions.
Source controls	
Construction hours and scheduling	Where feasible and reasonable, construction should be carried out during the standard daytime working hours. Work generating high noise and/or vibration levels should be scheduled during less sensitive time periods.
Construction respite period	High noise and vibration generating activities may only be carried out in continuous blocks, not exceeding three hours each, with a minimum respite period of one hour between each block.
Equipment selection	Use quieter and less vibration emitting construction methods where feasible and reasonable.
Maximum noise levels	The noise levels of plant and equipment must have operating sound power or sound pressure levels that would meet the predicted noise levels.
Rental plant and equipment	Noise emissions should be considered as part of the selection process.
Use and siting of plant	Avoid simultaneous operation of noisy plant within discernible range of a sensitive receiver. The offset distance between noisy plant and adjacent sensitive receivers is to be maximised. Plant used intermittently to be throttled down or shut down. Plant and vehicles to be turned off when not in use. Noise-emitting plant to be directed away from sensitive receivers.
Plan works site and activities to minimise noise and vibration	Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site.
Non-tonal reversing alarms	Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work.
Minimise disturbance arising from delivery of goods to construction sites	Loading and unloading of materials/deliveries is to occur as far as possible from sensitive receivers. Select site access points and roads as far as possible away from sensitive receivers. Dedicated loading/unloading areas to be shielded if close to sensitive receivers. Delivery vehicles to be fitted with straps rather than chains for unloading, wherever possible.
Construction related traffic	Schedule and route vehicle movements away from sensitive receivers and during less sensitive times. Limit the speed of vehicles and avoid the use of engine compression brakes. Maximise on-site storage capacity to reduce the need for truck movements during sensitive times.
Silencers on Mobile Plant	Where possible reduce noise from mobile plant through additional fittings including: • Residential grade mufflers • Damped hammers such as ‘City’ Model Rammer Hammers • Air Parking brake engagement is silenced

Action required	Safeguard details
Path controls	
Shield stationary noise sources such as pumps, compressors, fans etc.	Stationary noise sources should be enclosed or shielded whilst ensuring that the occupational health and safety of workers is maintained.
Shield sensitive receivers from noisy activities	Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where practicable) and consideration of site topography when situating plant.

In addition to the standard mitigation measures identified in the CNS, the following specific mitigation measures have been developed as a result of the predicted impacts associated with the Project:

- truck drivers should be advised of designated vehicle routes, parking locations, acceptable delivery hours or other relevant practices (e.g. minimising the use of engine brakes, and no extended periods of engine idling). Construction sites should be arranged to limit the need for reversing associated with regular / repeatable movements (e.g. trucks transporting spoil) to minimise the use of reversing alarms. Where feasible and reasonable, non-tonal reversing alarms should be used, taking into account the requirements of the Workplace Health and Safety legislation

For vibration-intensive activities which occur within the tunnels, management methods to mitigate potential vibration impacts should include, as a minimum, the following:

- the use of less vibration-intensive methods of construction or equipment is preferred where practical to reduce the potential for cosmetic damage. All equipment should be maintained and operated in an efficient manner, in accordance with manufacturer's specifications, to reduce the potential for adverse vibration impacts
- it is recommended that a structural engineer oversee vibration-intensive activities, including undertaking regular inspections, to monitor for potential impacts to the integrity of the brickwork surrounding the working area.
- it is recommended that attended vibration measurements are undertaken when work commences, to determine site-specific safe working distances. Vibration intensive work should not proceed within the safe working distances unless a permanent vibration monitoring system is installed around one metre from the tunnel footprint, to warn personnel (e.g. via flashing light, audible alarm, SMS) when vibration levels are approaching the peak particle velocity objective. It is also advisable to carry out condition surveys of tunnels before construction works begins.

4.7.2 Community consultation and complaints handling

All residents and sensitive receivers impacted by noise and vibration from the Project which are expected to exceed the NML should be informed about the Project prior to the commencement of construction, with the highest consideration given to those that are predicted to be most affected as a result of the works.

The information provided to the residents / building occupants should include:

- programmed times and locations of construction work
- the hours of proposed works
- construction noise and vibration impact predictions
- construction noise and vibration mitigation measures being implemented on site.

Community consultation regarding construction noise and vibration would be detailed in a Community and Stakeholder Engagement Plan for the construction of the Project and would include a 24 hour hotline and complaints management process.

4.7.3 TfNSW's *Construction Noise Strategy* - Additional mitigation measures

Where exceedances in airborne noise are still expected to occur after standard mitigation measures have been applied, the CNS recommends the implementation of additional mitigation measures. These mitigation measures are specified within TfNSW's CNS and presented in Table 15.

The provision of additional mitigation is based on the predicted exceedances above RBLs and when the exceedances occur. The RBLs can be found in Table 4.

Table 15 Additional mitigation measures matrix for airborne construction noise

Time period		Mitigation measures $L_{Aeq(15minute)}$ noise level above the background Qualitative assessment of noise levels[1]			
		0 to 10 dBA Noticeable	10 to 20 dBA Clearly audible	20 to 30 dBA Moderately intrusive	>30 dBA Highly intrusive
Standard	Mon-Fri (7am-6pm) Sat (8am-1pm) Sun/Pub Hol (Nil)	-	-	LB, M	LB, M
OOHW[3] Period 1	Mon-Fri (6pm-10pm) Sat (7-8am) & (1pm-10pm) Sun/Pub Hol (8am-6pm)	-	LB	M, LB	M, IB, LB, RO, PC, SN, RO[2]
OOHW[3] Period 2	Mon-Fri (10pm-7am) Sat (10pm-8am) Sun/Pub Hol (6pm-7am)	LB	M, LB, RO[2]	M, IB, LB PC, SN, RO[2]	AA, M, IB, LB, PC, SN, RO

Notes:
1. For some types of construction activities, a qualitative assessment of the potential noise impacts can be undertaken in lieu of detailed noise modelling. For these activities, noise mitigation measures should be evaluated on the basis of the noise levels being noticeable, clearly audible, moderately intrusive or highly intrusive. The qualitative assessment should consider the type of equipment being used, the character of the noise emissions, time of day, the location of the nearest receivers and the noise sensitivity of the nearest receivers. Where a qualitative assessment is being undertaken, this will need to be approved by the Environmental Management Representative.
2. Respite Offers identified in Period 2 for clearly audible (10 to 20dBA) and moderately intrusive (20 to 30dBA) work shall only apply if works are expected to continue for more than 3 consecutive evenings for Period 1 or more than 2 consecutive nights for Period 2.
3. Out of Hours Works (OOHW) – Outside of standard hours.
4. The following abbreviations have been used (as described in more detail in Table 16):

   AA: Alternative accommodation, M: Monitoring, IB: Individual briefings, LB: Letter box drops, RO: Project specific respite offer, PC: Phone calls, SN: Specific notifications.

Three residential receivers (R3, R4 and R5) are expected to exceed the NMLs during out of hours work in the evening (OOHW Period 1) and night time (OOHW Period 2). As the exceedance is predicted to be up to one decibel, based on the CNS recommendations, these three residences should receive letter box drops.

Table 16 outlines the additional mitigation measures, as outlined in the CNS.

Table 16 Description of additional mitigation measures

Abbreviation	Mitigation measure	Explanation
LB	Letter Box Drops	All residences should be notified as a minimum by letterbox drop seven days ahead of construction activities.
M	Monitoring	Attended noise monitoring is to be undertaken as follows: At the commencement of out-of-hours works (within the first two nights), where out-of-hours works activities change; and Noise measurements shall be undertaken in accordance with the procedure documented in AS1055.1-1997 *Acoustics - Description and Measurement of Environmental Noise - General Procedures*.
IB	Individual Briefings	Individual briefings are used to inform stakeholders about the impacts of high noise activities and mitigation measures that would be implemented. Communications representatives from the contractor would visit identified stakeholders at least 48 hours ahead of potentially disturbing construction activities. Individual briefings provide affected stakeholders with personalised contact and tailored advice, with the opportunity to comment on the project.
RO	Project Specific Respite Offer	Residents subjected to lengthy periods of noise or vibration may be eligible for a project specific respite offer. The purpose of such an offer is to provide residents with respite from an ongoing impact. The offer could comprise pre-purchased movie tickets or similar offer. This measure is determined on a project-by-project basis.
PC	Phone Calls	Phone calls detailing relevant information would be made to identified/affected stakeholders within seven days of proposed work. Phone calls provide affected stakeholders with personalised contact and tailored advice, with the opportunity to provide comments on the proposed work and specific needs etc.
SN	Specific Notifications	Specific notifications are letterbox dropped or hand distributed to identified stakeholders no later than seven days ahead of construction activities that are likely to exceed the noise management levels. This form of communication is used to support periodic notifications, or to advertise unscheduled works.
AA	Alternative Accommodation	Alternative accommodation options should be provided for residents living in close proximity to construction works that are likely to incur noise levels significantly above the applicable level.

5 Operational noise assessment

Environmental noise emissions from the operation of the modified tunnels are not expected to change significantly as a result of the Project, as such an assessment under the *Noise Policy for Industry* (EPA, 2017) is not required.

The New Intercity Fleet is expected to be quieter than the existing intercity trains, in particular wheel squeal and engine noise is likely to be lower. Tunnel lining modifications will only modify the interior of the tunnels by a maximum of 127 millimetres, therefore operational noise from rail movements through the tunnels is expected to remain the same or be reduced from the current situation. Therefore, an assessment under the *Rail Infrastructure Noise Guideline* is not required.

Appendix A Acoustic terminology

The following is a brief description of acoustic terminology used in this report.

Terminology	Meaning
Sound power level	The total sound emitted by a source
Sound pressure level	The amount of sound at a specified point
Decibel [dB]	The measurement unit of sound
A Weighted decibels [dB(A])	The A weighting is a frequency filter applied to measured noise levels to represent how humans hear sounds. The A-weighting filter emphasises frequencies in the speech range (between 1kHz and 4 kHz) which the human ear is most sensitive to, and places less emphasis on low frequencies at which the human ear is not so sensitive. When an overall sound level is A-weighted it is expressed in units of dB(A).
Decibel scale	The decibel scale is logarithmic in order to produce a better representation of the response of the human ear. A 3 dB increase in the sound pressure level corresponds to a doubling in the sound energy. A 10 dB increase in the sound pressure level corresponds to a perceived doubling in volume. Examples of decibel levels of common sounds are as follows: 0dB(A) - Threshold of human hearing 30dB(A) - A quiet country park 40dB(A) - Whisper in a library 50dB(A) - Open office space 70dB(A) - Inside a car on a freeway 80dB(A) - Outboard motor 90dB(A) - Heavy truck pass-by 100dB(A) - Jackhammer/Subway train 110 dB(A) - Rock Concert 115dB(A) - Limit of sound permitted in industry 120dB(A) - 747 take off at 250 metres
Frequency [f]	The repetition rate of the cycle measured in Hertz (Hz). The frequency corresponds to the pitch of the sound. A high frequency corresponds to a high pitched sound and a low frequency to a low pitched sound.
Equivalent continuous sound level [L_{eq}]	The constant sound level which, when occurring over the same period of time, would result in the receiver experiencing the same amount of sound energy.

Terminology	Meaning
L_{aeq}	This level is the equivalent continuous sound level and has the same sound energy over the sample period as the actual noise environment with fluctuating sound levels.
L_{max}	The maximum sound pressure level measured over the measurement period
L_{min}	The minimum sound pressure level measured over the measurement period
L_1	The sound pressure level exceeded for 1 per cent of the measurement period. For 1 percent of the measurement period it was louder than the L_1.
L_{10}	The sound pressure level exceeded for 10 per cent of the measurement period. For 10 per cent of the measurement period it was louder than the L_{10}.
L_{90}	The sound pressure level exceeded for 90 per cent of the measurement period. For 90 per cent of the measurement period it was louder than the L_{90}.
Ambient noise	The all-encompassing noise at a point composed of sound from all sources near and far.
Background noise	The underlying level of noise present in the ambient noise when extraneous noise (such as transient traffic and dogs barking) is removed. The L_{90} sound pressure level is used to quantify background noise.
Traffic noise	The total noise resulting from road traffic. The L_{eq} sound pressure level is used to quantify traffic noise.
Day	The period from 0700 to 1800 h Monday to Saturday and 0800 to 1800 h Sundays and Public Holidays.
Evening	The period from 1800 to 2200 h Monday to Sunday and Public Holidays.
Night	The period from 2200 to 0700 h Monday to Saturday and 2200 to 0800 h Sundays and Public Holidays.
Assessment background level [ABL]	The overall background level for each day, evening and night period for **each day** of the noise monitoring.
Rating background level [RBL]	The overall background level for each day, evening and night period for the **entire length** of noise monitoring.
Weighted sound reduction index [R_w]	A single figure representation of the air-borne sound insulation of a partition based upon the R values for each frequency measured in a laboratory environment.

*Definitions of a number of terms have been adapted from Australian Standard AS1633:1985 *"Acoustics – Glossary of terms and related symbols"*, the EPA's NSW *Industrial Noise Policy* and *Road Noise Policy*.

Appendix B Noise logging location

AECOM

Zig-Zag Station

Newnes Junction Station

CLARENCE COLLIERY ROAD

CHIFLEY ROAD

PETRA AVENUE

KERMA CRESCENT

DONALD ROAD

VALLEY VIEW ROAD

SANDHAM ROAD

20 Sandham Road, Bell

10 10 9 9 8 8 7 7 6 6 5 5 4 4 2 2 1 1

R1 R2 R3 R4 R5

Receivers

Tunnel Ends

Logger Location

N

0 250 500 1,000 Meters

New Intercity Fleet – Route Clearance Works

Tunnel Modification Works - Logger Location

Aug 2017

60528375

Fig. **1**

Bell - 31/03/17 - 10/04/17

Logger Setup

Logger Type: Rion NL52

Serial No : 1043455

Address: 20 Sandham Road , Bell

Location: Front Yard

Facade / Free Field: Free Field

Environment: Next to the rail line. Wind noise dominant. Distant sound of highway in background. Train passed during attended measurement, 76dBA.

Logger Setup Photo

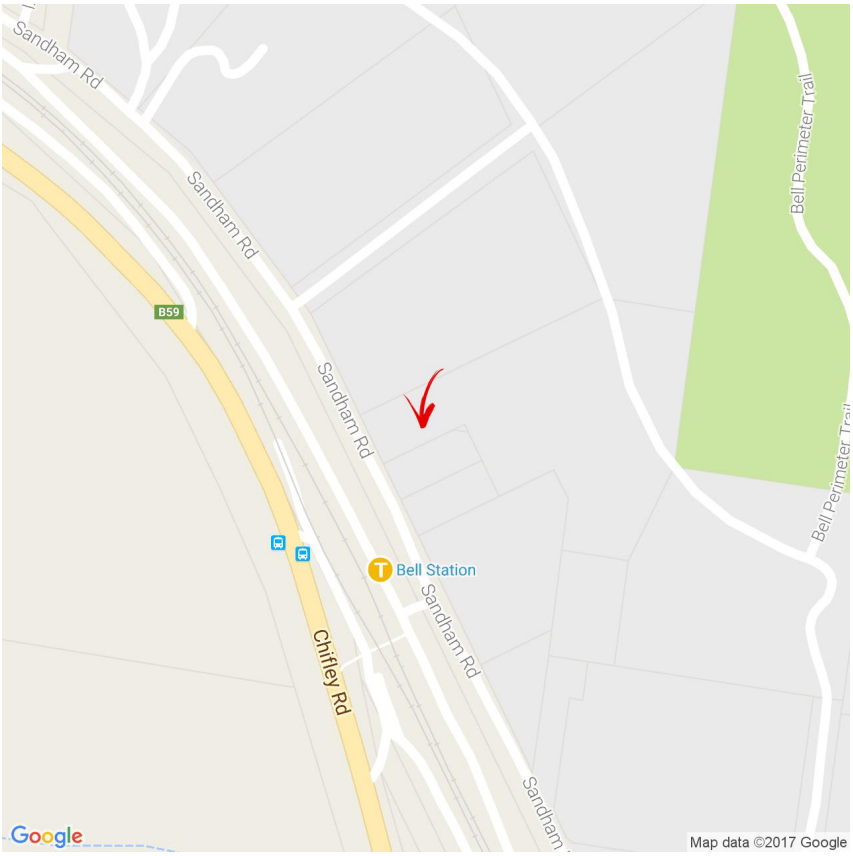
INP Noise Level, dB(A)

	Log Average	RBL
Day	45	31
Evening	44	26
Night	43	17

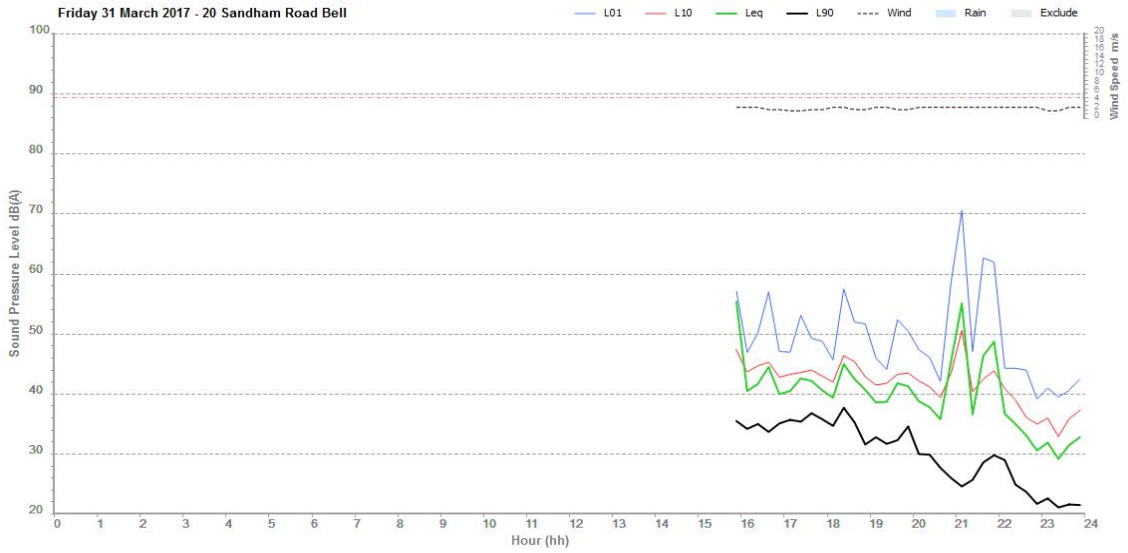
RNP Noise Level, dB(A)

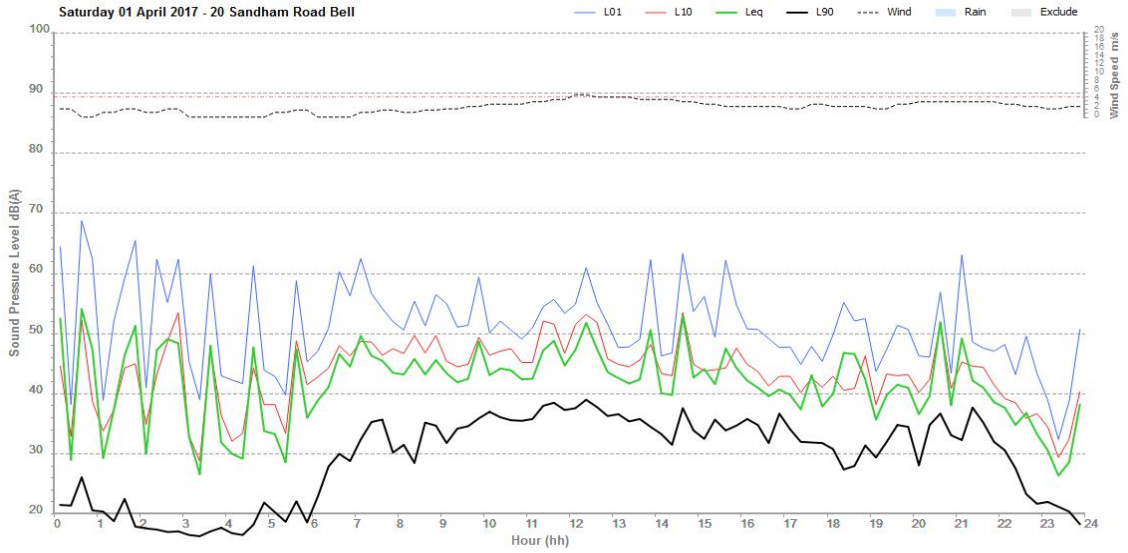
	$L_{Aeq(1hr)}$	$L_{Aeq(period)}$
Day (7am - 10 pm)	-	-
Night (10pm - 7am)	-	-

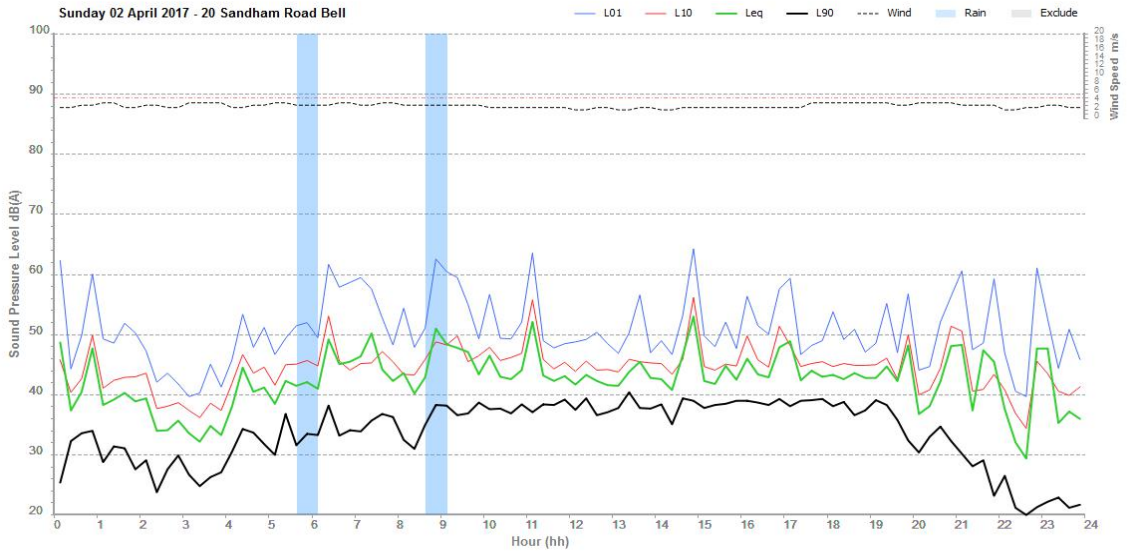
Logger Location Map



Logger Graphs







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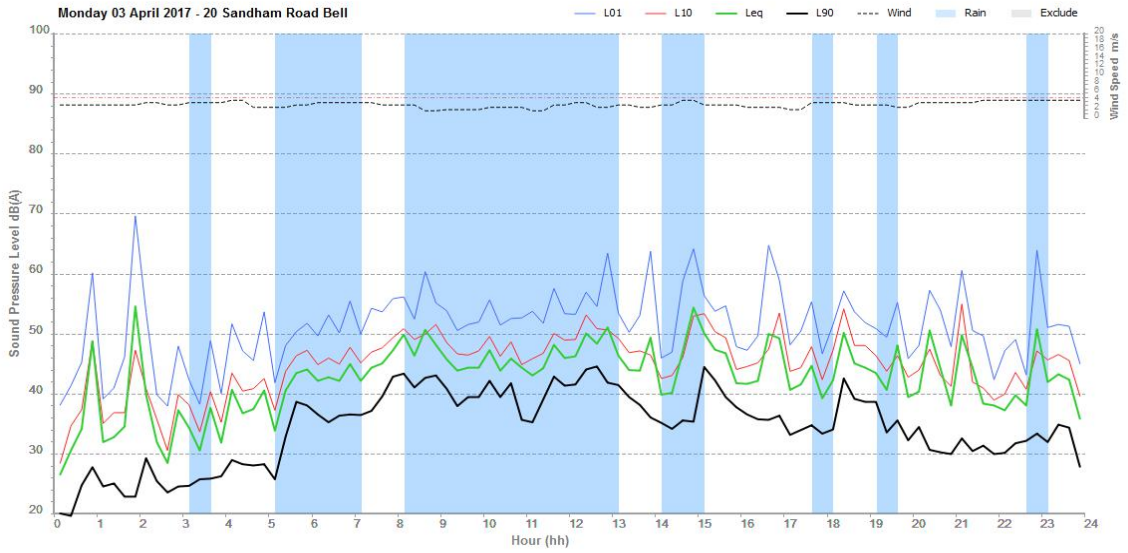

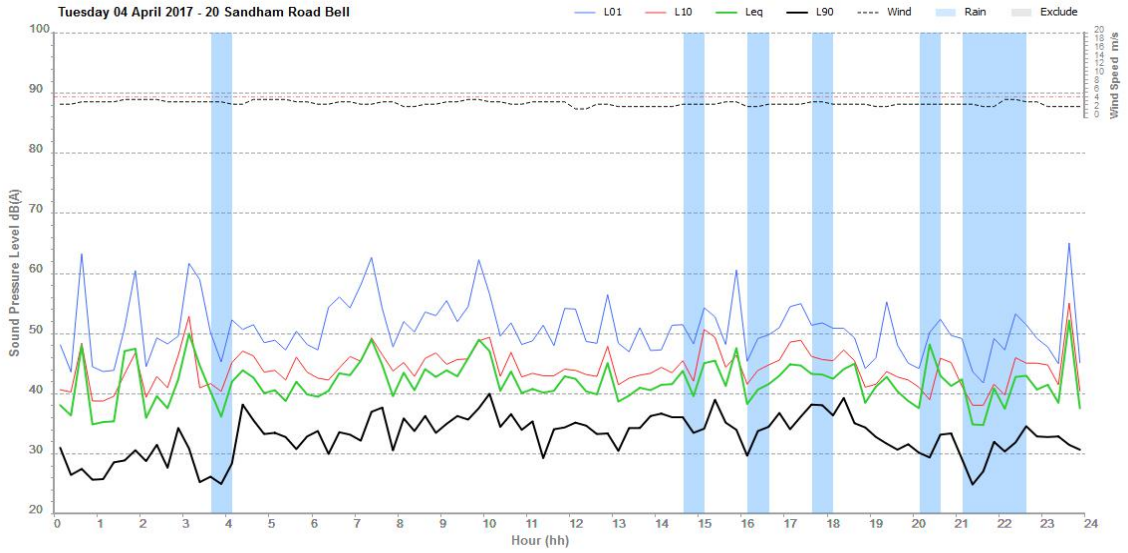

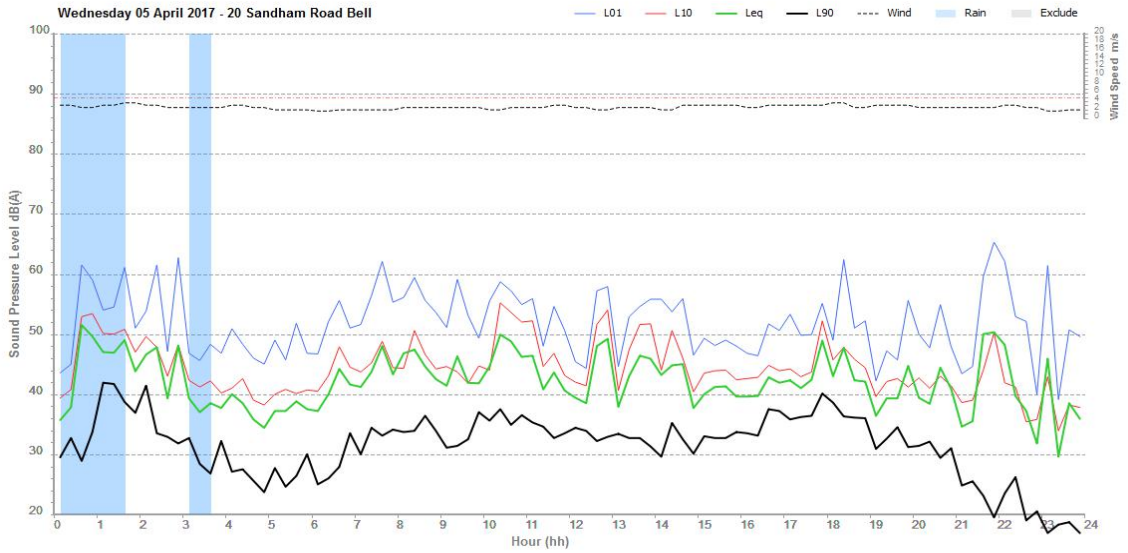

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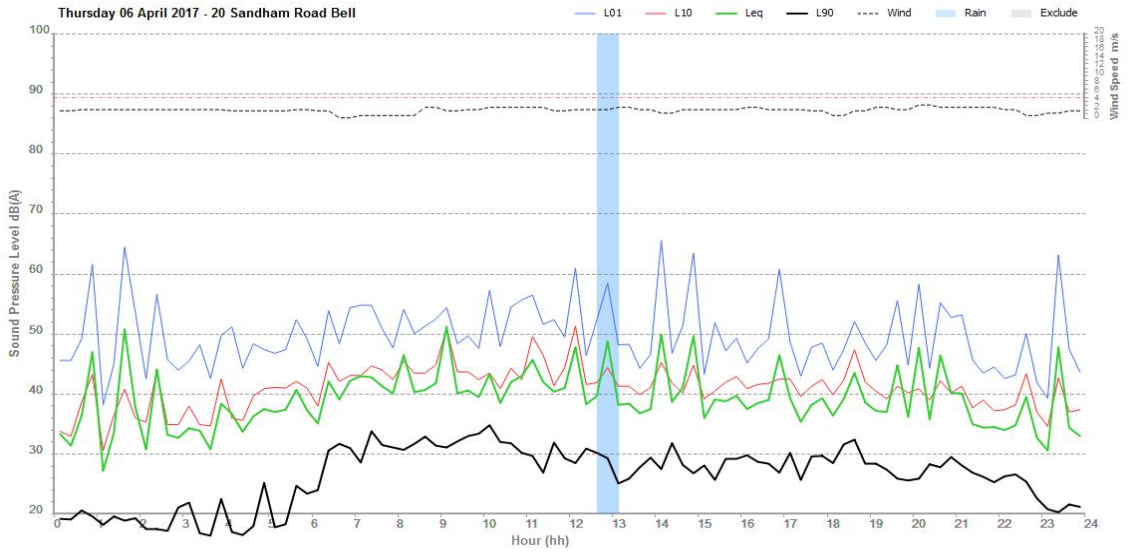
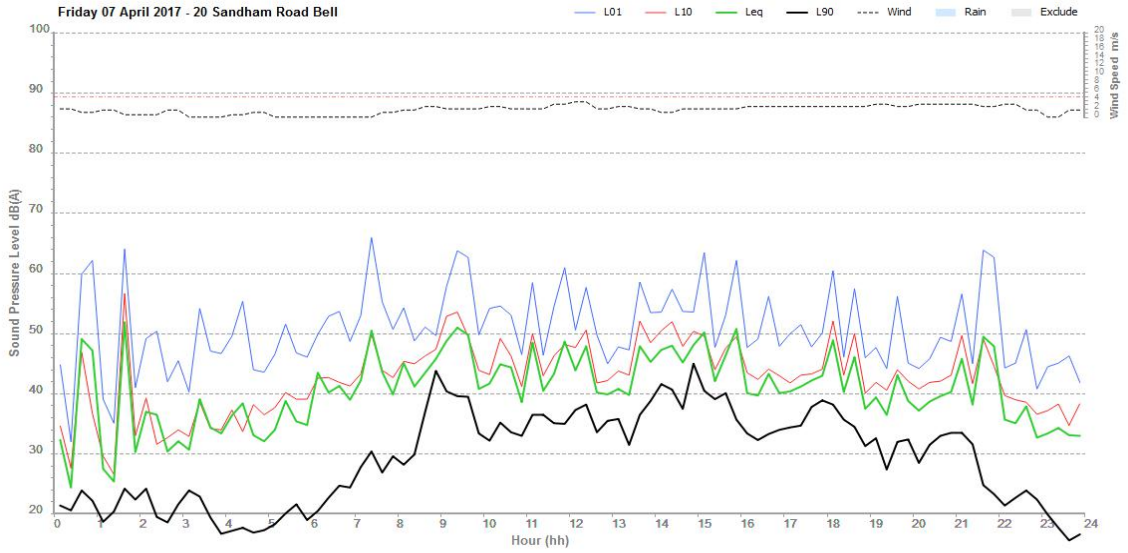
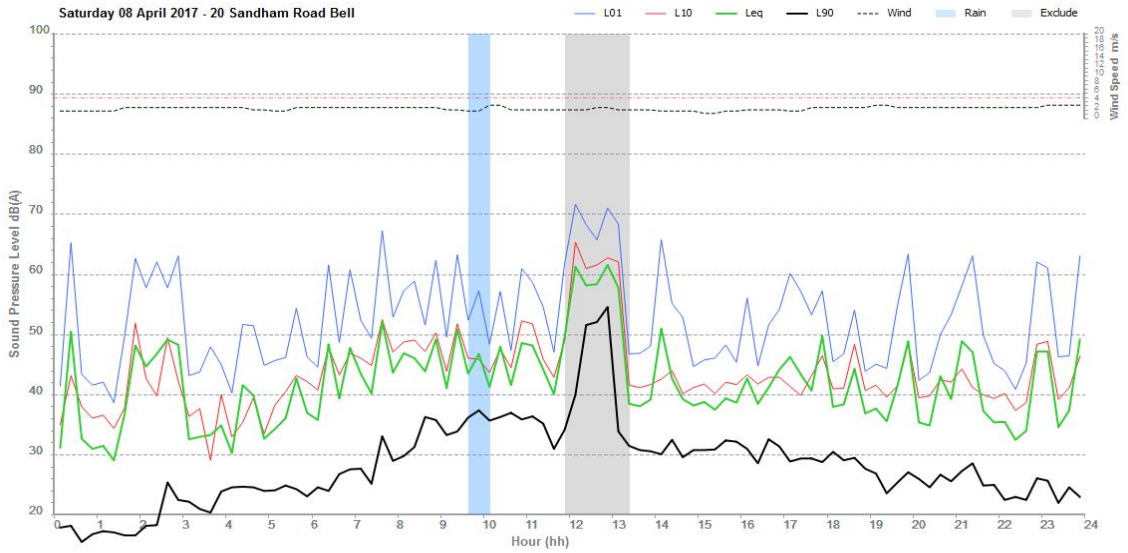
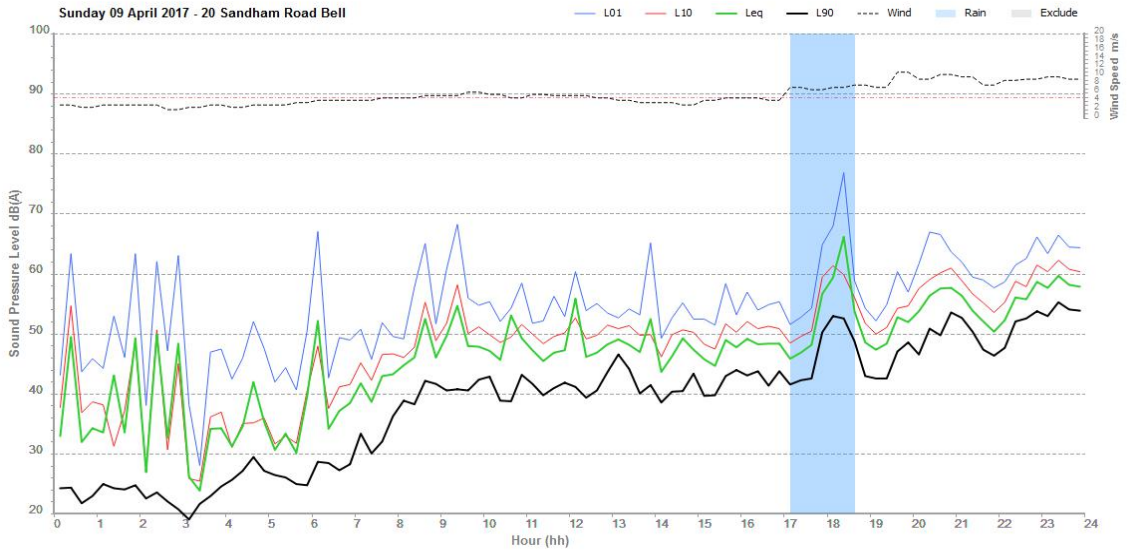
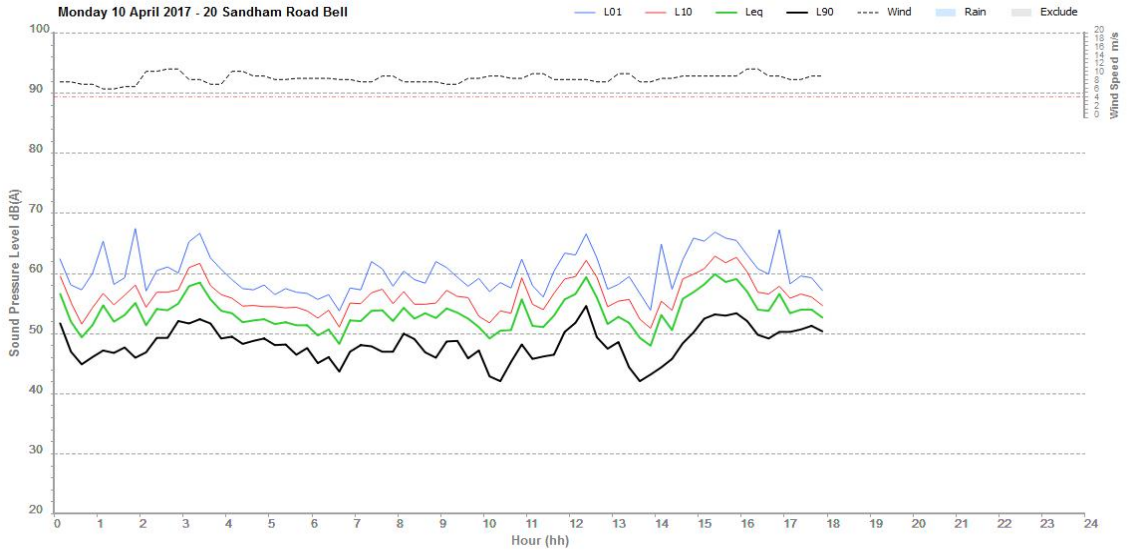






Logger Graphs





Appendix C Noise contour maps

AECOM

CHIFLEY ROAD
PETRA AVENUE
KERMA CRESCENT
DONALD ROAD
R1
R2
R3
R4
R5
10
9
8
7
6
5
4
2
1

Service Layer Credits: © Land and Property Information 2015

Sound Pressure Level, L_{Aeq} dB(A)

< 35 | 35 - 40 | 40 - 45 | 45 - 50 | 50 - 55 | 55 - 60 | 60 - 65 | > 65

Receivers

Tunnel Ends

New Intercity Fleet – Route Clearance Works

Tunnel Modification Works - Predicted Noise Levels

Aug 2017

60528375

N

0 100 200 400 Meters

Fig. **1**