Sydney Metro

Technical Paper 3

Noise and vibration assessment

Central | Town Hall Square | Martin Place | Barangaroo–Wynyard | Pyrmont | Rozelle

CBD Metro

Environmental Assessment

Technical Paper 3 – Noise and Vibration Assessment Construction, Operations and Maintenance

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CBD Metro Noise and Vibration Assessment

Construction, Operations and Maintenance

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DOCUMENT CONTROL

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10-7795-R1	Revision 0	19 August 2009	Antony Williams John Sleeman Michael Allan James Hong David Geiger Mikel Lacis	Conrad Weber Richard Heggie	Conrad Weber

This report is to be read in conjunction with the Environmental Assessment for the Sydney Metro Network Stage 1 (CBD Metro) project dated September 2009.

The project as described within the Environmental Assessment will prevail in the event of any inconsistency with the project as described in the following document.

EXECUTIVE SUMMARY

INTRODUCTION

The proposed CBD Metro will run from Central to Rozelle and consist of approximately 7 km of underground railway with six stations. The majority of the proposed alignment would be located within twin-bored tunnels, with the tunnels running beneath or close to numerous buildings. Some of these buildings within the CBD are already exposed to railway noise and/or vibration as a result of train operations on the existing CityRail underground rail network. Residential buildings in Pyrmont and Rozelle are also close to the proposed route of the Metro.

The objective of this study is to evaluate and assess the potential noise and vibration impacts associated with the construction, operation and maintenance of the CBD Metro, including the operating railway lines, stations, train depot and other associated facilities. It identifies appropriate design goals based on local and international guidelines. Where noise and vibration levels are predicted to exceed the design goals, options and recommendations for mitigating or managing the potential impacts are presented.

This report has been prepared in accordance with the requirements of Part 3A of the Environmental Planning and Assessment Act 1979 and the Director-General's Requirements (DGRs) for the Environmental Assessment (EA), issued on 27 February 2009.

The potential noise and vibration impacts have been categorised as follows:

- Impact of the construction phases of the project, inclusive of:
  - Construction noise; and
  - Construction vibration and ground-borne noise.
- Operational impacts after commissioning, consisting of:
  - Ground-borne noise from train operations;
  - Ground-borne vibration from train operations;
  - Airborne noise from train operations;
  - Airborne noise from train stabling and maintenance activities; and
  - Airborne noise at stations, portals and ventilation shafts.

For each of the above, the report describes the relevant noise and vibration design goals, background information, the assessment methodology, results of any calculations/modelling, comparison of the results to the relevant design goals and a description of the indicative impact and the likely management and mitigation measures. Following on from these sections are a draft Statement of Commitments (SoC) and the overall conclusions of the assessment.

The assessment embodied within this report is based entirely upon the Reference Design. This represents one example of how the project could be constructed, operated and maintained. During the detailed design stage of the project, and following the award of the construction and operation contracts, the successful tenderers may choose to construct, operate and maintain the CBD Metro in a different manner to that which is described in this report.

Should circumstances arise that result in minor changes to the Reference Design, the noise and vibration impacts as a result of the CBD Metro would not be expected to be greater than those described and assessed within this report. If the detailed design phase does result in significant changes, these will need to be assessed and approved on a case by case basis in consultation with the affected community. It is also noted that the project noise and vibration design goals are unlikely to change throughout the project, and that the successful tenderers would be required to comply with the SoC described in this report.

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For the proposed station at Pyrmont, two options are currently being considered. These are referred to as Pyrmont Station Alternative 1 and Pyrmont Station Alternative 2. In the main body of this report, the Pyrmont Station Alternative 1 option has been assessed. The potential noise and vibration impacts associated with the Pyrmont Station Alternative 2 option are assessed in **Appendix N**.

IDENTIFICATION OF SENSITIVE RECEIVERS

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and activities within the affected premises. Site inspections were undertaken within a corridor extending approximately 30 m either side of the nearest CBD Metro tunnel to identify the sensitivity of each nearby receiver. Receivers were classified as commercial, educational, industrial, residential, worship or other sensitivity to assist in determining appropriate noise and vibration design goals.

Within the CBD, the majority of receivers near the proposed alignment are commercial properties. These are less sensitive to noise and vibration compared to residential receivers. Outside the CBD, the alignment runs under several residential areas in Pyrmont and Rozelle. Whilst most commercial receivers are generally less sensitive than residential receivers, several commercial properties have been identified as being potentially susceptible to noise and vibration as a result of sensitive equipment being located within these buildings. These are identified within the report.

AMBIENT NOISE MONITORING

In order to characterise the existing ambient noise environment across the project areas (in relation to both construction and operation), environmental noise monitoring was performed at 19 representative locations during March, April and May 2009.

The purpose of the unattended noise monitoring was to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods. These were used to assist in determining the appropriate noise design goals as a basis for assessing the potential noise impacts during construction and operations.

Attended noise measurements were also undertaken at 24 representative locations in order to quantify the noise levels from the various noise sources. During each of the attended noise surveys, the observer noted the various noise sources and levels influencing the ambient noise environment. The acoustic environment at the attended locations is described in the following:

- At locations surrounding the former Rozelle Marshalling Yard and the White Bay construction site the ambient noise environment was dominated by traffic on City-West Link Road/Victoria Road/Anzac Bridge, resulting in relatively high noise levels. These included the suburbs of Annandale, Lilyfield, Rozelle, Balmain and Glebe Point.
- At locations surrounding Rozelle Station the ambient noise environment was dominated by traffic on Victoria Road, resulting in relatively high noise levels. Dwellings to the south of the site are shielded by the Tigers Leagues Club resulting in lower levels, compared to those fronting Victoria Road.
- At Pyrmont locations the ambient noise environment was dominated by local traffic and urban hum, resulting in medium to high noise levels.
- At city locations corresponding to Central, Town Hall Square, Martin Place and Barangaroo-Wynyard the ambient noise environment was dominated by city traffic and urban hum, resulting in high noise levels. Slightly higher levels where recorded at Town Hall and Martin Place, when compared to Central and Wynyard, as a result of these locations being on busier CBD streets.

ATTENDED GROUND-BORNE NOISE AND VIBRATION MEASUREMENTS

Attended ground-borne noise and vibration measurements were undertaken at seven representative locations above or near existing railway tunnels within the CBD. The purpose of these measurements was to quantify the existing ground-borne noise and vibration levels from existing train operations and to assist in determining appropriate design goals for non-residential receivers.

At three locations, the ground-borne noise and vibration was not able to be measured as the levels from train passbys were below ambient levels. At the remaining four locations, ground-borne noise levels typically ranged between 35 dBA and 50 dBA.

In commercial buildings (offices and conference rooms), ground-borne noise levels of 40 dBA were just audible and not considered to be intrusive. In these spaces, a ground-borne noise level of 40 dBA was typically 2 dBA to 5 dBA above general office noise depending on usage.

Tactile vibration levels became faintly "feelable" when ground-borne noise levels reached approximately 45 dBA. Ground-borne noise levels from train passbys at 50 dBA are likely to be intrusive for general office areas and other similar environments.

CONSTRUCTION NOISE

Worksites

The CBD Metro represents a major infrastructure development project. It would be constructed over several years, and as such there would be periods when impacts on the surrounding areas are expected.

For the proposed CBD Metro, the major worksites would be located at White Bay (for the Tunnel Boring Machine launch site and support facilities) and the adjoining stabling and maintenance depot at Rozelle. Construction sites would also be located at the station sites of Central, Town Hall Square, Martin Place, Barangaroo-Wynyard, Pyrmont and Rozelle. Significant activities would involve demolition (at some sites), with the use of jackhammers and rockbreakers, excavation using rockbreakers and roadheaders, earthworks, removal of spoil and station construction.

Construction Noise Goals

Heggies has conducted a review of guidelines and current practices for the assessment and subsequent mitigation of construction noise, and has adopted the following approach for the CBD Metro Project. Project specific **Noise Management Levels** (NMLs) have been developed for Noise Affected receivers to deal with construction noise in a transparent and consistent way. Consistent with this approach, the following project specific $L_{Aeq(15minute)}$ NMLs have been adopted for sensitive receivers:

- Daytime (7 am to 6 pm) RBL or L_{A90} Background +10 dBA
- Evening (6 pm to 10 pm) RBL or L_{A90} Background + 5 dBA
- Night-time (10 pm to 7 am) RBL or L_{A90} Background + 5 dBA

At commercial receivers the recommended NML is 70 dBA. Construction noise goals have also been determined for other sensitive receivers such as schools, childcare centres and churches and are discussed in the relevant sections of the report.

It is noted that the above assessment approach is consistent with the DECCW's current "*Interim Construction Noise Guideline*" (2009).

Daytime Construction Works

Where demolition of existing structures is required these activities will occur during the daytime only, and typically last for up to 3 months, except where multistorey buildings are to be demolished where the demolition period may be up to 9 months. At all sites, following demolition works, construction activities would be likely to occur over a period greater than one year. The potential noise and vibration impacts would be highest during any demolition works (if required) and during initial site excavation works. These initial works would primarily be undertaken during daytime periods (7 am to 6 pm Monday to Friday and 8 am to 1 pm on Saturdays) using conventional methods. Construction noise and vibration levels during these initial stages would be similar to those that occur at many other building sites across the CBD.

Out of Hours Works

Following any demolition and the initial site excavation works, some construction activities are anticipated to occur during the daytime and night-time for the duration of the construction period. Prior to undertaking significant "out of hours" works, noise mitigation and management measures would be implemented (where required) to minimise the potential noise and vibration impacts at nearby sensitive receivers. At some construction sites, this is likely to involve the construction of acoustic enclosures and/or noise barriers to contain noise emissions. Some noise intensive activities such as rockbreaking may need to be restricted to daytime and evening periods only.

Construction Noise Strategy

The Director-General's Requirements for the project recognise that there are likely to be potential noise and vibration impacts associated with the proposed construction works. An extract from the Director-General's Requirements is provided below:

> *"**General Construction Impacts** - [The Environmental Assessment must] consider the potential impacts associated with the construction of the project, and present a management framework for construction works to ensure that impacts are mitigated, monitored and managed. The EA must include consideration of, and a management framework for:*
>
> ** construction noise and vibration, including a considered approach to scheduling construction works having regard to the nature of construction activities (including transport, blasting and tonal or impulsive noise-generating works), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially-affected human receivers and structures, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic or spoil management). The EA must also present a strategy for monitoring and mitigating construction noise and vibration, with a particular focus placed on those activities identified as having the greatest potential for adverse noise or vibration impacts, and a broader, more generic approach developed for lower-risk activities"*

Sydney Metro is in the process of developing a *"Construction Noise and Vibration Strategy"* that will be adopted by all contractors to address the above requirements. In preparing this strategy, consideration has been given to several guideline documents including DECCW's *"Interim Construction Noise Guideline"*, Transport Infrastructure Development Corporation's *"Construction Noise Strategy (Rail Projects)"* and Australian Standard AS 2436-1981 *"Guide to noise control on construction, maintenance and demolition sites"*.

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The *"Construction Noise and Vibration Strategy"* will provide practical guidance on how to minimise, to the fullest extent practicable, the impacts on the community from airborne noise, ground-borne noise and vibration generated during the construction of the CBD Metro through the application of all feasible and reasonable mitigation measures. It will contain a standard suite of noise and vibration mitigation measures to be applied at all construction sites. It will also outline additional mitigation and management measures required when predicted construction noise or vibration levels exceed the construction noise and vibration goals. The document will also provide guidance in relation to undertaking regular noise and vibration monitoring and audits.

A framework for the *"Construction Noise and Vibration Strategy"* is provided in **Section 7**.

White Bay and Rozelle Stabling Yards Construction Site

The White Bay construction site would include the TBM launching site and associated facilities for tunnel construction including spoil removal from behind the TBMs and tunnel fitout including rail systems. The site would also be used as a general construction site, for the temporary storage of spoil and construction materials. At the Rozelle stabling area adjacent to the west, construction of train stabling and the maintenance depot will occur as well as construction of the associated on-site buildings and facilities.

Noise levels have been predicted at the nearest receivers using 3D computer modelling for comparison with the project specific NMLs. At White Bay, construction activities would occur during the daytime and night-time periods to service the TBMs. Compliance with the daytime and night-time NMLs is predicted. It is noted the White Bay site is well placed for construction works, with sensitive receivers distant and in many instances shielded by topography and commercial/industrial buildings.

At the Rozelle stabling and maintenance depot site, activities are expected to occur during the daytime period, and for general earthworks, minor exceedances are predicted. Compliance is predicted for construction of the building facilities. During portal and dive structure construction and excavation, a significant exceedance of up to 11 dBA occurs primarily as a result of the high noise levels from the excavation equipment, and the relative close proximity of Lilyfield receivers. The Sydney Metro *"Construction Noise and Vibration Strategy"* would be implemented to manage the potential noise impacts.

Station Construction Sites

At the CBD stations at Central, Town Hall Square, Martin Place, Barangaroo-Wynyard, and the urban stations at Pyrmont and Rozelle, there will generally be two or more construction sites to access the underground station caverns that are typically 140 m in length (at platform level). Significant activities include initial demolition of existing buildings and site establishment including spoil handling facilities followed by vertical excavation and then horizontal excavation of the station cavern. The stations will then be constructed, fitted out and commissioned.

In order to complete the station excavation before the arrival of the TBMs, the horizontal cavern excavation and spoil storage/removal is required to occur during the daytime and night-time periods. Based on the indicative project timetable, vertical shaft excavation at station sites and excavation for the station cavern heading will take 6 to 12 months to complete, depending on depth. Cavern excavation will take approximately 9 months, cavern concreting and lining approximately 9 months and completion of the station structure approximately 9 months.

At all station sites, the immediate surrounding area is commercial/residential with schools and churches also located at some station sites.

The predicted levels for excavation and construction at all station sites indicate significant exceedances of the NMLs for daytime operations at most receivers. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs. Careful management will be required at the nearest receivers to all the station sites.

To mitigate impacts, feasible mitigation measures are likely to include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting that noise walls are effective for receivers at or near ground level (eg outdoor eating areas) and not effective for receivers overlooking the sites. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. The indicative enclosure construction would consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where increased noise insulation is required this can be achieved by upgrading the enclosure elements by using, for example, a double skin or masonry construction. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project.

Excavation activities using conventional methods are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities. These mitigation measures could also include the use of alternative excavation methods such as penetrating cone fracture techniques.

Having considered all reasonable and feasible noise mitigation, the CBD Metro *"Construction Noise and Vibration Strategy"* would be implemented to manage the potential noise impacts.

CONSTRUCTION VIBRATION

The effects of vibration in buildings can be divided into three main categories:

- Those in which the occupants or users of the building are inconvenienced or possibly disturbed (human perception or human comfort vibration).
- Those where the building contents may be affected.
- Those in which the integrity of building elements or the structure itself may be prejudiced.

Vibration damage goals have been established on the basis of British Standard BS 7385 Part 2-1993. The vibration levels specified in these standards are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

Buildings that are potentially at risk of threshold or cosmetic damage would be identified by the contractor prior to the commencement of construction works. At these locations, impacts will be managed in accordance with the procedures outlined in Sydney Metro's *"Construction Noise and Vibration Strategy",* which may require building condition surveys to be conducted before the commencement of construction activities and after construction is completed.

Where buildings are located close to vibration generating activities, attended vibration measurements will be undertaken under carefully controlled equipment testing regimes at the commencement of the works to establish safe operating distances. At some sites, long-term monitoring systems may be required to ensure that vibration levels remain within the established limits.

Human comfort vibration goals have been established on the basis of the DECCW's *"Assessing vibration - a technical guideline"* (2006). Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

Some scientific equipment (eg electron microscopes and microelectronics manufacturing equipment) can however require more stringent design goals than those applicable to human comfort. Where these are identified, vibration goals will be obtained from the specific equipment manufacturers.

Where exceedances of the human comfort or sensitive equipment vibration goals are predicted, these will need to be managed or mitigated in accordance with the procedures outlined in Sydney Metro's *"Construction Noise and Vibration Strategy"*.

CONSTRUCTION GROUND-BORNE NOISE

Ground-borne noise emissions are mostly generated from excavation equipment such as roadheaders, tunnel boring machines, rockbreakers and drilling rigs.

Ground-borne noise goals have been established on the basis of a review of several recent rail, road and electrical tunnel projects. Most recent tunnel projects have not specified ground-borne noise goals for the daytime period. This is on the basis that there are no practical measures available (other than alternative construction methods) to mitigate ground-borne noise and vibration from tunneling activities using such equipment as roadheaders, tunnel boring machines and rockbreakers.

For this project, internal ground-borne noise goals of L_{Aeq} 40 dBA and 35 dBA have been adopted during the evening and night-time periods respectively for residential receivers. These levels are consistent with the DECCW's current "*Interim Construction Noise Guideline"* (2009).

Potential ground-borne noise impacts are likely to be highest at sensitive receiver locations close to the station caverns or main tunnel alignments. At station cavern sites, roadheaders are anticipated to operate during the daytime and night-time periods. Ground-borne noise levels may exceed the design goals when the roadheader is located close to sensitive receivers. At these locations, the ground-borne noise levels are likely to reduce over time as the roadheader moves away from the receiver and the depth of the station cavern increases.

The railway tunnels are proposed to be excavated using tunnel boring machines between White Bay and Central Station and using roadheaders between White Bay and Rozelle/Lilyfield. Tunneling activities are anticipated to occur on 24 hour per day basis. At any particular receiver location, the potential ground-borne noise impact from tunneling operations is anticipated to occur only for short periods of time when each roadheader or tunnel boring machine passes by. On the Epping to Chatswood Rail Line project, the tunnel boring machines moved forward at an average advance rate of approximately 300 m per month. On this basis, the potential ground-borne noise impacts at any one location would be limited to a period of approximately one week. For roadheaders, the rate of progress would be less than for the tunnel boring machines, but the overall ground-borne noise levels would be lower.

Where exceedances of the ground-borne noise goals are predicted, these will need to be managed or mitigated in accordance with the procedures outlined in Sydney Metro's *"Construction Noise and Vibration Strategy"*.

OPERATIONAL NOISE AND VIBRATION ASSESSMENT - GENERAL COMMENTS

The proposed CBD Metro represents a unique opportunity to influence the design, maintenance and operation of a low noise and vibration railway system. Sydney Metro's Acoustical Technical Advisor (Heggies) has been a key member of the design team from the outset of the project, providing input to the route options studies, track design, rolling stock specifications and maintenance practices.

As such, there is an expectation that the source noise and vibration levels from the proposed railway operations will be significantly lower than what are currently achievable on existing railway lines in Sydney, which comprise of a variety of different rolling stock types, constructed over several decades.

As the CBD Metro would operate a captive train fleet, the track design, wheel/rail profiles and track/train dynamics will be optimised to reduce noise and vibration emissions and minimise the wear of wheel and rail surfaces. The proposed metro trains are also smaller and lighter than the existing double deck suburban trains operating in Sydney, which results in lower source noise and vibration levels.

Sydney Metro has also made a commitment to achieve ongoing compliance with the project noise and vibration objectives. If a train with poor wheel condition results in the ground-borne noise and vibration goals being exceeded, this train would be identified via an automated monitoring system and taken out of service for repair at the earliest possibility. The CBD Metro system will also include a wheel lathe (to restore the wheel profile to an as new condition) and a rail grinding machine (to restore the rail profile to an as new condition).

The alignment of the CBD Metro has been designed to avoid major buildings as far as possible by running the route in line with existing roads. In view of the very built-up nature of the area however, the Metro will inevitably pass beneath or close to many buildings. The vertical alignment (tunnel depth) has also been maximised, where possible, to reduce potential noise and vibration impacts, subject to other physical constraints including several existing rail/road tunnels and other underground services.

GROUND-BORNE VIBRATION ASSESSMENT – TRAIN OPERATIONS

During train operations within the tunnels, vibration generated at the wheel/rail interface will be transferred via the rail mounts into the track support system and surrounding ground. It then travels through the ground or structures and may sometimes be felt as tactile vibration by the occupants of buildings.

The vibration design goals adopted for the CBD Metro are based on human comfort considerations, rather than the less stringent building damage risk levels or potential effects on building contents. During operations, there is a negligible risk of potential damage to nearby buildings, including heritage structures.

The proposed vibration design goal for residential receivers is based on the lower daytime value in Australian Standard AS 2670, namely 106 dB_V (0.2 mm/s rms). This level is recommended for both the daytime and night-time periods, recognising the intermittent nature of train vibration events and their lower frequency of occurrence during the night-time period. Higher vibration levels are applicable for commercial and industrial receivers. The 106 dB_V (0.2 mm/s rms) level is approximately 4 dB lower than the recommended design goals in the DECCW's *"Assessing vibration - a technical guideline"*.

For the ground-borne noise and vibration modelling, there are currently no commercially available modelling software packages. The modelling for the CBD Metro was therefore carried out using a Heggies-developed modelling process for the core calculations. The algorithms incorporated into the in-house model are well documented in authoritative references and are widely used within the acoustical consulting profession, both in Australia and internationally.

Where possible, this model was validated using measurement data collected from the Epping to Chatswood Railway Line (ECRL) which was opened to the public in February 2009. The ECRL and proposed CBD Metro projects share similar design characteristics in relation to the circular tunnel cross-section, the typical ground conditions and the slab track design. Where differences exist between the ECRL and CBD Metro (eg rolling stock and maintenance practices), these have been accounted for in the ground-borne noise and vibration predictions.

The modelling approach was based on the guidelines contained in International Standard ISO 14837-1 2005 *"Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance"*, taking into account the source vibration levels, the propagation in the ground between the source and receiver, the vibration propagation within the building and finally, the conversion of the vibration to noise within nearby buildings.

On the basis of the proposed alignment, operating speeds and design/maintenance assumptions, the predicted ground-borne vibration levels with the proposed standard trackform design are more than 10 dB below the design goals at the nearest sensitive receiver locations. On this basis, vibration levels from train passbys are not likely to be perceptible within nearby buildings.

GROUND-BORNE NOISE ASSESSMENT - TRAIN OPERATIONS

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. The vibration is initially generated by wheel/rail interaction (as described above) and is transmitted from the trackbed, through the tunnel structure, via the ground and into the adjacent building structures. After entering a building, this vibration causes the walls and floors to vibrate faintly and hence to radiate noise (commonly termed "ground-borne noise").

If it is of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be experienced in buildings adjacent to many urban underground rail systems, including several buildings close to the CityRail tunnels in the Sydney CBD.

The ground-borne noise goals for residential receiver locations are based on the ground-borne noise trigger levels in the DECCW's *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* (IGANRIP). This guideline recommends a ground-borne noise "trigger level" of L_{Amax} (slow) 35 dBA during the night-time period. At other sensitive receiver locations, ground-borne noise goals have been based on IGANRIP (for educational facilities and places of worship) as well as on Heggies experience on other underground railway lines. Attended measurements undertaken within the Sydney CBD (discussed above) support the adopted ground-borne noise goals of 40 dBA to 45 dBA within commercial buildings.

For most new railway lines (including the ECRL and the CBD Metro), the standard track design usually incorporates resilient rail fasteners to reduce the dynamic forces that occur at the wheel-rail interface. This resilience also serves to provide some isolation of ground-borne vibration, which in turn reduces the ground-borne noise levels in buildings near the railway tunnel.

For the proposed CBD Metro, two trackforms have been proposed as part of the Reference Design to achieve the ground-borne noise objectives. These comprise a "standard attenuation" trackform with moderately resilient rail fasteners and a "high attenuation" trackform incorporating highly resilient rail fasteners. Whilst the Reference Design is based on the Sonneville Booted Sleeper systems, equivalent performance track design options are available from several other suppliers. These may be adopted for the final design (on the provision that the acoustic performance is equivalent to or better than the Sonneville Booted Sleeper systems).

The ground-borne noise modelling indicates that the "standard attenuation" trackform will not achieve compliance with the ground-borne noise goals at all locations. At critical locations (which include residential receivers in Pyrmont and Rozelle), a "high attenuation" trackform will be required to achieve the ground-borne noise design goals. With the proposed combination of "standard attenuation" and "high attenuation" trackforms, compliance with the ground-borne noise design goals is predicted at all sensitive receiver locations.

AIRBORNE NOISE ASSESSMENT - TRAIN OPERATIONS

Between the proposed train stabling facility and the tunnel portals near Lilyfield Road, trains on the surface will operate at a maximum speed of 40 km/h. For these operations, airborne noise levels are required to be assessed in accordance with the DECCW's *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* (IGANRIP).

This guideline recommends airborne noise "trigger levels" of $L_{Amax\ (Fast)}$ 80 dBA (daytime and night-time), $L_{Aeq(15hour)}$ 60 dBA (daytime) and $L_{Aeq(9hour)}$ 55 dBA (night-time) at residential receiver locations adjacent to new rail developments. These have been adopted as design goals for the CBD Metro project.

The main sources of airborne noise from moving electric passenger trains originate at the wheel-rail interface as a result of surface irregularities on the wheel and/or rail running surfaces and interaction forces. During a train passby, the wheel, bogies, rail and rail support system vibrate and hence radiate airborne noise.

As the maximum train speed within the stabling and maintenance facility will be limited to 40 km/h, other noise sources on electric metro trains (such as air conditioning plant and air compressors) will also contribute to the overall noise levels. These noise sources are normally insignificant when trains travel at speeds greater than 50 km/h, where wheel/rail noise becomes dominant.

Impact noise from rail discontinuities such as turnouts and mechanical joints or uneven welded joints also has an effect on the level of wheel-rail noise emission, as impulsive noise is emitted as each wheel of the train impacts the discontinuity. In track sections having tight radius curves, flanging noise or curve squeal may also increase the levels of noise emission. All relevant factors are taken into consideration as part of the noise modelling.

To ensure operational noise impacts at sensitive receiver locations in the vicinity of the tunnel portals are minimised, the portals are proposed to be extended in length by enclosed concrete structures. At this stage in the assessment the details of the tunnel portal extensions has not been finalised. It is anticipated that a noise barrier and/or full enclosure will be required in the area of the portals if the detailed assessment indicates a curving noise is likely.

On the basis of the small number of anticipated train passbys and low train speeds, together with the portal design features, airborne noise levels are predicted to comply with the noise goals. The predicted noise levels also comply with the noise goals in the event that additional trains could be stabled at this site as part of any future extension of the CBD Metro.

During the detailed design stage, careful attention will need to be taken to ensure that the risk of curve flanging and curve squeal do not occur at locations where the curve radius is less than approximately 300 m. It is anticipated that gauge face lubrication and top of rail friction modification may be required near the tunnel portals to minimise the risk of curving noise.

AIRBORNE NOISE ASSESSMENT - TRAIN STABLING AND MAINTENANCE

The Rozelle stabling and maintenance depot is proposed to be situated at the former Rozelle Marshalling Yard and will operate on a 24 hour per day basis. The stabling and maintenance depot is located in a 3 m to 7 m cutting between Lilyfield Road and the northwest end of depot.

The existing land uses on the northern and southern sides are predominantly residential with a small number of commercial buildings. Lilyfield Road and the City-West Link Road separate these residences from the depot. The noise emissions from these roads therefore contribute to increased ambient noise levels at the nearby residential receivers.

The Sydney Light Rail currently operates between Lilyfield and Central, running parallel to the City-West Link Road from Lilyfield station, located to the south-west of the depot. There is a noise barrier (approximately 1.5 m to 2.5 m high) situated between the Sydney Light Rail line and the City-West Link Road.

For the CBD Metro, up to 11 trains are proposed to be located at the stabling and maintenance depot. The current CBD Metro schedule details that all trains are expected to depart the facility from 5:30 am to 6:30 am for the morning peak hour with about half of the fleet returning at about 9:00 am. These trains would then depart again for the afternoon peak and return to the depot at about 7:00 pm. The remaining trains would return to stabling around midnight, when the Infrastructure Maintenance Operations Period would commence. Infrastructure maintenance trains would leave the depot around midnight and return about 5:00 am.

Maintenance of the CBD Metro rolling stock fleet would be performed within the proposed depot. The majority of the noise intensive maintenance works would be carried out within dedicated on-site maintenance buildings during daytime and evening periods. These activities would include major overhauls and general routine maintenance of all train sets, wheel profile correction using an underfloor wheel lathe and automated train washing.

In order to ensure no disruption to the CBD Metro train services, all track and tunnel maintenance activities would be confined to night-time periods when train operations have ceased. These activities will include routine track inspections, loading of equipment onto hi-rail vehicles, entering tunnels and operation of a diesel or battery powered maintenance locomotive for track inspections and maintenance. It is likely that the maintenance would be undertaken during the weekdays, except for the emergency works.

Airborne noise impacts can be a key issue for sensitive receivers near the proposed stabling depot. The potential noise sources include train movements within the depot, steady noise from train auxiliary systems during daytime and night-time periods and noise emissions from train maintenance activities. Potential airborne noise emissions from operational train movements within the depot have been assessed in a separate section of the report. For all other noise sources within the train stabling and maintenance depot, the potential noise impacts have been assessed in accordance with the DECCW's *"Industrial Noise Policy"* (INP).

The INP assessment procedure for industrial noise sources has two components:

- Controlling the intrusive noise impacts in the short-term for residents; and
- Maintaining noise level amenity for particular land uses for residences and other land uses.

The **intrusive** $L_{Aeq(15minute)}$ residential noise goal limits noise emission levels to the Rating Background Level (RBL) plus 5 dBA. The **amenity** noise goal depends upon existing ambient L_{Aeq} noise levels within a locality and their relation to the acceptable noise levels for an urban area. Both noise goals (intrusive and amenity) are applicable at residential and other sensitive receiver locations.

The DECCW's sleep disturbance screening criterion is also applicable to address the maximum noise level of short term events during night-time periods. These are based on the $L_{A1(1minute)}$ noise levels not exceeding the L_{A90} background noise level by more than 15 dBA.

A computer noise model was developed to predict the noise emissions from the proposed train stabling and maintenance operations at nearby sensitive receivers. The source noise levels were based generally on measurements of Singapore Metro trains (which are considered to be comparable to typical modern metro trains around the world in terms of the noise specifications for auxiliary systems). Source noise levels were also supplemented by relevant data for the NSW CityRail Millennium trains due to the absence of alternative noise data for metro trains.

Noise emissions associated with train and track maintenance activities were based on previous measurements on other projects and the anticipated operations.

The noise modelling assumes that the testing of train horns will not be required within the stabling facility as train horns are not required for an Automatic Train Operation system with driverless capability. Unlike at some other stabling facilities in Australia, the CBD Metro trains will have all auxiliary systems turned off after a shut-down procedure once a train is brought to a standstill in the sidings. Some of these auxiliary systems may however need to be left on temporarily for the train cleaning staff.

The noise modelling indicates that noise levels will comply with the intrusive and amenity goals at all locations in the vicinity of the facility. This compliance is primarily due to the proposed depot being located in a cutting with respect to the surrounding residences. The cutting forms an effective noise barrier, despite the relative proximity of residential areas to the proposed depot.

It is also unlikely that the short duration of high noise emissions from air dryer and brake testing, which will peak in the early hours of the morning as trains prepare for service, would cause sleep disturbance at any residences. Additional mitigation measures are available if required to manage this risk effectively.

The noise emissions from the proposed substations near the tunnel portal are likely to be negligible considering the masking effects of road traffic noise along the Lilyfield Road, which would be much higher than the noise from the substations. Likewise the potential noise impact due to the car park near the Gordon Street entrance would be minimal.

There may be a requirement to accommodate additional train sets in the stabling and maintenance depot as part of an extension of the CBD Metro. In this case, the potential noise levels may be marginally higher predicted for CBD Metro trains alone. On the basis that the CBD Metro trains are proposed to be stabled at the northern extent of the stabling facilities (close to residential receivers at Lilyfield Road), any potential noise increase from additional trains (stabled further away) would be likely to be less than 2 dBA and therefore not noticeable at the nearest receivers.

AIRBORNE NOISE ASSESSMENT - ANCILLARY FACILITIES

At underground sections of track, airborne noise generated by trains is reduced to inaudible levels at above-ground receivers by the intervening rock and soil above the tunnels. The exception to this is at ventilation stacks and draught relief shafts. At these locations, airborne noise from trains may be audible even though there is little or no visible evidence of rail operations. Other ancillary noise sources would typically include mechanical services plant to ventilate underground areas and surface buildings.

EXECUTIVE SUMMARY

At this stage the exact location and specification of the ancillary equipment which is likely to be used as part of the Reference Design has not yet been fixed and may be subject to change. This desktop assessment has therefore been limited to establishing noise goals and determining the maximum allowable noise emissions at each location where noise would be emitted to the external environment.

The noise design goals for the external noise emissions associated with mechanical services are taken from the NSW Department of Environment, Climate Change and Water (DECCW) *"Industrial Noise Policy"* (INP) (as described above for the Airborne Noise Assessment of Stabling and Maintenance).

Noise emissions from the mechanical services are normally of a continuous nature and do not change unless operational conditions vary. As a result of the general reduction in ambient existing noise levels during the latter periods of the day, the night-time INP noise goals are the most stringent at all locations.

The maximum allowable sound power levels emitted by industrial-type noise sources have been predicted for each location in order to meet the noise goals at nearby sensitive receivers. The predicted sound power levels range from 60 dBA to 100 dBA.

Mitigation measures are likely to be required for some station and tunnel ventilation equipment/locations in order to comply with the INP noise goals. Mitigation measures that will need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train passby noise emitted from ventilation shafts or other openings has been considered with regard to noise goals which are consistent with the adopted design goals for the Epping to Chatswood Rail Line (ECRL) and Sydney Airport Rail Line, and are also more stringent than the noise goals applied in the DECCW's *"Interim Guideline for the Assessment of Noise from Infrastructure Projects"* (IGANRIP), relating to airborne noise from the operation of trains on surface track.

The assessment indicates that train noise break-out through the tunnel ventilation shafts from trains operating within the tunnel is not expected to exceed the noise goals. However, all draught relief shafts will require mitigation measures (typically in-duct noise attenuation) in order to comply with the noise goals at the nearby sensitive receivers. Applying the nominal insertion loss values of a 3 m long attenuator would allow for compliance at residential receivers 10 m from the shaft opening.

STATEMENT OF COMMITMENTS

The Director-General's Requirements (DGRs) for the Environmental Assessment requires a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessment. For the operation and maintenance phases of the project, the relevant SoC's are provided in each relevant section of the report and summarised in **Section 18**. For the construction phase of the project, the relevant SoC's are provided in the Environmental Assessment.

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APPENDICES

1 INTRODUCTION

In conjunction with Sydney Metro, a team of specialist consultants has prepared an Environmental Assessment (EA) for the proposed CBD Metro.

The proposed CBD Metro will run from Central to Rozelle and consist of approximately 7 km of underground railway with six stations. The majority of the proposed alignment would be located within twin-bored tunnels, with the tunnels running beneath or close to numerous buildings. Some of these buildings within the CBD are already exposed to railway noise and/or vibration as a result of train operations on the existing CityRail underground rail network. Residential buildings in Pyrmont and Rozelle are also close to the proposed route of the Metro.

The CBD Metro will be the first stage of a Sydney-wide metro network, designed to set new benchmarks for customer experience with a fast, frequent and reliable service. The proposed alignment allows for future extension of the CBD Metro to the west from Central and to the north-west from Rozelle.

It is proposed that the project would be delivered in one stage, with construction commencing in 2010 and the entire CBD Metro being operational by the end of 2015.

The objective of this study is to evaluate and assess the potential noise and vibration impacts associated with the construction, operation and maintenance of the proposed CBD Metro, including the operating railway lines, stations, train depot and other associated facilities. It identifies appropriate design goals based on local and international guidelines and where noise and vibration levels are predicted to exceed the design goals, presents options and recommendations for mitigating or managing the potential impacts.

This report has been prepared in accordance with the requirements of Part 3A of the Environmental Planning and Assessment Act 1979 and the Director-General's Requirements (DGRs) for the EA, issued on 27 February 2009.

2 PROJECT DESCRIPTION

2.1 General

The alignment of the proposed CBD Metro, as assessed in this report, is referred to as the Reference Design Alignment. The design of this alignment is consistent with the design contained within the EA and includes a total of six stations between Central and Rozelle, as shown in **Figure 1**. Reservation for a future station at White Bay is incorporated within the design should future development in this area necessitate a service.

The proposed station locations are:

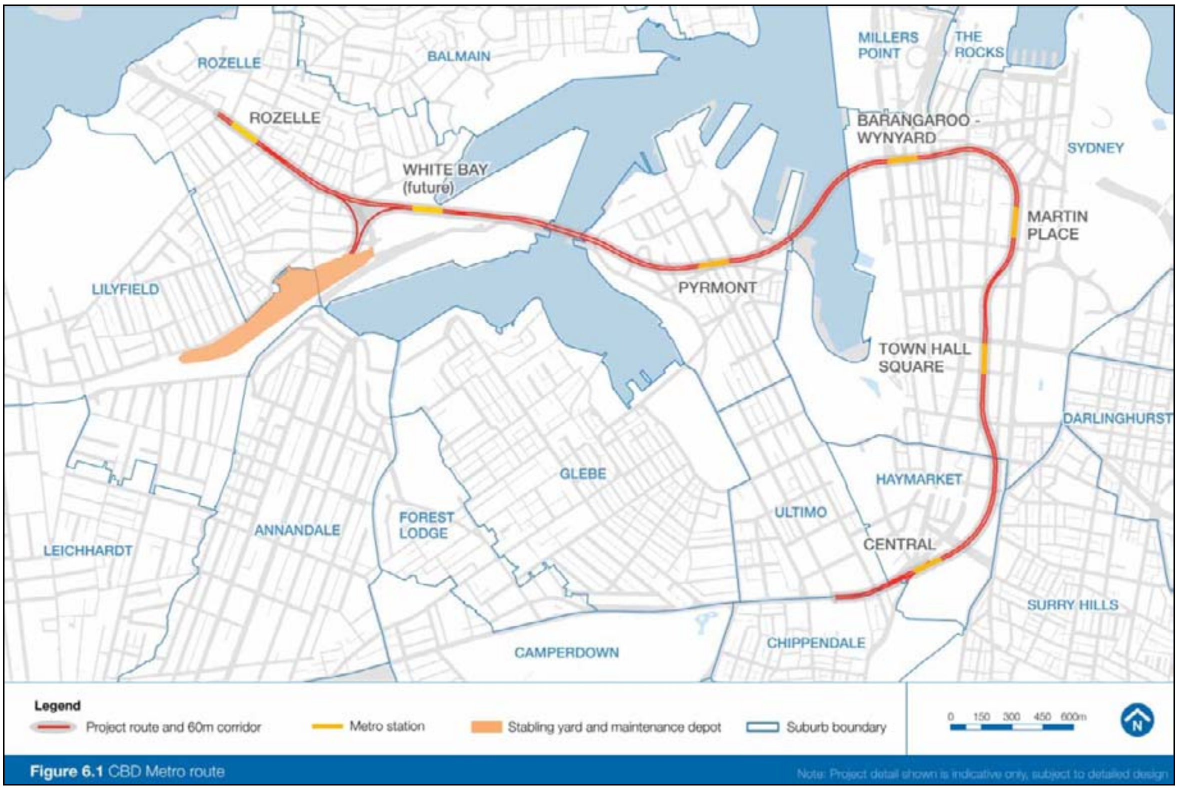
- Central Station;
- Town Hall Square Station;
- Martin Place Station;
- Barangaroo-Wynyard Station;
- Pyrmont Station;
- White Bay Station (reservation for future requirements); and
- Rozelle Station.

For the proposed station at Pyrmont, two options are currently being considered. These are referred to as Pyrmont Station Alternative 1 and Pyrmont Station Alternative 2. In the main body of this report, the Pyrmont Station Alternative 1 option has been assessed. The potential noise and vibration impacts associated with the Pyrmont Station Alternative 2 option are assessed in **Appendix N**.

The alignment has been designed to avoid major buildings insofar as possible by running the route in-line with existing roads. In view of the very built-up nature of the area however, it will inevitably pass beneath or close to many buildings. The vertical alignment (tunnel depth) has also been maximised where possible to reduce potential noise and vibration impacts, subject to other physical constraints including several existing rail/road tunnels and other underground services.

Similarly, the train stabling and maintenance facility is proposed to be located within the former Rozelle Marshalling Yard in an area which is adjacent to residential, commercial and industrial land uses.

Figure 1 Route of the Proposed CBD Metro



The CBD Metro will provide a frequent train service between the six stations, with trains anticipated to run every two to three minutes during peak times. The CBD Metro is proposed to operate under an Automatic Train Operation (ATO) system with driverless capability.

The majority of the proposed alignment will run within twin-bored tunnels, with the only section of surface track being located at the Rozelle stabling and maintenance depot. A set of twin portals at the depot will provide the entry/exit points to and from the underground tunnel sections.

All stations will incorporate platform screen doors to separate the stations from the tunnel and trains. This will ensure less disruption to services, reduced littering and trackside cleaning, improved safety and reduce the extent of mechanical ventilation. Station platforms are situated under existing roads, where possible, to ensure the impacts of noise and vibration emissions during construction and operations are minimised.

It is proposed to operate the CBD Metro between 5.30 am and 12.00 midnight Sunday to Thursday, and between 5.30 am and 1.00 am on Friday and Saturday. An approximate journey time of 10 minutes between Central and Rozelle is expected.

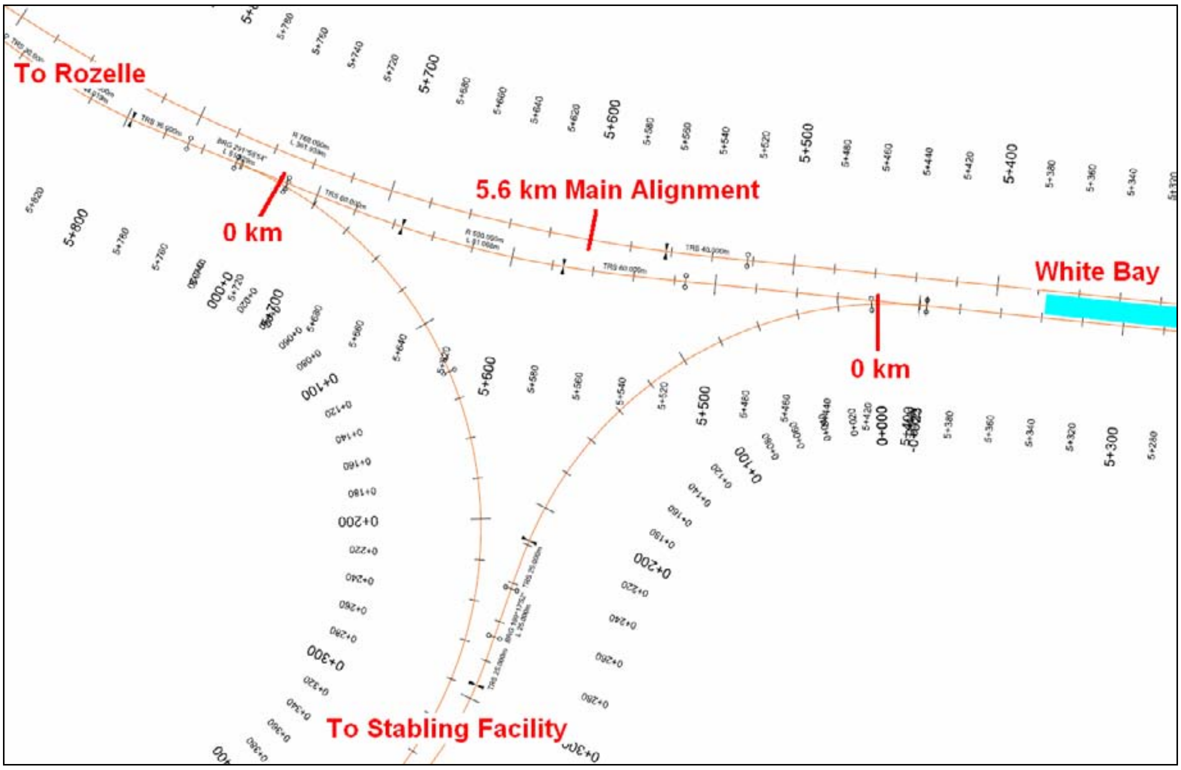
2.2 Terminology

2.2.1 Track Chainage and Directions

Consistent with normal rail terminology, track chainages for the main alignment are referenced to 0 km at Central Metro Station. Down and Up directions refer to trains travelling from Central Station and to Central Station, respectively. The Down and Up sides of the corridor are the left-hand and right-hand sides, respectively, when facing away from Central Station (ie facing in the direction of increasing chainage).

For both connections to the Rozelle stabling and maintenance depot, the track chainage starts at 0 km from the point at which each track meets the main alignment, and increases towards the stabling facility (see **Figure 2**). The track chainages are also illustrated on the site plan in **Appendix B**.

Figure 2 Track Chainages at Connections to Rozelle Stabling and Maintenance Depot



2.2.2 Noise and Vibration Terminology

Detailed descriptions of the acoustic terminology used within this report, together with a glossary of terms, are presented within **Appendix A**.

2.2.3 Types of Noise and Vibration

The most common form of noise experienced by people is termed "airborne noise", indicating that it propagates between the source and receiver primarily through the air. This is the primary form of noise that occurs adjacent to surface railway tracks and roadways.

For some noise sources (such as transformer hum, blasting and aircraft sonic booms), the frequency content of the noise is predominantly in the low frequency region below 100 Hz. If the low frequency pressure fluctuations are of sufficient magnitude, the airborne noise may cause windows and similar light-weight structures to vibrate.

Airborne noise does not propagate effectively through the ground, hence airborne noise emissions from the tunnels and underground stations will be limited to locations near tunnel openings such as pressure relief vents, station ventilation shafts and station entrances.

When trains operate in tunnels, as is proposed for the CBD Metro, vibration is generated as a result of wheel-rail interaction and can propagate through the ground and into nearby building structures. This "ground-borne vibration" may cause the walls and floors of nearby building structures to faintly vibrate and hence radiate noise (termed "ground-borne noise"). If it is of sufficient magnitude to be audible, the ground-borne noise has a low frequency rumbling character.

In the absence of suitable mitigation measures, vibration from trains in tunnels located very close to buildings may possibly be felt by the occupants, such as is experienced at certain locations in proximity to the existing underground CityRail network. Invariably however, train vibration is not of sufficient magnitude to cause even minor damage in buildings.

Ground-borne noise and vibration can also occur during construction works involving plant items such as rockbreakers, drilling rigs, roadheaders and tunnel boring machines. In some cases, ground-borne vibration from excavation and construction can be felt by building occupants. The vibration may also induce secondary effects such as the rattling of crockery and other loose fittings and furnishings, but again is rarely of sufficient magnitude to cause direct damage to buildings.

For new railway projects (and despite the relatively low emission levels compared to most other sources of noise in urban environments), noise and vibration emissions during construction and operation are usually key issues of concern to the surrounding community. These are discussed individually below.

2.3 Construction

Generally speaking, people are usually more tolerant to noise and vibration impacts during the construction phase of projects than during full operations. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, noise and vibration assessment goals are normally set to be less stringent during the construction phase of projects than during operations.

Construction often requires the use of heavy machinery which can generate significant noise and vibration emissions at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential noise and vibration impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration emissions, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

2.3.1 White Bay / Lilyfield Construction Site

The majority of the 7 km long CBD Metro tunnels will be excavated using Tunnel Boring Machines (TBMs). These are proposed to be launched from the White Bay/Lilyfield construction site and operated concurrently for approximately 5 km to Central Station, where they would be retrieved at the Belmore Park construction site. Excavated spoil is proposed to be removed from White Bay via conveyors behind the TBMs.

The remaining section of tunnels from White Bay to Rozelle (including the depot and stabling facility connections) are likely to be excavated by roadheaders. Spoil is proposed to be removed via both the White Bay/Lilyfield and Rozelle construction sites. The proposed Tunnelling Sequence is illustrated in **Figure 3**.

Figure 3 Tunnelling Sequence

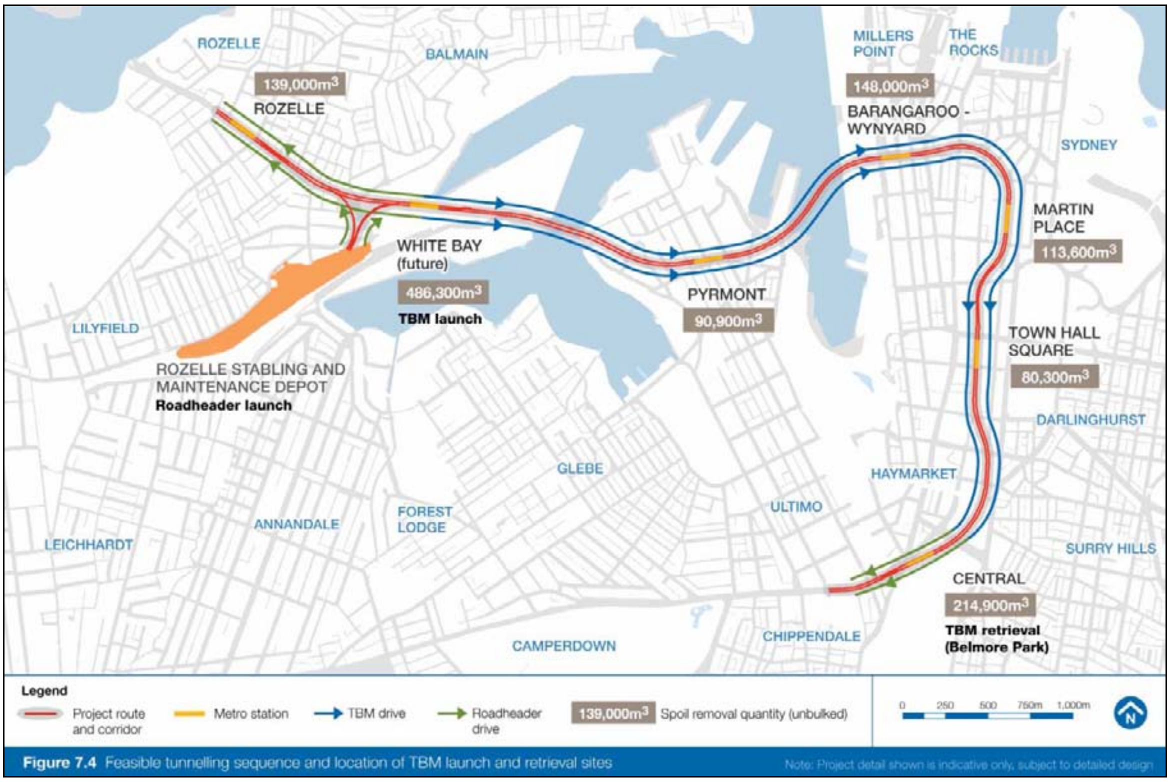


Figure 7.4 Feasible tunnelling sequence and location of TBM launch and retrieval sites

Note: Project detail shown is indicative only, subject to detailed design

The White Bay/Lilyfield construction site would also include the following general work activities:

- Establishment of a site compound;
- Tunnel construction water treatment plant and water tanks;
- Tunnel air ventilation and extraction plant;
- Assembly and launching of TBMs;
- Spoil storage area and disposal by road, rail and/or barge;
- Tunnel precast segment lining delivery and storage;
- Electrical and mechanical lay down areas;
- Tunnel grout or concrete batching plant;
- Tunnel rail systems including track work, and electrical and mechanical installation works;
- Excavation of tunnel decline access for road/rail plant; and
- Construction of the stabling and maintenance depot.

2.3.2 Stations

Where demolition of existing structures is required these activities will occur during the daytime only, and typically last for up to 3 months, except where multistorey buildings are to be demolished where the demolition period may be up to 9 months. At all station locations, following demolition, construction works are proposed to occur over a period greater than one year. The highest noise and vibration impacts are likely to take place during the initial site demolition and excavation works. These works will primarily be undertaken during the daytime period with construction noise and vibration levels being similar to those from typical building sites across the CBD.

Following the initial site excavation works, some construction activities are anticipated to occur up to 24 hours per day. For construction activities that are required to be undertaken outside normal daytime periods, careful attention will be required to manage and mitigate the potential noise and vibration impacts. These are documented in later sections of this report.

When excavation and station fit-out works are being undertaken underground, the potential noise and vibration impacts will be dependent on the distance between the works, the sensitivity of the receiver type (eg residential, commercial, etc), the times and durations when the noise and vibration occurs and the proposed mitigation and management measures.

Nearby receivers may also be affected by materials and equipment deliveries, spoil removal (if required) and general construction of the station entry points.

2.3.3 Tunnelling (TBM and Roadheader, plus Rockbreakers at Some Locations)

During underground tunnelling operations, ground-borne noise and vibration emissions are often able to be heard or felt in buildings located within approximately 50 m to 100 m of the works.

As some construction works are proposed to occur on a 24 hour per day basis, the ground-borne noise and vibration levels could exceed guideline levels at residential receiver locations during the night-time period when people are resting or sleeping.

Certain above ground activities which support the tunnelling and fit out process would also be undertaken on a 24 hour per day basis, however at above ground locations where sensitive noise receptors are close to the proposed construction works, specific noisier activities are likely to be restricted to the daytime and evening periods.

The vibration caused by underground tunnelling equipment can also impact upon sensitive equipment such as electron microscopes and precision balancing equipment. Depending on the rate of tunnelling progress, the potential noise and vibration impacts are likely to prevail for only relatively short periods at most locations.

Spoil from underground tunnelling operations is required to be brought to the surface and transported to disposal sites via heavy vehicles, trains or barges. The potential noise emissions are generated by sources such as heavy vehicles or train movements, spoil conveyors, loading operations, tunnel ventilation fans, dust collectors, and materials and equipment deliveries. Potential noise emission impacts may occur at the spoil extraction points and disposal sites where sensitive receivers are located nearby. Heavy vehicle movements on local roads during the night-time period would also be a source of potential noise impact.

2.3.4 Construction Traffic

Traffic involved in construction of the CBD Metro would be continuous at the White Bay site, Rozelle stabling and maintenance depot site, and the station sites for the duration of the project. The majority of construction traffic movements would occur during daytime, however for certain activities such as the delivery of large equipment (eg TBMs and Roadheaders), and the removal of spoil from some station sites, night-time movements would occur.

For the White Bay construction site access would be from the Western Distributor and then James Craig Road, and for the Rozelle stabling and maintenance depot site the Western Distributor directly. Given construction traffic for these sites accesses the Western Distributor directly no impacts at sensitive receivers are anticipated.

Station sites would be accessed via local collector roads and then the Eastern Distributor or Western Distributor in the case of the CBD and Pyrmont Station sites, and Victoria Road or westbound on Darling Street for the Rozelle Station site. During the daytime, sensitive receivers on access roads are not expected to be impacted given the high volume of existing daytime vehicle flows. During the night-time, spoil removal is proposed from some station sites, therefore sensitive receivers on access roads may be affected due to lower existing traffic volumes.

2.3.5 Timing and Duration of Construction Works

A constructability assessment was undertaken for the CBD Metro project and it was determined that a TBM/roadheader tunnel construction method in conjunction with top down station cavern excavation would be required for the project. Accordingly, the timing of the project is determined by the progression rate of the TBMs. This requires the station excavation to be coordinated with the TBM progression.

Based on the anticipated TBM progression rate the construction activities associated with the permanent works would be approximately 4 years in duration. Further, it is not feasible to operate the TBMs on an intermittent basis. Consequently, spoil storage, removal and management and associated traffic management would be required on a 24 hour basis. However, spoil and traffic management practices would be implemented to reduce surface activities between the hours of 10.00 pm and 7.00 am.

2.3.6 Other Construction Works

An underground pedestrian link would be provided between Barangaroo and Wynyard Park beneath Margaret Street. The majority of the construction works would be undertaken during the daytime period, with construction noise levels being similar to those that occur at many other building sites across the CBD.

Service relocation works would also be required at a number of sites as part of the CBD Metro Project. These activities would also be undertaken predominantly during daytime periods.

A detailed assessment of the potential noise and vibration impacts associated with the above activities will be undertaken during the construction planning and site establishment phases of the project.

2.4 CBD Metro Operations

2.4.1 Operational Noise and Vibration Issues

For new underground railway projects, consideration of the potential noise and vibration impacts during the design stage is critical in order to achieve a cost-effective and acceptable environmental outcome for the surrounding community. The application of add-on mitigation measures after construction is completed is usually very expensive, and in many cases is not feasible after train operations commence.

A summary of the potential noise and vibration impacts during operations is provided below.

2.4.2 Noise and Vibration from Train Passbys

When trains operate within tunnels, noise and vibration events occur during train passbys. The level of noise and vibration during each event is affected by factors such as the track design, rolling stock design, train speed, wheel condition and ground type.

Depending on the relative significance of the above factors, unmitigated ground-borne noise and vibration levels could exceed acceptable or guideline levels at distances of up to approximately 50 m from the railway line. By implementing good acoustical design practices and regular maintenance, guideline levels can be achieved at buildings with basements and/or foundations located as close as 5 m from the tunnels.

2.4.3 Noise and Vibration at Stations

At underground station locations, nearby sensitive receivers may be potentially impacted by noise sources such as station PA systems, electrical sub-stations and other mechanical services plant and tunnel ventilation equipment.

Airborne noise from trains operating within tunnels can also be emitted to the surface via pressure relief or ventilation shafts. Potential noise and vibration from individual items of plant and equipment will be contained within the internal spaces of the station itself and are mitigated as part of the normal design process.

2.4.4 Noise and Vibration at Train Stabling Facilities

When trains are parked at train stabling facilities during the daytime or night-time periods, ancillary equipment on the trains (such as air conditioners and air compressors) are sometimes left running. For the proposed CBD Metro, compressors and other significant noise sources on the trains will only operate for short periods of time after trains arrive and before they depart.

At some facilities, horn testing is required to be undertaken prior to trains entering service for the day and this source can generate very high noise levels at nearby receiver locations. As the CBD Metro is proposed to operate under an Automatic Train Operation (ATO) system with driverless capability, there is no requirement for train horns to be used or tested within the train stabling facility. There may be a requirement for maintenance trains to test their horns during the daytime period, however this would be likely to happen on an infrequent basis. Other potential noise sources associated with brake testing and air discharge from the compressors will be addressed through the rolling stock design process.

The potential vibration impacts associated with train stabling facility and maintenance depots will be negligible due to the reduced train speeds within the facility and adequate separation distance to nearby receivers.

2.4.5 Noise from Tunnel Ventilation Shafts

When trains operate within tunnels, airborne noise generated within the tunnel may be audible at the surface via tunnel ventilation and/or pressure relief shafts. Ventilation and pressure relief shafts will be situated near all stations. Noise from these sources will be mitigated to achieve the noise goals as part of the design process.

2.4.6 Tunnel Portals

Noise breakout may be a potential issue at sensitive receiver locations in the vicinity of tunnel portals near Rozelle. Noise from the operation of tunnel ventilation fans (if located near the portals) and from reverberant train noise in the tunnels and dives is likely to be audible at nearby sensitive receivers. Mitigation, in the form of acoustic absorption material applied to the tunnel surfaces may therefore be required at the portals.

2.4.7 Stabling and Maintenance

The stabling and ongoing maintenance of the CBD Metro rolling stock fleet would be performed at the Rozelle stabling and maintenance depot, which is located at-grade within the former Rozelle Marshalling Yard. As the main CBD Metro rail lines are located underground, the approach tracks to the stabling and maintenance depot are inclined to allow trains to be brought up to surface level. Activities undertaken at this site would include train stabling during off-peak periods, train cleaning, major and minor maintenance, staff vehicle movements, materials delivery and garbage collection.

The stabling and maintenance depot also includes associated offices and storage facilities. General administration and training areas would also be accommodated here.

At the planned time of opening, the stabling facility is proposed to accommodate up to approximately 11 trains, with the possibility of future expansion to ultimately stable up to approximately 30 trains. For the CBD Metro, one train is proposed to be stabled at Central Station and one at Rozelle to allow for efficient early morning start up operations.

Other noise sources associated with the train maintenance facility are similar to most industrial maintenance facilities. They include the use of hand tools, cranes, wheel lathe, mechanical services and other similar equipment. Heavy vehicles and other mobile plant will also be utilised.

The majority of the maintenance works performed at the stabling and maintenance depot would usually take place during the daytime and evening periods and be contained wholly within purpose-built maintenance buildings.

The maintenance activities would typically include the following:

- Maintenance of all train sets;
- Wheel profile correction using an underfloor wheel lathe; and
- Automated train washing.

Access to the railway corridor will not be permitted during normal train operation hours. As such, all track maintenance within the railway corridor will occur during night-time periods when no trains are operational. These activities may include:

- Loading of equipment onto hi-rail or other rail vehicles prior to these accessing the tunnels; and
- Operation of a diesel or battery powered maintenance locomotive for track inspections and maintenance.

Rail grinding, tunnel cleaning and major track maintenance would also occur during the night-time shutdown period, however these activities are typically performed on an infrequent basis. Emergency maintenance works may also become necessary at any point on the network at any time.

2.4.8 General Comments on Project Design

The proposed CBD Metro represents a unique opportunity to influence the design, maintenance and operation of a low noise and vibration railway system. Sydney Metro's Acoustical Technical Advisor (Heggies) has been a key member of the design team from the outset of the project, providing input to the route options studies, track design, rolling stock specifications and maintenance practices.

As such, there is an expectation that the source noise and vibration levels from the proposed railway operations will be significantly lower than what are currently achievable on existing railway lines in Sydney, which comprise of a variety of different rolling stock types, constructed over several decades.

As the CBD Metro would operate a captive train fleet, the track design, wheel/rail profiles and track/train dynamics would be optimised to reduce noise and vibration emissions and minimise the wear of wheel and rail surfaces. The proposed metro trains are also smaller and lighter than the existing double deck suburban trains operating in Sydney, which results in lower source noise and vibration levels.

Sydney Metro has also made a commitment to achieve ongoing compliance with the project noise and vibration objectives. If a train with poor wheel condition results in the ground-borne noise and vibration goals being exceeded, this train will be identified via an automated monitoring system and taken out of service for repair at the earliest possibility. The CBD Metro system will also include a wheel lathe (to restore the wheel profile to an as new condition) and a rail grinding machine (to restore the rail profile to an as new condition).

3 DIRECTOR-GENERAL'S REQUIREMENTS

A Project Application for the CBD Metro proposal was lodged with the Department of Planning on 16 February 2009. Following receipt of the Project Application, Director-General's Requirements (DGRs) were issued for the Environmental Assessment on 27 February 2009. This report has been prepared to address the DGRs that relate to potential noise and vibration impacts. The specific requirements that relate to the CBD Metro proposal are provided below:

Director General's Requirements (Noise and Vibration)

3. *an assessment of the key issues, with the following aspects addressed for each key issue (where relevant):*
   * *describe the existing environment;*
   * *assess the potential impacts (both direct and indirect) of the project for both construction and operation stages, in accordance with relevant policies and guidelines;*
   * *identify how relevant planning, land use and development matters, (including relevant strategic and statutory matters), have been considered in the impact assessment and/ or in developing management/ mitigation measures; and*
   * *describe measures to be implemented to avoid, minimise, manage, mitigate, offset and/or monitor the impacts of the project and any residual impacts.*
4. *a draft Statement of Commitments (SoC), incorporating or otherwise capturing measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the impact assessment sections of the EA. The SoC must clearly articulate the desired environmental outcome of the commitment. The SoC must be achievable, measurable (with respect to compliance), and time-specific, where relevant.*

Key Noise and Vibration Issues

General Construction Impacts - consider the potential impacts associated with the construction of the project, and present a management framework for construction works to ensure that impacts are mitigated, monitored and managed. The EA must include consideration of, and a management framework for:

* *construction noise and vibration, including a considered approach to scheduling construction works having regard to the nature of construction activities (including transport, blasting and tonal or impulsive noise-generating works), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially-affected human receivers and structures, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic or spoil management). The EA must also present a strategy for monitoring and mitigating construction noise and vibration, with a particular focus placed on those activities identified as having the greatest potential for adverse noise or vibration impacts, and a broader, more generic approach developed for lower-risk activities.*

Operational Noise and Vibration Impacts - including:

* *an assessment of the noise and vibration impacts associated with the operation of the project, including rail operations, the operation of stabling and maintenance facilities, relevant ancillary facilities (such as substations and venting sites), and ongoing maintenance to the metro line;*
* *consideration of air-borne and regenerated [ground-borne] noise and vibration impacts, having regard to both human receivers and structures. The assessment must include specific consideration of impacts to sensitive receivers (schools, hospitals, aged care facilities) and sensitive structures (particularly heritage structures and key utilities/ infrastructure); and*
* *the assessment must take into account the following guidelines as relevant NSW Industrial Noise Policy, Assessing Vibration: A Technical Guideline, and Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects [IGANRIP].*

Environmental Risk Analysis - notwithstanding the above key assessment requirements, the EA must include an environmental risk analysis to identify potential environmental impacts associated with the project (construction and operation), proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures. Where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of this additional key environmental impact must be included in the EA.

4 REPORT OVERVIEW

For the proposed CBD Metro, the potential noise and vibration impacts may be categorised as follows:

- Impact of the construction phases of the project, inclusive of:
  - Construction noise; and
  - Construction vibration and ground-borne noise.
- Operational impacts after commissioning, consisting of:
  - Ground-borne noise from train operations;
  - Ground-borne vibration from train operations;
  - Airborne noise from train operations;
  - Airborne noise from train stabling and maintenance activities; and
  - Airborne noise at stations, portals and ventilation shafts.

Within this report each of the above issues is addressed within an individual section. For each section, separate sub-sections describe the relevant noise and vibration design goals, relevant background information, the assessment methodology, results of any calculations/modelling, comparison of the results to the relevant design goals, a description of the indicative impact and the likely management and mitigation measures. Following on from these sections are a draft Statement of Commitments (SoC) and the overall conclusions of the assessment.

The assessment embodied within this report is based entirely upon the Reference Design. This represents one example of how the project could be constructed, operated and maintained. During the detailed design stage of the project, and following the award of the construction and operation contracts, the successful tenderers may choose to construct, operate and maintain the CBD Metro in a different manner to that which is described in this report.

Should circumstances arise that result in minor changes to the Reference Design, the noise and vibration impacts as a result of the CBD Metro would not be expected to be greater than those described and assessed within this report. If the detailed design phase does result in significant changes, these will need to be assessed and approved on a case by case basis in consultation with the affected community. It is also noted that the project noise and vibration design goals are unlikely to change throughout the project, and that the successful tenderers would be required to comply with the SoC described in this report.

5 DESCRIPTION OF EXISTING ENVIRONMENT

5.1 Existing Environment

The existing noise environment varies along the length of the proposed alignment, as would be expected from the wide range of commercial, urban and residential land uses within the study area and from the proximity of several major roads and rail corridors. The steady overall ambient noise from the ventilation systems and other services in many hundreds of buildings is prevalent throughout the project area.

In the area around Central Station, the existing noise environment is controlled by rail operations at CityRail's Central Station, along with road traffic noise from the numerous roads in the vicinity.

Between Central Station and Barangaroo-Wynyard Station, the existing noise environment is controlled by road traffic noise and ambient noise associated with general CBD activities.

Between Barangaroo-Wynyard Station and Pyrmont Station, the alignment runs under the Western Distributor motorway, Barangaroo, Darling Harbour and Pyrmont Bay. As such the noise climate in this area is affected by road traffic, patrons and activities in the Darling Harbour precincts, and general CBD activities.

Pyrmont, White Bay and Rozelle generally consist of mixed residential and commercial uses. Anzac Bridge along with a number of other busy roads are also in the vicinity of these areas. White Bay is further affected by the industrial activities that are carried out at the nearby dockyard facilities.

5.2 Future Environment

There are two main areas where the future land use adjacent to the CBD Metro corridor is planned for development. These are at Barangaroo and White Bay.

5.2.1 Barangaroo

The Barangaroo site, formerly known as East Darling Harbour, is a 22 hectare land parcel that is owned by the State of New South Wales. The site, which was vacated in 2007 and is now mainly open space with a ferry passenger terminal at the southern end, is planned to be renewed as an extension of Sydney's commercial business district.

The various concept designs which are currently under consideration for this site all show the southern end of the development as being earmarked for retail, residential and commercial space. Buildings containing multiple levels are therefore likely to be constructed in this locality. The proposed CBD Metro alignment runs underneath the south east corner of the site. An illustration of one of the concept designs for the Barangaroo site is provided in **Figure 4**.

Figure 4 Concept Design of Barangaroo Site (Barangaroo News, Issue 4 - October 2008)

The future noise environment in this vicinity is therefore anticipated to change significantly as the Barangaroo site is developed. Future background noise levels would be expected to be similar to the noise levels measured in other similar parts of the CBD.

5.2.2 White Bay

White Bay, the former Rozelle Marshalling Yard, Rozelle Bay and Glebe Island - collectively known as the Bays Precinct - have also been identified as an area for potential development.

The NSW Government has committed to preparing a masterplan for the future use of the Bays Precinct with particular emphasis on the renewal of White Bay and the former Rozelle Marshalling Yard. Some of the development options being considered would be compatible with a Metro station at White Bay.

The proposed Rozelle stabling and maintenance depot is also located in the Bays Precinct area, at the site of the former Rozelle Marshalling Yard.

The current usage of the Bays Precinct is related to industrial activities performed at the dockyard facilities, therefore redevelopment of this locality could significantly alter the ambient noise climate.

5.3 Ambient Noise Surveys

5.3.1 Monitoring Locations

In order to characterise the existing ambient noise environment across the project areas (in relation to both construction and operation) and to establish present ambient noise levels upon which to base the noise emission targets, where appropriate, environmental noise monitoring was performed at a number of representative locations during March, April and May 2009.

These locations were selected based on a detailed inspection of all the potentially affected areas, giving consideration to other noise sources which may influence the recordings, security issues for the noise monitoring devices and gaining permission for access to the location from the resident or landowner.

Table 1 lists the various monitoring locations in tabular form, whilst **Appendix B** illustrates the locations graphically on the Site Plan.

Table 1 Noise Monitoring Locations

Location	Type of Measurements	Address	Area
B01	Unattended Ambient Noise Logging (for airborne noise assessments)	812 George Street (Christ Church St Laurence)	Central
B02		260 Pitt Street (Criterion Hotel)	Town Hall
B03		60 Castlereagh Street (Veranda Bar)	Martin Place
B04		20 Sussex Street (Morton's Hotel)	Wynyard
B05		1 Union Street (Rear Balcony)	Pyrmont
B06		56 Mount Street	Pyrmont
B07		32/501 Glebe Point Road	Glebe
B08		27/1 Batty Street	Rozelle
B09		36 Lilyfield Road	Rozelle
B10		43/4 Hornsey Street	Rozelle
B11		38 Burt Street	Rozelle
B12		118 Victoria Road (Old Rozelle Hotel)	Rozelle
B13		99 Victoria Road (Child Care Centre)	Rozelle
B14		665a Darling Street (Community Centre/Church)	Rozelle
B15		26 Waterloo Street	Rozelle
B16		2 Hutcheson Street	Rozelle
B17		101 Lamb Street	Lilyfield
B18		8 Pritchard Street	Annandale
B19		52 Starling Street	Lilyfield
N01	Attended Noise Measurements (for airborne noise assessments)	509 Pitt Street (Wake Up Hostel)	Central
N02		264 Pitt Street (Uniting Church)	Town Hall
N03		60 Castlereagh Street (Veranda Bar)	Martin Place
N04		52-53 Martin Place	Martin Place
N05		19 Martin Place (CTA Business Club, MLC Centre)	Martin Place
N06		9 York Street (Travelodge Hotel)	Wynyard
N07		Corner Kent Street and Napoleon Street	Wynyard
N08		1 Paternoster Road	Pyrmont
N09		93 Miller Street	Pyrmont
N10		Corner Miller and Mount Street	Pyrmont
N11		32/501 Glebe Point Road	Glebe
N12		27/1 Batty Street	Rozelle
N13		Robert Street (Opposite Shipping Yard)	White Bay
N14		36 Lilyfield Road	Rozelle
N15		43/4 Hornsey Street	Rozelle

Location	Type of Measurements	Address	Area
N16		38 Burt Street	Rozelle
N17	Attended Noise Measurements (for airborne noise assessments)	99 Victoria Road (Child Care Centre)	Rozelle
N18		663 Darling Street (School)	Rozelle
N19		683 Darling Street	Rozelle
N20		26 Waterloo Street	Rozelle
N21		2 Hutcheson Street	Rozelle
N22		101 Lamb Street	Lilyfield
N23		8 Pritchard Street	Annandale
N24		52 Starling Street	Lilyfield
V01	Attended Noise and Vibration Measurements (for ground-borne noise and vibration assessments)	2 Cunningham Street (Quest World Square Apartments)	Sydney City
V02		60 Goulburn Street (First Floor, Masonic Centre)	Sydney City
V03		60 Goulburn Street (Ground Floor, Masonic Centre)	Sydney City
V04		370 Pitt Street (Ada Evans Chambers, Level 1)	Sydney City
V05		98 Liverpool Street (Sydney Central Courts)	Sydney City
V06		130 Elizabeth Street	Sydney City
V07		299 Elizabeth Street	Sydney City

5.3.2 Methodology for Unattended Noise Monitoring

The purpose of the unattended noise monitoring is to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime and night-time periods. These were used to assist in determining the appropriate noise design goals and as a basis for assessing the potential noise impacts during construction and operations.

Unattended noise loggers were deployed adjacent to sensitive receivers over a minimum period of one week in order to measure the prevailing levels of background noise with confidence. The measurements were generally conducted at a height of 1.5 m above the ground level and 1 m from the facade of the subject building, where possible. For security/access reasons, a number of the loggers were required to be deployed on the balconies of certain buildings.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of AS 1259.2-1990 *"Acoustics - Sound Level Meters. Part 2: Integrating - Averaging"* and carried appropriate and current NATA calibration certificates.

The equipment utilised for the continuous unattended noise surveys comprised of Acoustic Research Laboratories Type EL215 and Type EL316 Environmental Noise Loggers fitted with microphone wind shields.

The calibration of the loggers was checked both before and after each measurement survey, and the variation in calibration at all locations was found to be within acceptable limits at all times.

All noise loggers were set to record statistical noise descriptors in continuous 15 minute sampling periods for the duration of their deployment.

Weather data recorded during the noise monitoring survey periods by the Sydney Bureau of Meteorology (at Fort Denison and Observatory Hill) were used to assist in identifying potentially adverse weather conditions, such as excessively windy or rainy periods, so that affected data could be discarded.

5.3.3 Unattended Noise Monitoring Results

The results of the unattended ambient noise surveys are presented in tabular form in **Table 2**, with the 24 hour average noise level plots for each monitoring location being shown graphically in **Appendix C**.

Representative Rating Background Levels (RBL) and L_{Aeq} (energy averaged) noise levels during DECCW's standard daytime, evening and night-time hours, as required by the NSW "*Industrial Noise Policy"* (INP), are shown in the table.

Table 2 Summary of Unattended Noise Logging - Construction and Operational Indices

Location	Noise Level (dBA)[1]					
	Daytime 7.00 am - 6.00 pm		Evening 6.00 pm - 10.00 pm		Night 10.00 pm - 7.00 am	
	RBL	LAeq	RBL	LAeq	RBL	LAeq
B01 - 812 George Street	58	70	56	69	52	66
B02 - 260 Pitt Street	66	71	64	70	61	68
B03 - 60 Castlereagh Street	65	69	62	67	56	64
B04 - 20 Sussex Street	61	69	60	68	49	63
B05 - 1 Union Street	49	56	50	54	46	51
B06 - 56 Mount Street	52	57	51	56	46	51
B07 - 32/501 Glebe Point Road	54	57	52	55	46	53
B08 - 27/1 Batty Street	51	57	49	53	42	47
B09 - 36 Lilyfield Road	56	62	57	62	49	59
B10 - 43/4 Hornsey Street	66	71	64	70	52	66
B11 - 6 Burt Street	45	60	46	58	36	48
B12 - 118 Victoria Road	62	73	61	72	47	69
B13 - 99 Victoria Road	59	70	56	68	42	65
B14 - 665a Darling Street	58	65	55	65	44	62
B15 - 26 Waterloo Street	46	59	47	57	38	52
B16 - 2 Hutcheson Street	57	65	57	64	49	60
B17 - 101 Lamb Street	56	66	55	64	47	59
B18 - 8 Pritchard Street	53	59	51	58	44	54
B19 - 52 Starling Street	49	58	49	57	42	51

Note 1: The Rating Background Level (RBL) and L_{Aeq} noise levels have been obtained using the calculation procedures documented in the DECCW's Industrial Noise Policy.

The results of the noise monitoring have been processed in accordance with the procedures contained in the INP so as to establish representative noise levels at the residences. Based on the meteorological results obtained from the Sydney Bureau of Meteorology, rain and wind affected results have been excluded.

5.3.4 Attended Noise and Vibration Measurements

Attended Airborne Noise Measurements

Attended noise measurements were undertaken at the locations listed in **Table 1** (and illustrated in the Site Plan in **Appendix B**) in order to quantify the noise levels from the various noise sources in the vicinity of the unattended noise monitoring locations.

At each location the attended measurements were performed using a Brüel & Kjær Type 2260 sound level meter for a minimum period of 15 minutes. Wind Speeds were measured to be below 5 m/s at all times, and all measurements were performed at a height of 1.5 m above ground level.

Calibration of the sound level meter was checked before and after each measurement and the variation in calibration at all locations was found to be within acceptable limits at all times. A summary of the measured noise levels and observations is provided in **Appendix D**.

During each of the attended noise measurements the observer noted the various noise sources and levels influencing the ambient noise environment. The acoustic environment at the attended locations is described below:

- At locations surrounding the former Rozelle Marshalling Yard and the White Bay construction site the ambient noise environment was dominated by traffic on City-West Link Road/Victoria Road/Anzac Bridge, resulting in relatively high noise levels. These included the suburbs of Annandale, Lilyfield, Rozelle, Balmain and Glebe Point.
- At locations surrounding Rozelle Station the ambient noise environment was dominated by traffic on Victoria Road, resulting in relatively high noise levels. Dwellings to the south of the site are shielded by the Tigers Leagues Club resulting in lower levels, compared to those fronting Victoria Road.
- At Pyrmont locations the ambient noise environment was dominated by local traffic and urban hum, resulting in medium to high noise levels.
- At city locations corresponding to Central, Town Hall Square, Martin Place and Barangaroo-Wynyard the ambient noise environment was dominated by city traffic and urban hum, resulting in high noise levels. Slightly higher levels where recorded at Town Hall and Martin Place, when compared to Central and Wynyard, as a result of these locations being on busier CBD streets.

Attended Ground-borne Noise and Vibration Measurements

Attended ground-borne noise and vibration measurements were undertaken at the locations listed in **Table 1**, and illustrated on the Site Plan in **Appendix B**. These surveys took place within several buildings above or near the existing CityRail tunnels in order to quantify the typical internal vibration and ground-borne noise levels from the operation of the existing CityRail network.

At each location the attended noise measurements were undertaken using a Brüel & Kjær Type 2260 Sound Level Meter. The measurements were performed for a representative number of passbys at each location and the observer noted any factors that may have influenced the measured noise levels.

Attended vibration measurements were undertaken using a Brüel & Kjær Type 4370 accelerometer, a Brüel & Kjær Type 2635 charge amplifier, a Brüel & Kjær Type 2260 Spectrum Analyser and a Rion DA-20 recorder.

Calibration of the noise and vibration instruments was checked before and after each series of measurements. In all cases the calibration drift was within the acceptable limits. A summary of the measured noise and vibration levels, and observations is provided in **Table 3**.

Ground-borne noise and vibration measurements were undertaken at seven locations above existing tunnels in the CBD. The building occupancy details for these locations are shown below:

- V01 - Level 5, 2 Cunningham Street (serviced residential apartment)
- V02 - Level 1, Grand Lodge Room, Masonic Centre, 60 Goulburn Street (auditorium)
- V03 - Level G, Doric Theatre, Masonic Centre (conference room)
- V04 - Level 1, 370 Pitt Street (open plan office)

- V05 - Level G, 98 Liverpool Street, Local Courts (hallway)
- V06 - Level 1, 130 Elizabeth Street (open plan commercial office)
- V07 - Level 4, 299 Elizabeth Street (open plan commercial office)

Table 3 Summary of Attended Ground-borne Noise and Vibration Measurements

Receiver Location	Time of Day	Background L_{Aeq} Noise Level	Measured Noise Levels (dBA)		Measured Vibration Levels (dBv)		Observations
			Avg	Max	Avg	Max	
V01	07:30 to 08:00	40[1]	<40	<40	N/A	N/A	Levels below ambient.
V02	15:03 to 15:20	-	45	50	95	103	Ground-borne noise levels were clearly audible. Vibration levels were perceptible for some trains.
V03	12:52 to 13:37	38	50	62	98	115	Ground-borne noise levels in this space were higher than anticipated due to the room construction. Vibration levels were perceptible for most trains.
V04	11:16 to 12:50	38	46	55	100	103	Ground-borne noise levels were audible for most trains with the noise levels being much higher for one of the tracks. Vibration levels were perceptible for the loudest trains.
V05	15:13 to 15:47	39	47	54	98	102	Ground-borne noise levels were clearly audible. Vibration levels were perceptible for most trains.
V06	11:00 to 11:30	37	<37	<37	-	-	Levels below ambient.
V07	12:30 to 13:00	38	<38	<38	-	-	Levels below ambient.

Note 1: Background noise levels at this location are higher than expected due to nearby construction noise

The attended noise and vibration measurements are presented in more detail in **Appendix E**.

Ground-borne noise and vibration levels at Locations V01, V06 and V07 could not be measured as the levels were well below ambient levels.

Measured ground-borne noise levels at the remaining measurement locations typically ranged between 35 dBA to 50 dBA. Maximum noise levels were typically between 50 dBA and 55 dBA, with maximum noise levels as high as 62 dBA within the Doric Theatre at the Masonic Centre. Noise levels below 35 dBA often could not be detected in an empty office space due to background noise from building services such as air-conditioning. Noise levels below 38 dBA in an occupied office space were considered difficult to measure due to higher ambient noise levels from general office noise.

Noise levels in a conference or meeting room were just audible at 40 dBA however, were not considered to be intrusive. From discussions with building occupants at locations with frequent train passbys, the occupants were not concerned about ground-borne noise levels from train passbys at approximately 40 dBA. At a level of 40 dBA, the ground-borne noise was typically 2 dBA to 5 dBA above general office noise depending on usage. This supports the recommended ground-borne noise design goals of 45 dBA for general office areas and 40 dBA for private offices and conference rooms (refer **Table 87**).

Tactile vibration became faintly "feelable" when ground-borne noise levels reached approximately 45 dBA. Ground-borne noise levels from train passbys at 50 dBA are likely to be intrusive for general office areas and other similar environments.

6 IDENTIFICATION OF SENSITIVE RECEIVERS

6.1 Noise and Vibration Sensitivity

6.1.1 General

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. For example, recording studios are more sensitive to vibration and ground-borne noise than residential premises, which in turn are more sensitive than typical commercial premises.

The sensitivity may also depend on the existing noise and vibration environment. For example, the DECCW's *"Industrial Noise Policy"* and AS/NZS 2107:2000 *"Recommended Design Sound Levels and Reverberation Times for Building Interiors"* recommend higher acceptable noise levels in urban areas compared with suburban areas. Guidelines produced by the American Public Transit Association (APTA) also nominate higher ground-borne noise goals for multi-family dwellings than for single-family dwellings.

6.1.2 CBD Metro Sensitive Receivers

Following receipt of the horizontal alignment for the Reference Design, Heggies staff members undertook site inspections within a corridor extending approximately 30 m either side of the nearest CBD Metro tunnel. Each building was classified into the following receiver categories:

1. Residential
2. Commercial
3. Educational
4. Industrial
5. Mixed residential/commercial
6. Place of Worship
7. Museum
8. Heritage Item
9. Special Sensitive

In the noise and vibration modelling presented in this report, all residential receivers are considered to be sensitive. Within the CBD, the majority of receivers near the proposed alignment are commercial properties. These are less sensitive to noise and vibration compared to residential receivers. Outside the CBD, the alignment runs under several residential areas in Pyrmont and Rozelle.

Table 4 presents details of the sensitive receiver locations, excluding those of a residential nature, that are situated along the length of the alignment. The locations of these receivers are also shown on the Site Plan in **Appendix B**.

Whilst most commercial receivers are generally less sensitive than residential receivers, several commercial properties have been identified as being potentially susceptible to noise and vibration as a result of sensitive equipment being located within these buildings. These are also shown in **Table 4**.

Table 4 Identified Sensitive Receivers (Non-Residential)

Name of Receiver	Area	Approximate Chainage (km)	Sensitive Receiver Type
Perpetual Trustee Company Limited building	Sydney City	+2.130	Heritage Item
St. Philip's Church	Sydney City	+2.660	Heritage Item
Moreton's Hotel/Pub	Sydney City	+2.820	Heritage Item
Sydney Water Heritage Item	Sydney City	+2.820	Heritage Item
Pyrmont Post Office	Pyrmont	+3.870	Heritage Item
White Bay Power Station	Rozelle	+5.540	Heritage Item
Health and Beauty Pharmacy, (York Building)	Rozelle	+6.170	Heritage Item
St Thomas Church	Rozelle	+6.170	Heritage Item
Catering (York Building)	Rozelle	+6.140	Heritage Item
Furniture shop (York Building)	Rozelle	+6.150	Heritage Item
Clothes shop (York Building)	Rozelle	+6.160	Heritage Item
York Building	Rozelle	+6.175	Heritage Item
Furniture shop (York Building)	Rozelle	+6.180	Heritage Item
St Paul's Church	Rozelle	+6.260	Heritage Item
Rozelle Primary Public School	Rozelle	+6.280	Heritage Item
Australian International Conservatorium of Music	Rozelle	+6.080	Heritage Item/Educational
UTS University	Chippendale	-0.325	Educational
TAFE	Haymarket	-0.080	Educational
Actors College of Theatre & Television	Haymarket	+0.140	Educational
Childcare Centre (Level 2)	Sydney City	+2.500	Educational
CFK Childcare Centre located below Western Distributor viaduct	Sydney City	+2.740	Educational
KU Maybanke Pre-school (2-5yrs old)	Pyrmont	+3.910	Educational
Rosebud Cottage Childcare Centre	Rozelle	+5.640	Educational
Sydney Community College	Rozelle	+5.800	Educational
Childcare Centre	Rozelle	+6.150	Educational
Greater Union/Cinemas (Level 2)	Sydney City	+1.440	Theatre
State Theatre + Offices	Sydney City	+1.550	Theatre
Theatre Royal	Sydney City	+1.830	Theatre
StarCity Lyric Theatre	Pyrmont	+3.680	Theatre
Café and Pilgrim theatre	Sydney City	+1.300	Commercial/Theatre
Christ Church St. Laurence	Haymarket	+0.120	Place of Worship
Pitt Street Uniting Church	Sydney City	+1.200	Place of Worship
Scots Presbyterian Church Sydney and residences on top of church building	Sydney City	+2.600	Place of Worship/Residential
UTS University/Optometrist on G level	Chippendale	-0.225	Commercial/Educational
UTS University/Co-op bookshop on G level	Chippendale	-0.250	Commercial/Educational

Name of Receiver	Area	Approximate Chainage (km)	Sensitive Receiver Type
Retails on G level, Australian Pacific College	Sydney City	+1.220	Commercial/Educational
Madame Korner Skin Care Beauty Salon&Beauty Therapy College	Pyrmont	+3.780	Commercial/Educational
Australian Maritime Museum	Pyrmont	+3.420	Museum
Centre Point Tower	Sydney City	+1. 660	Special Sensitive
CSC Data Centre	Pyrmont	+3.710	Special Sensitive
Channel Ten	Pyrmont	+4.120	Special Sensitive

Note 1: Positive values represent locations north of Central Station. Negative Values represent locations south of Central Station.

7 CONSTRUCTION NOISE AND VIBRATION GOALS

7.1 Introduction

The following sections contain an assessment of the construction noise and vibration impacts associated with the project. Construction noise and vibration goals have been determined based on the relevant government guidelines and industry standards. Noise and vibration emission levels have been determined based on expected activities and where exceedances are predicted, feasible and reasonable impact mitigation measures are considered. The CBD Metro represents a major infrastructure development project, constructed over several years, and as such there would be periods when impacts on the surrounding areas are expected.

The Director-Generals Requirement (DGRs) (refer **Section 3**) state that the Environmental Assessment (EA) is to include consideration of the potential impacts associated with, and a management framework for construction works to ensure impacts are mitigated monitored and managed.

The EA must include a considered approach for the scheduling of works (balance overall duration and respite periods), and a strategy for monitoring and mitigating noise and vibration (with focus on the activities identified as having the greatest impact, and a generic approach for lower risk activities).

7.2 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

$L_{A1(1minute)}$ the "typical maximum noise level" for an event, used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the L_{Amax} or maximum noise level

$L_{Aeq(15minute)}$ the "energy average noise level" evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

L_{A90} the "background noise level" in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $L_{A10(15\ minute)}$ construction noise goals are based on the L_{A90} background noise levels.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

7.2.1 Project Specific Noise Management Levels

Residences

The CBD Metro would be constructed over several years, and as a significant amount of the construction would be conducted underground, works would often be required to be conducted during the night-time period as well as the daytime. Heggies has conducted a review of guidelines and current practices for the assessment and subsequent mitigation of construction noise, and has adopted the following approach for the CBD Metro Project:

- Determine project specific **Noise Management Levels** (NMLs) for noise affected receivers consistent with current practices to deal with construction noise in a transparent and consistent way.
- Where the construction noise levels are predicted to exceed the NMLs, all **feasible** and **reasonable** work practices will be investigated to minimise noise emissions.

- Having investigated all **feasible** and **reasonable** work practices, if construction noise levels are still predicted to exceed the NMLs then Sydney Metro would manage the potential noise impacts via site specific construction noise management plans.

Consistent with this approach, the following project specific $L_{Aeq(15minute)}$ NMLs have been adopted for sensitive receivers:

- Daytime (7.00 am to 6.00 pm) RBL or L_{A90} Background +10 dBA
- Evening (6.00 pm to 10.00 pm) RBL or L_{A90} Background +5 dBA
- Night-time (10.00 pm to 7.00 am) RBL or L_{A90} Background +5 dBA

It is noted that the above assessment approach is consistent with the DECCW's "*Interim Construction Noise Guideline"*.

Guidance on implementing the site specific construction noise management plans will be provided in the Sydney Metro *"Construction Noise and Vibration Strategy"* (this is presented in more detail in **Section 11**).

Sleep Disturbance

The most recent guidance in relation to sleep disturbance are those contained in the DECCW's *"Application Notes - NSW Industrial Noise Policy"*. The pertinent section of the DECCW's Application Notes states the following:

> *"DECC*[W] *reviewed research on sleep disturbance in the NSW Environmental Criteria for Road Traffic Noise (ECRTN) (EPA, 1999). This review concluded that the range of results is sufficiently diverse that it was not reasonable to issue new noise criteria for sleep disturbance.*
>
> *From the research, DECC*[W] *recognised that current sleep disturbance criterion of an L_{A1}, (1 minute) not exceeding the L_{A90}, (15 minute) by more than 15 dBA is not ideal. Nevertheless, as there is insufficient evidence to determine what should replace it, DECC*[W] *will continue to use it as a guide to identify the likelihood of sleep disturbance. This means that where the criterion is met, sleep disturbance is not likely, but where it is not met, a more detailed analysis is required.*
>
> *The detailed analysis should cover the maximum noise level or L_{A1}, (1 minute), that is, the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the appendices to the ECRTN. Other factors that may be important in assessing the extent of impacts on sleep include:*
>
> - *How often high noise events will occur.*
> - *Time of day (normally between 10pm and 7am).*
> - *Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).*
> - *The LA1, (1 minute) descriptor is meant to represent a maximum noise level measured under "fast" time response. DECC*[W] *will accept analysis based on either LA1, (1 minute) or LAmax"*

Schools and Childcare Centres

Rozelle Primary School is located opposite the main Rozelle Station construction site, and a childcare centre is located adjacent to the Rozelle worksite on the north-east corner of Victoria Road and Darling Street.

AS/NZS 2107:2000 "*Recommended design sound levels and reverberation times for building interiors"* provides general guidance on background levels for educational facilities and recommends an internal maximum design sound level L_{Aeq} of 45 dBA. Given the relative sensitivity of schools and child care centres, it is considered appropriate to adopt this internal noise level as the goal for construction noise.

On the assumption that the schools operate with openable windows, and that typically a 10 dBA reduction from outside to inside is applicable for openable windows, a resulting external L_{Aeq} noise level of 55 dBA is required to comply with the internal target.

Churches and Places of Worship

Similarly to schools and childcare centres AS/NZS 2107:2000 has been used for guidance, and results in an internal maximum design sound level L_{Aeq} of 40 dBA. The resultant external NML is 50 dBA for openable windows, and 60 dBA for fixed windows, when the facility is in use.

Commercial Premises

For commercial premises, which include offices, retail outlets and small commercial premises an external NML of $L_{Aeq(15minute)}$ 70 dBA has been adopted. This level is consistent with current practice and the DECCW's current "*Interim Construction Noise Guideline."*

Passive and Active Recreation Areas

For passive recreation areas (for example characterised by contemplative activities such as reading) an external NML of $L_{Aeq(15minute)}$ 60 dBA has been adopted. For active recreation (for example sporting activities which generate their own noise) an external NML of $L_{Aeq(15minute)}$ 65 dBA has been adopted.

These management levels are consistent with the DECCW's current "*Interim Construction Noise Guideline".*

7.2.2 Ground-borne Noise

Ground-borne construction noise is usually present on tunnelling projects when vibration from activities such as rock breaking, road heading, rotary cutting, tunnel boring and rock drilling/sawing can be transmitted through the ground and into the habitable areas of nearby buildings. Ground-borne (or regenerated) noise occurs when this vibration in the ground and/or building elements is regenerated as audible noise within areas of occupancy inside the building.

Sometimes the vibration generated by the above activities may be perceptible in nearby buildings. In such cases, the human comfort vibration goals discussed in **Section 7.4** are applicable.

For most recent tunneling projects in Sydney (including the Cross City Tunnel and Lane Cove Tunnel), internal ground-borne noise goals of $L_{Aeq(15minute)}$ 40 dBA (evening) and $L_{Aeq(15minute)}$ 35 dBA (night-time) have been adopted for residential receivers. These goals have been adopted for the proposed CBD Metro.

The ground-borne noise goals are consistent with the guideline levels in the DECCW's "*Interim Construction Noise Guideline"* and are only applicable during the evening (6 pm to 10 pm) and night-time (10 pm to 7 am) periods, and when the ground-borne noise levels are higher than the airborne noise levels inside residential dwellings. During daytime periods, the human comfort vibration goals are applicable.

7.3 Vibration Damage Goals - Surface Structures

Most commonly specified "safe" structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

7.3.1 British Standard 7385: Part 2 - 1993 Guidelines

In terms of the most recent relevant vibration damage goals, Australian Standard AS 2187: Part 2-2006 *"Explosives - Storage and Use - Part 2: Use of Explosives"* recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 *"Evaluation and measurement for vibration in buildings Part 2"* as they "are applicable to Australian conditions".

The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 5** and graphically in **Figure 5**.

Table 5 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

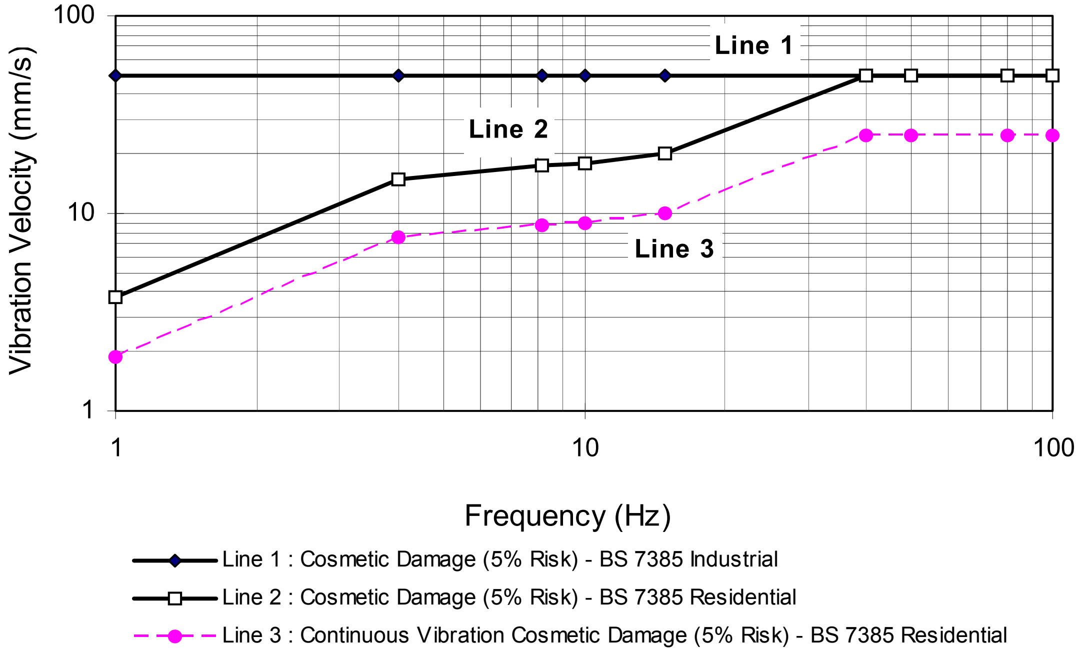
Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	**15 Hz and Above**
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The Standard states that the guide values in **Table 5** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 5** may need to be reduced by up to 50%.

Note: rockbreaking/hammering and sheet piling activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

Figure 5 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to "Line 2" are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 5**, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 5** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the guidance curves presented in **Figure 5**.

It is noteworthy that extra to the guide values nominated in **Table 5**, the standard states that:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK."*

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

For most construction activities involving intermittent vibration sources such as rockbreakers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range). On this basis, a conservative vibration damage screening level of 7.5 mm/s has been adopted for preliminary assessment purposes.

At locations where the predicted and/or measured vibration levels are greater than 7.5 mm/s, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

7.4 Human Comfort Vibration Goals

7.4.1 General

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 6**.

Table 6 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		Degree of Perception
Peak Vibration Level	**RMS Vibration Level**	
0.10 mm/s	0.07 mm/s	Not felt
0.15 mm/s	0.1 mm/s	Threshold of perception
0.35 mm/s	0.25 mm/s	Barely noticeable
1 mm/s	0.7 mm/s	Noticeable
2 mm/s	1.4 mm/s	Easily noticeable
6 mm/s	4.2 mm/s	Strongly noticeable
14 mm/s	10 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 6 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s (RMS).

The DECCW's "*Assessing Vibration: a technical guideline*" notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Construction activities typically generate building vibrations that are intermittent or impulsive in nature, however vibration levels may sometimes be constant from sources such as generators or ventilation fans.

Examples of intermittent vibration events include the vibration generated by rockbreakers, vibratory rollers, drilling/piling and excavators. Examples of impulsive vibration events include the vibration generated by demolition activities, blasting or the dropping of heavy equipment.

The vibration generated by train passbys is classified as intermittent.

Where vibration is intermittent or impulsive in character, the DECCW vibration guideline (and other similar guidelines) recognise that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous vibration sources.

The following sections describe the applicable continuous and intermittent vibration goals for the CBD Metro construction activities.

7.4.2 Human Comfort Goals for Continuous and Impulsive Vibration

The DECCW's "*Assessing Vibration: a technical guideline*" is applicable for the CBD Metro and is based on the guidelines contained in British Standard BS 6472-1992 "*Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)*". The DECCW guideline refers only to human comfort considerations and nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers.

The criteria in the DECCW guideline are non-mandatory, "*they are goals that should be sought to be achieved through the application of all feasible and reasonable mitigation measures. Where all feasible and reasonable measures have been applied and vibration values are still beyond the maximum value, the operator would need to negotiate directly with the affected community*".

Construction vibration can be continuous, intermittent or impulsive and the DECCW's vibration guideline provides different goals for each category. The continuous vibration goals are most stringent and higher vibration levels are acceptable for intermittent and impulsive vibration on the basis of the shorter exposure times. Examples of typical vibration sources are provided in **Figure 6**.

Figure 6 Examples of Vibration (DECCW Vibration Guideline)

Examples of types of vibration

Continuous vibration	Impulsive vibration	Intermittent vibration
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading. Blasting is assessed using ANZECC (1990).	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer this would be assessed against impulsive vibration criteria.

The applicable human comfort vibration goals for continuous, intermittent and impulsive vibration sources are provided in **Table 7**, **Table 8** and **Table 9** respectively. In all cases, the vibration goals are expressed in terms of the RMS vibration velocity level in mm/s, measured in the most sensitive direction (z-axis).

The DECCW vibration guideline notes the following in relation to the preferred and maximum vibration levels:

> *"There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the maximum value may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*
>
> *In circumstances where work is short term, feasible and reasonable mitigation measures have been applied, and the project has a demonstrated high level of social worth and broad community benefits, then higher vibration values (above the maximum) may apply. In such cases, best management practices should be used to reduce values as far as practicable, and a comprehensive community consultation program should be instituted."*

Table 7 Preferred and Maximum Vibration Levels for Continuous Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Woking Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.14	0.28
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 8 Preferred and Maximum Vibration Levels for Intermittent Vibration (Vibration Dose Values)

Building Type	Preferred Vibration Dose Value ($m/s^{1.75}$)	Maximum Vibration Dose Value ($m/s^{1.75}$)
Critical Woking Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: For the definition of the Vibration Dose Value refer to the discussion in the following section. Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

Table 9 Preferred and Maximum Vibration Levels for Impulsive Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.1	0.2
Residential Daytime	6.0	12.0
Residential Night-time	2.0	4.0
Offices, schools, educational institutions and places of worship	13.0	26.0
Workshops	13.0	26.0

Note: Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

7.4.3 Intermittent Vibration (Vibration Dose Values)

For most construction activities that generate perceptible vibration in nearby buildings, the character of the vibration emissions is intermittent. This includes equipment such as rockbreakers, excavators, piling rigs, rock drills, vibratory rollers and heavy vehicle movements.

Intermittent vibration is defined in the DECCW vibration guideline as follows:

*"**Intermittent vibration** can be defined as interrupted periods of continuous (e.g. a drill) or repeated periods of impulsive vibration (e.g. a pile driver), or continuous vibration that varies significantly in magnitude. It may originate from impulse sources (e.g. pile drivers and forging presses) or repetitive sources (e.g. pavement breakers), or sources which operate intermittently, but which would produce continuous vibration if operated continuously (for example, intermittent machinery, railway trains and traffic passing by). This type of vibration is assessed on the basis of vibration dose values".*

Where vibration comprises a number of events, a Vibration Dose (Dv) may be estimated for each event by the following formula using vibration measured in velocity:

$Dv = 0.07\ V\ (rms) \times t^{0.25}\ m/s^{1.75}$

Where, V (rms) = rms particle velocity (mm/s)

t = Total cumulative time (seconds) of the vibration event or period of vibration

The total vibration dose is then calculated using the following formula:

$$Dv = \left(\sum_{n=1}^{n=N} Dv_n^4 \right)^{0.25}$$

Where, Dv = Total vibration dose value for the day or night

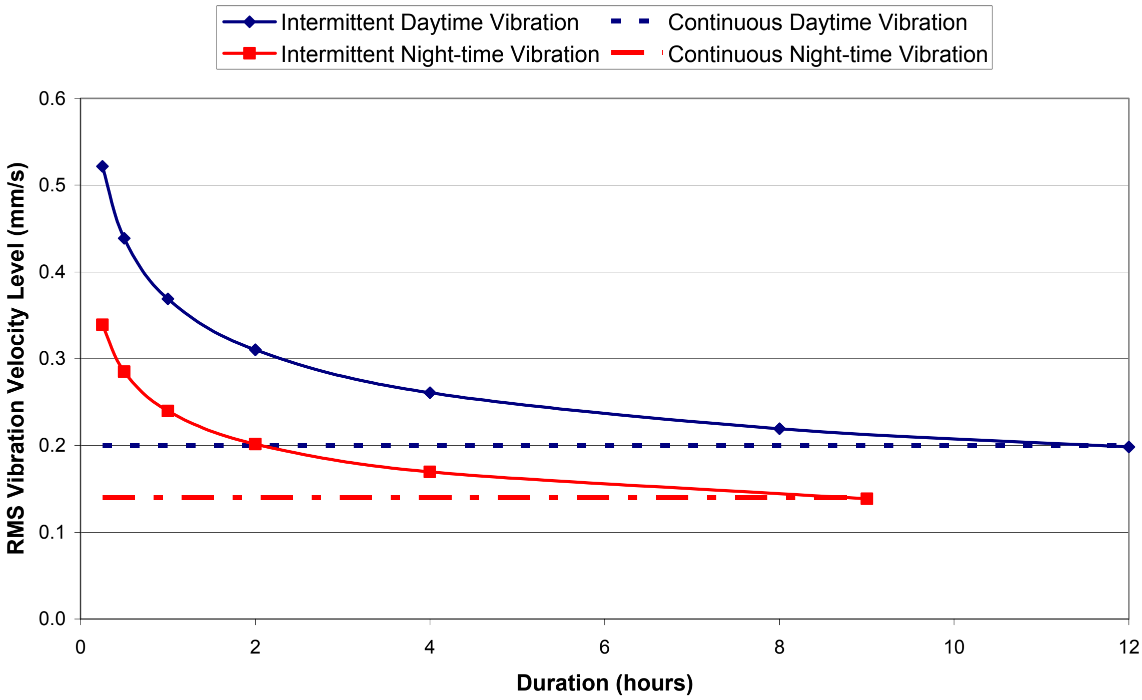
Dvn = Vibration dose value for each vibration dose event

N = Total number of vibration dose events

The permissible vibration level corresponding to the vibration dose value varies according to the duration of exposure. For example, higher vibration levels are permitted if the total duration of the vibration event(s) is small and lower vibration levels are permitted with if the total duration of the vibration event(s) is large.

This concept is illustrated graphically in **Figure 7**, where the intermittent vibration curves for the daytime and night-time periods correspond to the preferred Vibration Dose Values in **Table 8**. As the total duration of the intermittent vibration sources during the daytime and night-time periods get larger, the intermittent vibration goals approach the preferred continuous vibration goals in **Table 7**.

Figure 7 Vibration Levels Corresponding to "Low Probability of Adverse Comment" for Residential Receivers - Continuous and Intermittent Vibration



7.4.4 Site Specific Vibration Goals

In consideration of the above vibration standards and guidelines, and in relation to damage to surface structures, a vibration level of 7.5 mm/s at a residence or vibration sensitive receiver has been set as a threshold for further assessment and/or monitoring (for both continuous and intermittent or impulsive vibration sources). This screening level corresponds to the 4 Hz limit for "*continuous vibration cosmetic damage"* of **Figure 5**, noting for conventional construction activities generating vibration, such as excavation and earthworks, the frequency of vibration will be above 4 Hz and usually in the 10 Hz to 100 Hz range.

For continuous vibration, it is recommended that the vibration sources include mitigation measures (where feasible and reasonable) to achieve the continuous vibration goals.

In consideration of the above vibration standards and guidelines, and in relation to human comfort, for continuous vibration a daytime RMS level of 0.2 mm/s and night-time RMS level of 0.14 mm/s at a residence have been set as a trigger level. For offices the RMS trigger level is 0.4 mm/s. Typically continuous vibration expected with the project will be from TBM and roadheader operations. For continuous intermittent vibration (such as from rockbreakers or similar operations) the daytime RMS trigger levels are 1.4 mm/s. For impulsive vibration, such as from demolition, piling etc daytime RMS trigger levels are 6 mm/s for a residence and 13 mm/s for an office. Management levels should be based on the maximum vibration levels as presented in **Table 9**.

It is recommended for continuous intermittent and impulsive vibration VDV values be determined as part of the Sydney Metro "*Construction Noise and Vibration Strategy*".

7.5 Construction Traffic Noise Assessment Goals

For traffic operating on public roads to and from the subject sites the DECCW's "*Environmental Criteria for Road Traffic Noise*" (ECRTN) are appropriate for assessing potential road traffic noise impacts. The DECCW's recommended noise goals for the three most common road categories are set out in **Table 10**.

Table 10 DECCW Road Traffic Noise Goals

Development	Day (7.00 am to 10.00 pm)	Night (10.00 pm to 7.00 am)
7. Land use developments with potential to create additional traffic on existing FREEWAYS/ARTERIAL roads	$L_{Aeq(15hour)}$ 60 dBA	$L_{Aeq(9hour)}$ 55 dBA
8. Land use developments with potential to create additional traffic on COLLECTOR roads	$L_{Aeq(1hour)}$ 60 dBA	$L_{Aeq(1hour)}$ 55 dBA
13. Land use developments with potential to create additional traffic on LOCAL roads	$L_{Aeq(1hour)}$ 55 dBA	$L_{Aeq(1hour)}$ 50 dBA

Where the L_{Aeq} traffic noise levels already exceed the above noise goals, a 2 dBA increase in the overall traffic noise levels is normally regarded as an alternative target (having investigated the application of all feasible and reasonable noise mitigation) in order to maintain the general acoustic amenity of the area.

It is likely that on the roads immediately adjacent to the various subject work sites, the community will associate heavy vehicle movements with the project. Once the heavy vehicles move further from each of the sites onto major collector or arterial roads however, the noise may be perceived as part of the general road traffic.

Sleep Disturbance and Maximum Noise Level Events

The DECCW's ECRTN and the Road and Traffic Authority's (RTA's) *"Environmental Noise Management Manual"* (ENMM) provide guidance as to the likelihood of sleep disturbance resulting from maximum noise level events (mainly associated with heavy vehicle movements). The ECRTN points out the following:

> *"There are no universally accepted criteria governing the likelihood of sleep disturbance. In other words, at the current level of understanding, it is not possible to establish absolute noise levels that correlate to levels of sleep disturbance (for all or even a majority of people)."*

Notwithstanding the ECRTN/ENMM suggests that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause awakening reactions.
- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA, are not likely to affect health and wellbeing significantly.
- At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9hour)}$ target noise level should sufficiently account for sleep disturbance impacts.

- However, where the emergence of L_{Amax} noise levels over the ambient L_{Aeq} noise level is greater than 15 dBA, the L_{Aeq} criterion may not sufficiently account for sleep disturbance impacts.

A maximum noise event can be defined as any passby for which the difference in the L_{Amax} and $L_{Aeq(1hour)}$ noise levels is greater than 15 dBA. Furthermore, the ECRTN recommends that the assessment of sleep disturbance should include a consideration of the maximum noise level exceedances occurring during the night-time period and the emergence of these exceedances above the ambient noise level.

8 CONSTRUCTION SITE DESCRIPTIONS

For the proposed CBD Metro, the major worksites are located at White Bay (for the TBM launch site and support facilities) and the adjoining stabling and maintenance depot at Rozelle. Construction sites are also located at the station sites of Central, Town Hall Square, Martin Place, Barangaroo-Wynyard, Pyrmont and Rozelle. Significant noise generating construction activities will involve demolition of existing buildings, excavation using rockbreakers and roadheaders, earthworks, removal of spoil and station construction.

8.1 The White Bay, Rozelle Stabling and Maintenance Depot Construction Site

During the CBD Metro Project, the White Bay and Rozelle stabling construction site would be used for the following purposes:

- Proposed TBM launch site and associated facilities for tunnel construction
- Spoil removal from behind the TBMs
- Tunnel fitout including rail systems
- General construction site
- Construction of the White Bay Station box
- Construction of train stabling and maintenance facilities (at the Rozelle stabling and maintenance depot)
- Construction of other associated on-site buildings and facilities

The surrounding land uses of the White Bay and Rozelle stabling construction site relate to the Glebe Island port facilities. Residential development is located further to the north and White Bay is located adjacent to the site to the east. The area is already affected by noise related to industrial activities along with predominantly road traffic noise and general urban noise.

A site plan for White Bay and Rozelle is shown in **Figure 8** and **Figure 9** respectively. Two TBMs are proposed to be launched from the White Bay site, and the site would operate on a 24 hour per day basis to support the TBM operations. Spoil would also be potentially removed from this site on a continuous 24 hour per day basis. Depending on road network conditions, spoil removal by heavy vehicles would be likely to be restricted to occur outside of peak hours and special events. It may therefore occur overnight. Options for spoil removal by barge and/or train are also being considered.

White Bay Power Station is listed under the State Heritage Register, Sydney Regional Environmental Plan No. 26 - City West, Section 170 Register and on the Register of the National Estate. No direct impact to the Power Station is anticipated.

8.2 Station Construction Sites

Stations are proposed to be located at Central, Town Hall Square, Martin Place, Barangaroo-Wynyard, Pyrmont and Rozelle, as well as a “station box” at White Bay to enable potential construction of a future station on the site.

Key station site activities representative of the typical noise emissions expected to occur during the project are:

- Demolition of existing buildings, site establishment including spoil handling facilities
- Vertical excavation using rockbreakers and other construction plant
- Horizontal excavation of the station cavern using roadheaders

- Spoil removal from on site storage areas by heavy vehicle
- Station construction, fitout and commissioning

In order to complete the station excavation before the arrival of the TBMs, the horizontal cavern excavation and spoil storage/removal is required to occur during the daytime and night-time. Furthermore, to meet this project requirement, the vertical excavation is potentially also required to occur during the daytime and night-time.

For the project timetable, indicatively at station sites vertical shaft excavation and excavation for the station cavern heading will take 6 to 12 months to complete, depending on depth. Cavern excavation will take approximately 9 months, cavern concreting and lining approximately 9 months and completion of the station structure approximately 9 months.

Central Station

The location of the proposed Central Station would be on the western side of CityRail's Central Station, adjacent to the existing CityRail buildings. The station construction site would be located on the western side of the CityRail's Central Station, known as the Western Forecourt, bounded by Eddy Avenue and Pitt Street, as shown in **Figure 10**.

In addition, some construction activities may be required within Belmore Park for the removal of tunnel boring machines.

The station would be located under the Western Forecourt and would be constructed underground using a large single cavern with one cut and cover shaft required to provide construction access to the cavern. Entrances would be located within the Western Forecourt and Quay Street. In addition, pedestrian subways are proposed under the country and intercity platforms. The concourse would be below ground level, with escalator and lift access to platform level.

CityRail's Central Station is listed on the Register of the National Estate. The station includes all rail viaduct structures adjacent to Belmore Park and the colonnade along Eddy Avenue and Pitt Street. Railway Square Park is also part of this heritage item.

Town Hall Square Station

Town Hall Square Station would be located under Pitt Street, between Bathurst Street and Park Street. Worksites for station entrances and service shafts include sites at the south west corner of Pitt Street and Park Street, and Bathurst Street. In addition a pedestrian subway is proposed under Park Street to provide an entrance on Pitt Street near The Galleries Victoria. These locations are shown in **Figure 11**. Demolition works associated with the station site would include the buildings located on the corner of George Street, Park Street and Pitt Street.

Martin Place Station

Martin Place Station would be located under Castlereagh Street, between Hunter Street and King Street. The worksites for station entrances and service shafts include sites within Martin Place west of Castlereagh Street, along Castlereagh Street, and a site at the northern end of Castlereagh Street, bound between Castlereagh Street and Elizabeth Street. The station would be constructed underground using a large single cavern, with one cut and cover shaft required to provide construction access to the caverns. The proposed location is shown in **Figure 12**. Demolition works associated with the station site would include the commercial buildings located between Castlereagh Street and Elizabeth Street, near the corner of Hunter Street.

There are numerous heritage buildings in close proximity to the proposed station location, including the Perpetual Trustee Building and the Commonwealth Bank Building which are both listed on the State Heritage Register, Sydney Local Environmental Plan 2005 and Register of National Estate. None of these heritage items would be directly impacted.

Barangaroo-Wynyard Station

Barangaroo-Wynyard Station is proposed to be located beneath Margaret Street, Kent Street and Clarence Street. The station would be constructed underground using a large single cavern, with two cut and cover shafts providing construction access to the cavern. Construction work sites, as shown in **Figure 13**. A primary construction worksite would be located within the Barangaroo site, at the western end of the station cavern. The secondary construction site is located at 26 to 38 Clarence Street, between Clarence Street and York Lane. Demolition works associated with the station site would include the two buildings at 26-34 Clarence Street and at 36-38 Clarence Street..

Pedestrian entrances to the Barangaroo-Wynyard Station are proposed to allow for access from both Sussex Street and Kent Street, and in the vicinity of Jamison Street. The station would also include pedestrian linkages between the future development at Barangaroo, the new Barangaroo-Wynyard Station, and CityRail's Wynyard Station.

Pyrmont Station

Pyrmont Station is located within the urban and commercial area of Pyrmont with its historic significance. The station is proposed to be located beneath Union Square and buildings on Harris Street, near the intersection of Harris Street and Miller Street.

The station would be constructed underground using a large single cavern, with two cut and cover shafts providing construction access to the caverns, indicatively located at the corner of Mount Street and Miller Street and the corner of Union Street and Pyrmont Street.

These areas would be affected for the duration of construction works and are located as shown in **Figure 14**. Demolition works associated with the station site would include the commercial building located on the corner of Mount Street and Miller Street, and four terrace buildings on the corner of Union Street and Pyrmont Street.

The proposed Pyrmont Station is in a mixed use area, with medium-density apartment buildings and terraces, street level cafes and pubs, and some commercial development dominating the streetscape. Star City Casino is also located to the north east of the site.

Pyrmont is an historic area and contains many heritage assets. Numerous items are located in proximity to the proposed construction site. The most notable of these items is the Pyrmont Post Office which is located adjacent to the western end of the proposed station, and is listed on the Commonwealth Heritage list, State Heritage Register, Register of National Estate and Sydney Local Environmental Plan 2005. The heritage items would not be permanently affected by the Pyrmont Station construction works.

Rozelle Station

Rozelle Station is located in an inner suburban catchment area with surrounding land uses including restaurants, bars, food and clothes shops, and other specialised retailers located along Darling Street and Victoria Road. The station is proposed to be located under Victoria Road, adjacent to the Tigers site.

The station would be constructed using underground cavern construction techniques to minimise impacts on road and pedestrian traffic, including impacts on the adjacent school and community facilities.

The primary construction site providing access for the underground cavern and station construction is located within the Tigers Leagues Club site (to be redeveloped by Tigers following completion of the work required for the CBD Metro).

Smaller construction sites for the station would be required on either side of Darling Street for two cut and cover shafts required for station entrances, as shown in **Figure 15**. A third, smaller construction site for a station entrance would also be located on the northwest corner of Darling Street and Victoria Road. Demolition works associated with the station site would include the Tigers Leagues Club as well as the commercial buildings located on the northwest, northeast and south east corners of Victoria Road and Darling Street.

The station precinct is located within a Heritage Conservation Area under the Leichhardt LEP 2000.

Numerous heritage items are located within the vicinity of the station sites, including St Thomas Church Group (listed under the Leichhardt LEP 2000), the York Buildings, the Mechanics Institute (listed under the Leichhardt LEP), Rozelle Public School (listed in Leichhardt LEP 2000 and Register of National Estate) and St Paul's Church (listed under the Leichhardt LEP 2000 and Register of National Estate). None of these items would be directly affected by the Rozelle Station construction works.

9 CONSTRUCTION NOISE ASSESSMENT

9.1 Noise Modelling

In order to quantify noise emissions from construction, a three-dimensional computer noise model was prepared for the major construction sites of White Bay and the Rozelle stabling and maintenance depot. This was undertaken using the CONCAWE industrial noise algorithm as implemented in SoundPLAN acoustic modelling software. The model for these sites includes source noise emission levels, ground topography, location of sources and receivers, acoustic shielding provided by intervening ground topography, air absorption and ground effects. For the station sites, computer noise models were also developed and based on the CONCAWE industrial noise algorithm.

Ground topography was digitised from 2 m contour interval topographical data obtained from the proposed alignment drawings, and layouts based on the worksite drawings described in the EA.

Maximum sound power levels for equipment assumed in the modelling are presented in **Table 11**.

Table 11 Summary of Sound Power Levels used for Demolition and Construction Equipment (Prior to Mitigation)

Plant Item	L_{Amax} Sound Power Level (dBA)
Excavator Hammer	122
Dump Truck	108
Excavator (approx 20T)	105
Excavator (approx 30T)	110
Excavator (approx 40T)	115
Front End Loader	111
Compactor	105
Scraper	110
Grader	110
Water Cart	108
Concrete Saw	118
Jackhammer	113
Mobile Crane	110
Generator	104
Bored Piling Rig	110
Concrete Pump	109
Compressor	105
Vibratory Roller	114

Note 1: Source TIDC CNS, 2007

The sound power levels given in **Table 11** are maximum noise emission levels of plant that will or may be used on this project in typical operation. In order to apply the construction noise goals for the project, it is necessary to convert these levels to equivalent $L_{Aeq(15minute)}$ noise emissions. From numerous field studies on large construction projects, the measured difference values between the L_{Amax} and $L_{Aeq(15minute)}$ noise levels have been found to be up to 10 dBA depending on the mixture of the plant, intensity of operation and location of the plant relative to the receiver.

In the present study, where the equipment is generally confined to the station area and the receivers are relatively close, adjustments of 2 dBA to typically 5 dBA have been applied to convert the L_{Amax} noise levels shown in **Table 11** to L_{A10} noise levels for comparison with the construction noise design goals.

The proposed equipment used at the station sites will be a subset of that presented in **Table 11**, with the station noise models using sound power levels (SWLs) per activity and plant operating loads and cycles, based on the maximum noise levels presented in **Table 11**.

Based on these parameters, the $L_{Aeq(15minute)}$ SWL for each major noise generating activity at the station sites was estimated as follows:

- Demolition using jackhammers and rockbreakers - 120 dBA
- Excavation using rockbreakers - 120 dBA
- Earthworks and station construction - 110 dBA

During demolition the use of jackhammers and rockbreakers represent a 'worst case" condition, and noise levels will be typically 5 dBA to 10 dBA lower for the majority of demolition works.

9.1.1 Noise Mitigation

For the station sites there are negligible existing barriers between stations and noise sensitive receivers, therefore it is anticipated that the construction of minor to major noise barriers would result in the following reductions in noise levels:

- Minor barrier (hoarding indicative height 3 m) 5 dBA to 10 dBA reduction
- Moderate barrier (hoarding indicative height 6 m) 10 dBA to 15 dBA reduction
- Major barrier (Enclosure) 15 dBA to 25 dBA reduction

The (hoarding) noise barriers are effective for receivers at or near ground level (eg outdoor eating areas), they will however not attenuate noise at elevated receivers "overlooking" the construction sites. The noise barriers are required to be of a solid construction (eg 25 mm timber). It is also noted the use of noise barriers, and in particular site enclosures, is often not feasible prior to completion of the demolition phase of the works.

The indicative enclosure construction would consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where increased noise insulation is required this can be achieved by upgrading the enclosure elements by using, for example, double skin or masonry construction.

For the construction site plans of **Figure 8** to **Figure 15** the following colouring can be considered.

- Red — Construction Site
- Blue — Residential
- Yellow — Commercial
- Green — Educational
- Purple/Pink — Church or Place of Worship

9.2 White Bay Site - Noise Assessment

The nearest noise sensitive receivers to the White Bay Site are identified in **Table 12** with the receiver areas illustrated in **Figure 8**.

Figure 8 White Bay Construction Site and Receiver Areas

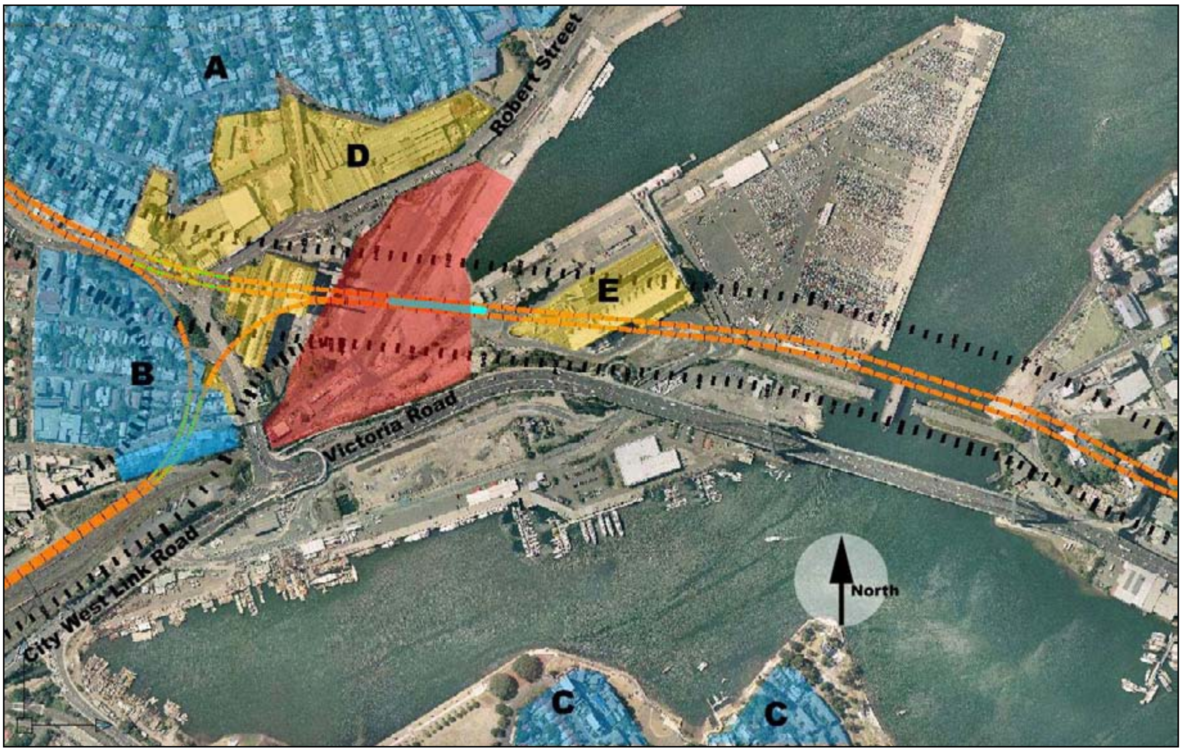


Table 12 Nearest Noise Sensitive Receivers - White Bay

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
White Bay Construction Site	A - Dwellings - N B - Dwellings - W C - Dwellings - SE D - Commercial - N E - Commercial - E	235 240 530 145 132
White Bay Tunnel	E - Commercial	15

9.2.1 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction noise goals are presented in **Table 13**.

Table 13 White Bay Construction NMLs

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
Batty Street - A	61	54	47
Hornsey Street - B	76	69	57
Glebe Point - C	64	57	51

9.2.2 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the proposed daytime and night-time operations, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Daytime - TBM boring with spoil removal
- Night-time - TBM assembly
- Night-time - TBM boring with spoil removal and spoil delivery from CBD station sites

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 14** to **Table 16**. Noise contours have also been predicted for the three scenarios, and are presented in **Appendix F**. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 14 White Bay Predicted Noise Levels - Spoil Removal - Daytime

Receiver Location	Receiver Area	NML (dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level (dBA)	NML Exceedance (dBA)
Batty Street	A - Dwellings N	61	46	-
Hornsey Street	B - Dwellings W	76	60	-
Glebe Point	C - Dwellings SE	64	53	-
	D - Commercial N	70	65	-
	E - Commercial E	70	60	

Table 15 White Bay Predicted Noise Levels - TBM Assembly - Night-time

Receiver Location	Receiver Area	NML (dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level (dBA)	NML Exceedance (dBA)
Batty Street	A - Dwellings N	49	33	-
Hornsey Street	B - Dwellings W	57	50	-
Glebe Point	C - Dwellings SE	51	42	-
	D - Commercial N	n/a	n/a	n/a
	E - Commercial E	n/a	n/a	n/a

Table 16 White Bay Predicted Noise Levels - Spoil Removal - Night-time

Receiver Location	Receiver Area	NML (dBA)	Predicted $L_{Aeq(15minute)}$ Noise Level (dBA)	NML Exceedance (dBA)
Batty Street	A - Dwellings N	49	38	-
Hornsey Street	B - Dwellings W	57	48	-
Glebe Point	C - Dwellings SE	51	45	-
	D - Commercial N	n/a	n/a	n/a
	E - Commercial N	n/a	n/a	n/a

Discussion

The predicted noise levels are presented in **Table 14** to **Table 16**, and the noise contours in **Appendix F**, show that compliance with the daytime and night-time NMLs is expected. It is noted the site is well placed for construction works, with sensitive receivers distant and in many instances shielded by topography and commercial/industrial buildings.

9.3 Rozelle Stabling Yard and Maintenance Depot Site - Noise Assessment

The nearest noise and vibration sensitive receivers to the Rozelle stabling and maintenance depot site are identified in **Table 17** with the receiver areas illustrated in **Figure 9**.

Figure 9 Rozelle Construction Site and Receiver Areas

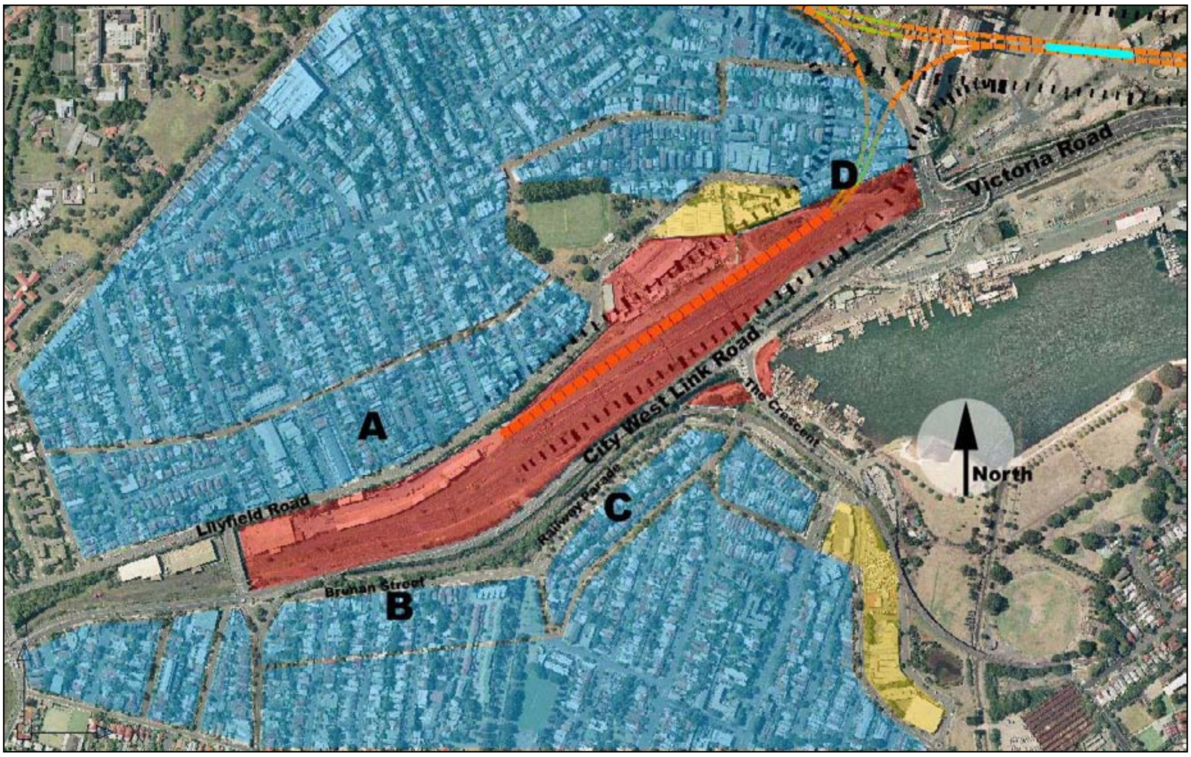


Table 17 Nearest Noise Sensitive Receivers - Rozelle

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Earthworks	A - Western Lilyfield Road	40
Building Construction	B - Brenan Street C - Railway Parade	60 80
Portal and dive structure construction and excavation	D - Eastern Lilyfield Road	70

9.3.1 Site Specific Construction Noise Goals

With reference the project NMLs and the ambient noise survey results summarised in **Table 2**. The site specific construction NMLs are presented in **Table 18**.

Table 18 Rozelle Construction Noise Management Levels

Receiver Location	LAeq(15minute) Construction NMLs (dBA)		
	Daytime	Evening	Night-time
A - Western Lilyfield Road	66	60	52
B - Brenan Street	59	54	47
C - Railway Parade	63	56	49
D - Eastern Lilyfield Road	66	62	54

9.3.2 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the proposed daytime and night-time operations, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- General earthworks
- Construction of buildings and facilities
- Portal and dive structure construction and excavation

The typical LAeq(15minute) noise levels with and without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 19** to **Table 21**. Noise contours have also been predicted for the three scenarios, and are presented in **Appendix G**.

Table 19 Rozelle Stabling and Maintenance Depot Predicted Noise Levels - Daytime

Construction Activity	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
General Earthworks	A - Western Lilyfield Road	66	60-70	4	4	-	n/a
Construction of Building Facilities	B - Brenan Street	59	56-59	-	-	-	n/a
	C - Railway Parade	63	59-62	-	-	-	n/a
Portal and dive structure	D - Eastern Lilyfield Road	66	67-77	11	11	6	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 20 Rozelle Stabling and Maintenance Depot Predicted Noise Levels - Evening

Construction Activity	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
General Earthworks	A - Western Lilyfield Road	62	60-70	8	8	1	n/a
Construction of Building Facilities	B - Brenan Street	54	56-59	5	5	5	n/a
	C - Railway Parade	56	59-62	6	6	6	n/a
Portal and dive structure	D - Eastern Lilyfield Road	60	67-77	17	17	12	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 21 Rozelle Stabling and Maintenance Depot Predicted Noise Levels - Night-time

Construction Activity	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
General Earthworks	A - Western Lilyfield Road	54	60-70	16	16	9	n/a
Construction of Building Facilities	B - Brenan Street	47	56-59	12	12	12	n/a
	C - Railway Parade	49	59-62	13	13	13	n/a
Portal and dive structure	D - Eastern Lilyfield Road	52	67-77	25	25	20	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- For daytime construction works, the predicted levels indicate a minor exceedance of 4 dBA at the nearest receivers for general earthworks, and compliance for construction of the building facilities. During portal and dive structure construction and excavation a significant exceedance of up to 11 dBA occurs primarily as a result of the high noise levels from the rockbreaking equipment, and the relative close proximity of Lilyfield receivers. Due to the location of construction equipment, and overlooking of the site, noise barriers are effective only for general earthworks and the portal and dive structure, and are required to be at least 6 m in height to mitigation noise . Furthermore the use of an enclosure in not feasible during earthworks and the construction of building facilities.
- For the evening period there are minor exceedances for construction of the building facilities, moderate exceedances for general earthworks, and significant exceedances for portal and dive structure construction and excavation.
- For the night-time period there are significant exceedances for all activities as a direct result of the more stringent NMLs.

The Sydney Metro "*Construction Noise and Vibration Strategy*" would be implemented to manage the potential noise impacts.

9.4 Station Sites - Airborne Noise Assessment

Assessment of the station sites is contained in this section.

9.4.1 Central Station Site

Central Station is located west of the existing CityRail Central Station, south of Eddy Avenue and east of Pitt Street. The station would be constructed via vertical excavation construction sites with the main underground station "cavern" connected between the sites. The main construction sites would be located north of Eddy Avenue and east of the George and Pitt Street intersection.

The nearest noise sensitive receivers to the Central Station sites are identified in **Table 22** with the receiver areas illustrated in **Figure 10**.

Figure 10 Central Station Construction Sites and Receiver Areas

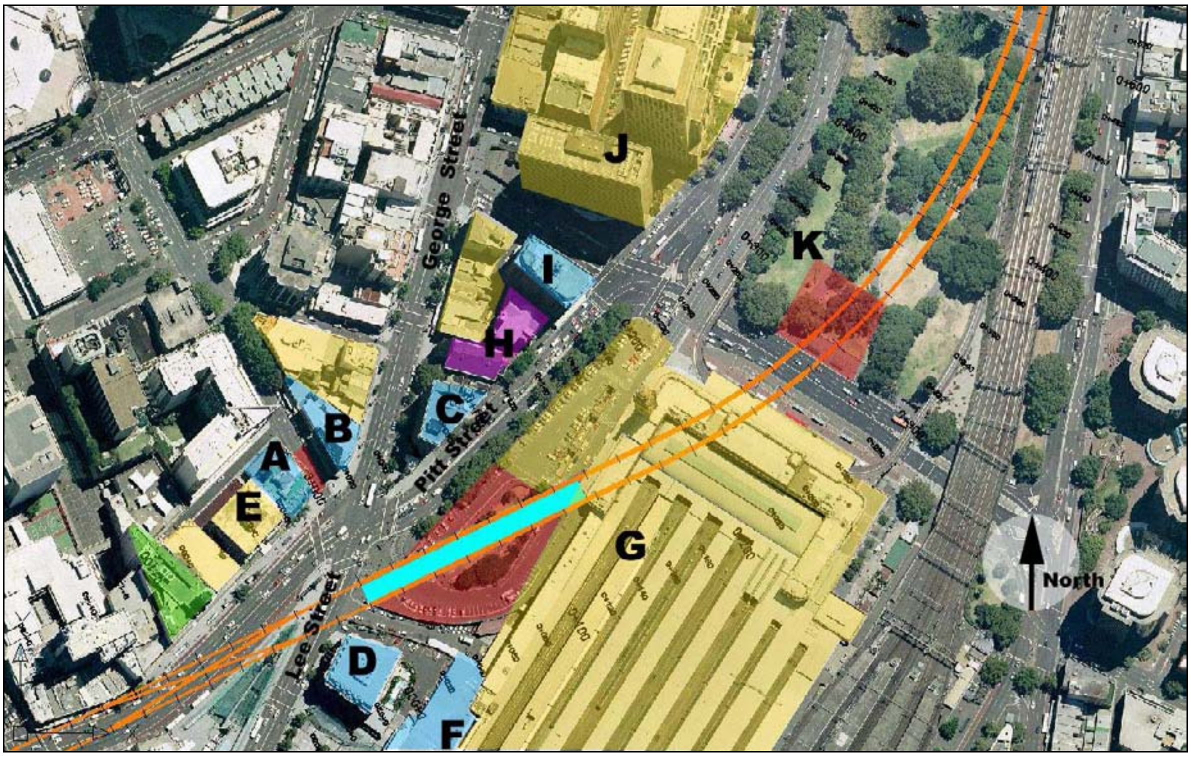


Table 22 Nearest Noise Sensitive Receivers - Central Station

Station Site/Excavation	Receiver Area	Location Relative to Works (m)
Central (West, Quay St)	A - Hotel B - Hotel C - Hostel D - Hotel E - Commercial	2 10 56 76 19
Central (Southern end of Car park)	F - Hostel/Commercial D - Hotel G - Commercial C - Hostel H - Church	18 20 35 85 120
Central (North, Belmore Park)	J - Commercial G - Commercial I - Hostel K - Belmore Park	80 60 90 3
Station Cavern	C - Hostel G - Central Station Commercial	55 11

9.4.2 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 23**.

Table 23 Central Station Construction NMLs

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
812 George Street	68	59	52

9.4.3 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 24** to **Table 29** together with the level of exceedance with varying levels of potential noise mitigation. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 24 Central Station Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted L_{Aeq} Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)	A - Hotel	68	90-106	38	28	23	13
	B - Hotel	68	88-92	24	14	9	-
	C - Hostel	68	75-77	9	-	-	-
	D - Hotel	68	71-74	6	-	-	-
	E - Commercial	70	84-86	16	6	1	-
Central (Southern end of Car park)	F - Hostel	68	77-87	19	9	4	-
	D - Hotel	68	78-86	18	8	3	-
	G - Commercial	70	75-81	11	1	-	-
	C - Hostel	68	72-73	5	-	-	-
	H - Church	50	69-70	20	10	5	-
Central (North, Belmore Park)	J - Commercial	70	70-74	4	-	-	-
	G - Commercial	70	73-76	6	-	-	-
	I - Hostel	68	68-73	5	-	-	-
	K - Belmore Park	60	66-102	42	32	27	17

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 25 Central Station Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted L_{Aeq} Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)	A - Hotel	59	90-106	47	37	32	22
	B - Hotel	59	88-92	33	23	18	8
	C - Hostel	59	75-77	18	8	3	-
	D - Hotel	59	71-74	15	5	0	-
	E - Commercial	70	84-86	16	6	1	-
Central (Southern end of Car park)	F - Hotel	59	77-87	28	18	13	3
	D - Hotel	59	78-86	27	17	12	2
	G - Commercial	70	75-81	22	12	7	-
	C - Hostel	59	72-73	14	4	-	-
	H - Church	50	69-70	20	10	5	-

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (North Belmore Park)	J - Commercial	70	70-74	4	-	-	-
	G - Commercial	70	73-76	6	-	-	-
	I - Hostel	59	68-73	14	4	-	-
	K - Belmore Park	60	66-102	42	32	27	17

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 26 Central Station Predicted Noise Levels - Excavation - Night-time

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)[2]	A - Hotel	52	90-106	54	44	39	29
	B - Hotel		88-92	40	30	25	15
	C - Hostel		75-77	25	15	10	0
	D - Hotel		71-74	22	12	7	-
	E - Commercial		84-86	n/a	n/a	n/a	n/a
Central (Southern end of Car park)	F - Hostel	52	77-87	35	25	20	10
	D - Hotel		78-86	34	24	19	9
	G - Commercial		75-81	n/a	n/a	n/a	n/a
	C - Hostel		72-73	21	11	6	-
	H - Church		69-70	n/a	n/a	n/a	n/a
Central (North, Belmore Park)	J - Commercial		70-74	n/a	n/a	n/a	n/a
	G - Commercial		73-76	n/a	n/a	n/a	n/a
	I – Hostel	52	68-73	21	11	6	-
	K – Belmore Park	60	66-102	42	32	27	17

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Night-time excavation activities are not anticipated at the Quay Street site

Table 27 Central Station Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)	A - Hotel	68	80-96	28	18	13	3
	B - Hotel	68	78-82	14	4	-	-
	C - Hostel	68	65-67	-	-	-	-
	D - Hotel	68	61-64	-	-	-	-
	E - Commercial	70	74-76	6	-	-	-
Central (Southern end of Car park)	F - Hostel	68	67-77	9	-	-	-
	D - Hotel	68	68-76	8	-	-	-
	G - Commercial	70	65-71	1	-	-	-
	C - Hostel	68	62-63	-	-	-	-
	H - Church	50	59-60	10	-	-	
Central (North, Belmore Park)	J - Commercial	70	60-64	-	-	-	-
	G - Commercial	70	63-66	-	-	-	-
	I - Hostel	68	58-63	-	-	-	-
	K - Belmore Park	60	56-92	32	22	17	7

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 28 Central Station Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)	A - Hotel	59	80-96	37	27	22	12
	B - Hotel	59	78-82	23	13	8	-
	C - Hostel	59	65-67	8	-	-	-
	D - Hotel	59	61-64	5	-	-	-0
	E - Commercial	70	74-76	6	-	-	-
Central (Southern end of Car park)	F - Hostel	59	67-77	18	8	3	-
	D - Hotel	59	68-76	17	7	2	-
	G - Commercial	70	65-71	1	-	-	-
	C - Hostel	59	62-63	4	-	-	-
	H - Church	50	59-60	10	-	-	-
Central (North, Belmore Park)	J - Commercial	70	60-64	-	-	-	-
	G - Commercial	70	63-66	-	-	-	-
	I - Hostel	59	58-63	4	-	-	-
	K - Belmore Park	60	56-92	32	22	17	7

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 29 Central Station Predicted Noise Levels - Construction - Night-time

Station	Receiver Area	NML	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Central (West, Quay Street)[2]	A - Hotel	52	80-96	44	36	29	19
	B - Hotel		78-82	30	20	15	5
	C - Hostel		65-67	15	5	0	-
	D - Hotel		61-64	12	2	-	-
	E - Commercial		74-76	n/a	n/a	n/a	n/a
Central (Southern end of Car park)	F - Hostel	52	67-77	25	15	10	0
	D - Hotel		68-76	24	14	9	-
	G - Commercial		65-71	19	n/a	n/a	n/a
	C - Hostel		62-63	11	1	-	-
	H - Church		59-60	n/a	n/a	n/a	n/a
Central (North, Belmore Park)	J - Commercial		60-64	n/a	n/a	n/a	n/a
	G - Commercial		63-66	n/a	n/a	n/a	n/a
	I - Hostel	52	58-63	11	1	-	-
	K - Belmore Park	60	56-92	32	22	17	7

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Night-time construction activities are not anticipated at the Quay Street site.

Discussion

- The predicted noise levels for demolition and excavation at the Central Station sites indicate significant exceedances of the NMLs for daytime operations at most sites. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. In particular there are adjacent receivers to the Quay St (Hotel), and Central (Railway Station and operating commercial premises in the Western Forecourt) that will require careful management. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting noise walls are effective for receivers at or near ground level (eg outdoor eating areas) and not effective for receivers overlooking the sites. The use of noise walls may also not be feasible during demolition. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project. In particular there are adjacent receivers to the Quay St (Hotel) and Central (Railway Station and operating commercial premises in the Western Forecourt) that will require careful management. Church exceedances assume open windows, and further investigation on the noise reduction from outside to inside is required during the construction planning and site establishment phases of the project, together with liaison with Church services.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites without significant noise mitigation and careful management of all noise-producing equipment and activities.
- Having considered all reasonable and feasible noise mitigation, the Sydney Metro *"Construction Noise and Vibration Strategy"* would be implemented to manage the potential noise impacts.

9.4.4 Town Hall Station Site

The nearest noise sensitive receivers to the Town Hall Station sites are identified in **Table 30** with the receiver areas illustrated in **Figure 11**.

Figure 11 Town Hall Construction Sites and Receiver Areas

Table 30 Nearest Noise Sensitive Receivers - Town Hall Station

Station Site/Excavation	Receiver Area	Location Relative to Works (m)
Town Hall (Pitt/Park/George)	A - Criterion Hotel -E B - Dwellings - E C - Church - E D - Commercial - S E - Commercial - W F - Commercial - N N - Dwellings - E	12 45 17 3 75 20 52
Town Hall (South of Bathurst Street)	G - Meriton Apartments H - Hotel - S I - Commercial W J - Commercial E K - Commercial - N	42 3 3 15 15
Town Hall (North, Pitt Street)	F - Commercial W L - Commercial - E A - Hotel - SE M - Hotel - N	3 10 30 55
Station Cavern	A - Hotel C - Church or Place of Worship D - Commercial G - Residential/Commercial K - Commercial	24 24 28 28 24

9.4.5 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 31**.

Table 31 Town Hall Station Construction NMLs.

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
260 Pitt Street	70	67	61

9.4.6 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 32** to **Table 37**, together with the level of exceedance with varying levels of potential noise mitigation. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 32 Town Hall Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	70	78-90	20	10	5	-
	B - Dwellings - E	70	73-79	9	-	-	-
	C - Church - E	50	76-87	37	27	22	12
	D - Commercial - S	70	71-102	32	22	17	7
	E - Commercial - W	70	70-75	5	-	-	-
	F - Commercial - N	70	76-86	16	6	1	-
	N - Dwellings - E	70	72-78	8	-	-	-
Town Hall (South of Bathurst Street)	G - Meriton Apartments	70	76-80	10	-	-	-
	H - Hotel - S		102-102	32	22	17	7
	I - Commercial - W		102-102	32	22	17	7
	J - Commercial - E		82-88	18	8	3	-
	K - Commercial - N		80-88	18	8	3	-
Town Hall (North, Pitt Street)	F - Commercial - W	70	90-102	32	22	17	7
	L - Commercial - E		86-92	22	12	7	-
	A - Hotel - SE		76-82	12	2	-	-
	M - Hotel - N		72-77	7	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 33 Town Hall Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	67	78-90	23	13	8	-
	B - Dwellings - E	67	73-79	12	2	-	-
	C - Church - E	50	76-87	37	27	22	12
	D - Commercial - S	70	71-102	32	22	17	7
	E - Commercial - W	70	70-75	5	-	-	-
	F - Commercial - N	70	76-86	16	6	1	-
	N - Dwellings - E	67	72-78	11	1	-	-
Town Hall (South of Bathurst Street)	G - Meriton Apartments	67	76-80	13	3	-	-
	H - Hotel - S	67	102-102	35	25	20	10
	I - Commercial - W	70	102-102	32	22	17	7
	J - Commercial - E	70	82-88	18	8	3	-
	K - Commercial - N	70	80-88	18	8	3	-
Town Hall (North, Pitt Street)	F - Commercial - W	70	90-102	32	22	17	7
	L - Commercial - E	70	86-92	22	12	7	0
	A - Hotel - SE	67	76-82	15	5	0	-
	M - Hotel - N	67	72-77	10	0	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 34 Town Hall Predicted Noise Levels - Excavation - Night-time

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	61	78-90	29	19	14	4
	B - Dwellings - E		73-79	18	8	3	-
	C - Church - E		76-87	n/a	n/a	n/a	n/a
	D - Commercial - S		71-102	n/a	n/a	n/a	n/a
	E - Commercial - W		70-75	n/a	n/a	n/a	n/a
	F - Commercial - N		76-86	n/a	n/a	n/a	n/a
	N - Dwellings -E		72-78	17	7	2	-
Town Hall (South of Bathurst St)	G - Meriton Apartments	61	76-80	19	9	4	-
	H - Hotel - S		102-102	41	31	26	16
	I - Commercial - W		102-102	n/a	n/a	n/a	n/a
	J - Commercial - E		82-88	n/a	n/a	n/a	n/a
	K - Commercial - N		80-88	n/a	n/a	n/a	n/a
Town Hall (North, Pitt Street)	F - Commercial - W	61	90-102	n/a	n/a	n/a	n/a
	L - Commercial - E		86-92	n/a	n/a	n/a	n/a
	A - Hotel - SE		76-82	21	11	6	-
	M - Hotel - N		72-77	16	6	1	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 35 Town Hall Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	70	68-80	10	-	-	-
	B - Dwellings - E	70	63-69	-	-	-	-
	C - Church - E	50	66-77	27	17	12	2
	D - Commercial - S	70	61-92	22	12	7	-
	E - Commercial - W	70	60-65	-	-	-	-
	F - Commercial - N	70	66-76	6	-	-	-
	N - Dwellings - E	70	62-68	-	-	-	-
Town Hall (South of Bathurst Street)	G - Meriton Apartments	70	66-70	-	-	-	-
	H - Hotel - S		92	22	12	7	-
	I - Commercial - W		92	22	12	7	-
	J - Commercial - E		72-78	8	-	-	-
	K - Commercial - N		70-78	8	-	-	-
Town Hall (North, Pitt Street)	F - Commercial - W	70	80-92	22	12	7	-
	L - Commercial - E		76-82	12	2	-	-
	A - Hotel - SE		66-72	2	-	-	-
	M - Hotel - N		62-67	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 36 Town Hall Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	67	68-80	13	3	-	-
	B - Dwellings - E	67	63-69	2	-	-	-
	C - Church - E	50	66-77	27	17	12	2
	D - Commercial - S	70	61-92	n/a	n/a	n/a	n/a
	E - Commercial - W	70	60-65	n/a	n/a	n/a	n/a
	F - Commercial - N	70	66-76	n/a	n/a	n/a	n/a
	N - Dwellings - E	67	62-68	1	-	-	-
Town Hall (South of Bathurst Street)	G - Meriton Apartments	67	66-70	3	-	-	-
	H - Hotel - S	67	92	25	15	10	-
	I - Commercial - W	70	92	n/a	n/a	n/a	n/a
	J - Commercial - E	70	72-78	n/a	n/a	n/a	n/a
	K - Commercial - N	70	70-78	n/a	n/a	n/a	n/a
Town Hall (North, Pitt Street)	F - Commercial - W	70	80-92	n/a	n/a	n/a	n/a
	L - Commercial - E	70	76-82	n/a	n/a	n/a	n/a
	A - Hotel - SE	67	66-72	5	-	-	-
	M - Hotel - N	67	62-67	0	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 37 Town Hall Predicted Noise Levels - Construction - Night-time

Station	Receiver Area	NML	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Town Hall (Pitt/Park/ George)	A - Criterion Hotel - E	61	68-80	19	9	4	-
	B - Dwellings - E		63-69	8	-	-	-
	C - Church - E		66-77	n/a	n/a	n/a	n/a
	D - Commercial - S		61-92	n/a	n/a	n/a	n/a
	E - Commercial - W		60-65	n/a	n/a	n/a	n/a
	F - Commercial - N		66-76	n/a	n/a	n/a	n/a
	N - Dwellings - E		62-68	7	-	-	-
Town Hall (South of Bathurst Street)	G - Meriton Apartments	61	66-70	9	-	-	-
	H - Hotel - S		92	31	21	16	6
	I - Commercial - W		92	n/a	n/a	n/a	n/a
	J - Commercial - E		72-78	n/a	n/a	n/a	n/a
	K - Commercial - N		70-78	n/a	n/a	n/a	n/a
Town Hall (North, Pitt Street)	F - Commercial - W	61	80-92	n/a	n/a	n/a	n/a
	L - Commercial - E		76-82	n/a	n/a	n/a	n/a
	A - Hotel - SE		66-72	11	1	-	-
	M - Hotel - N		62-67	6	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- The predicted noise levels for demolition and excavation at the Town Hall Station sites indicate significant exceedances of the NMLs for daytime operations at most sites. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. In particular there are adjacent receivers to all the sites (both commercial and residential hotels) that will require careful management. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting noise walls are effective for receivers at or near ground level (eg outdoor eating areas). The use of noise walls may also not be feasible during demolition activities, and will not offer benefit during demolition of the upper levels of the multistorey buildings. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where exceedances for construction activities are predicted using enclosures (eg the Hotel to the south of the Bathurst Street site), the noise insulation of the enclosure element(s) facing the receiver may need to be upgraded using, for example, a double skin or masonry construction. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project. Church exceedances assume open windows, and further investigation on the noise reduction from outside to inside is required during the construction planning and site establishment phases of the project, together with liaison with Church services.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities.

Having considered all reasonable and feasible noise mitigation, the CBD Metro *"Construction Noise and Vibration Strategy"* would be implemented to manage the potential noise impacts.

9.4.7 Martin Place Station Site

The nearest noise sensitive receivers to the Martin Place Station sites are identified in **Table 38** with the receiver areas illustrated in **Figure 12**.

Figure 12 Martin Place Construction Sites and Receiver Areas

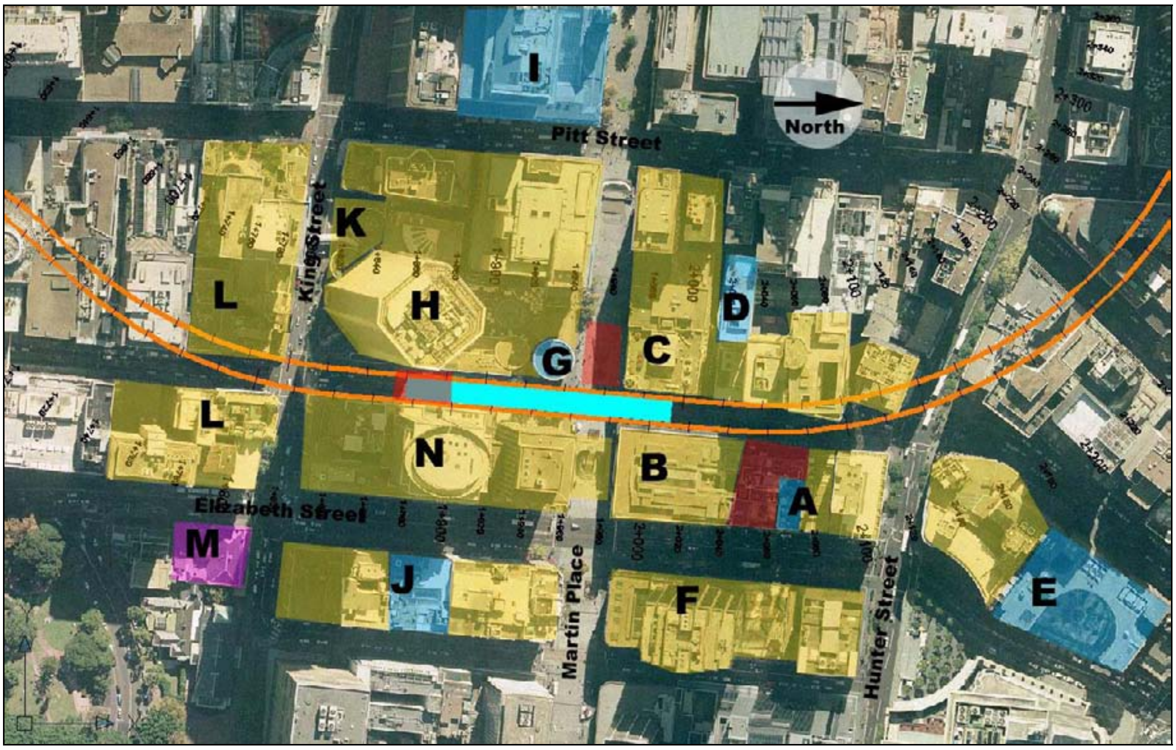


Table 38 Nearest Noise Sensitive Receivers - Martin Place Station

Station Site/Excavation	Receiver	Location Relative to Works (m)
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential/Commercial - N B - Commercial - adjoining - S C - Commercial - W D - Residential - W E - Hotel - NW F - Commercial - E G - Hotel - SW	3 3 18 50 95 25 95
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW C - Commercial - N H - Commercial - SW I - Hotel - W B - Commercial - NE N - Commercial - SE	9 10 13 97 25 30
Martin Place (South, Castlereagh Street)	G - Hotel - NW H - Commercial - W L - Commercial - S N - Commercial - E	45 3 65 3
Station Cavern	G - CTA - residence H - Commercial N - Commercial	26 26 26

9.4.8 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 39**.

Table 39 Martin Place Station Construction NMLs.

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
60 Castlereagh Street	70	65	56

9.4.9 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 40** to **Table 45**, together with the level of exceedance with varying levels of potential noise mitigation. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 40 Martin Place Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential - N	70	79-102	32	22	17	7
	B - Commercial - S		79-102	32	22	17	7
	C - Commercial - W		79-87	17	7	2	-
	D - Residential - W		74-78	8	-	-	-
	E - Hotel - NW		69-72	2	-	-	-
	F - Commercial - E		76-84	14	4	-	-
	G - Hotel - SW		70-72	-	-	-	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	70	84-93	23	13	8	-
	C - Commercial - N		87-92	22	12	7	-
	H - Commercial - SW		79-90	20	10	5	-
	I - Hotel - W		70-72	2	-	-	-
	B - Commercial - NE		76-84	14	4	-	-
	N - Commercial - SE		76-84	14	4	-	-
Martin Place (South, Castlereagh Street)	G - Hotel - NW	70	76-79	9	-	-	-
	H - Commercial - W		86-102	32	23	18	8
	L - Commercial - S		73-76	6	-	-	-
	N - Commercial - E		86-102	32	23	18	8

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 41 Martin Place Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential - N	65	79-102	37	27	22	12
	B - Commercial - S	70	79-102	32	22	17	7
	C - Commercial - W	70	79-87	17	7	2	-
	D - Residential - W	65	74-78	13	3	-	-
	E - Hotel - NW	65	69-72	7	-	-	-
	F - Commercial - E	70	76-84	14	4	-	-
	G - Hotel - SW	65	70-72	7	-	-	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	65	84-93	28	18	13	3
	C - Commercial - N	70	87-92	27	17	12	2
	H - Commercial - SW	70	79-90	25	15	10	0
	I - Hotel - W	65	70-72	7	-	-	-
	B - Commercial - NE	70	76-84	14	4	-	-
	N - Commercial - SE	70	76-84	14	4	-	-
Martin Place (South, Castlereagh Street)	G - Hotel - NW	65	76-79	14	4	-	-
	H - Commercial - W	70	86-102	32	23	18	8
	L - Commercial - S	70	73-76	6	-	-	-
	N - Commercial - E	70	86-102	32	23	18	8

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 42 Martin Place Predicted Noise Levels - Excavation - Night-time

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth St and Castlereagh St)	A - Residential - N	56	79-102	46	36	31	21
	B - Commercial - S		79-102	n/a	n/a	n/a	n/a
	C - Commercial - W		79-87	n/a	n/a	n/a	n/a
	D - Residential - W		74-78	22	12	7	-
	E - Hotel - NW		69-72	16	6	1	-
	F - Commercial - E		76-84	n/a	n/a	n/a	n/a
	G - Hotel - SW		70-72	16	6	1	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	56	84-93	37	27	22	12
	C - Commercial - N		87-92	n/a	n/a	n/a	n/a
	H - Commercial - SW		79-90	n/a	n/a	n/a	n/a
	I - Hotel - W		70-72	16	6	1	-
	B - Commercial - NE		76-84	n/a	n/a	n/a	n/a
	N - Commercial - SE		76-84	n/a	n/a	n/a	n/a
Martin Place (South, Castlereagh Street)	G - Hotel - NW	56	76-79	24	14	9	-
	H - Commercial - W		86-102	n/a	n/a	n/a	n/a
	L - Commercial - S		73-76	n/a	n/a	n/a	n/a
	N - Commercial - E		86-102	n/a	n/a	n/a	n/a

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 43 Martin Place Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential - N	70	69-92	22	17	12	2
	B - Commercial - S		69-92	22	12	7	-
	C - Commercial - W		69-77	7	-	-	-
	D - Residential - W		64-68	-	-	-	-
	E - Hotel - NW		59-62	-	-	-	-
	F - Commercial - E		66-74	4	-	-	-
	G - Hotel - SW		60-62	-	-	-	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	70	74-83	13	3	-	-
	C - Commercial - N		77-82	12	2	-	-
	H - Commercial - SW		69-80	10	-	-	-
	I - Hotel - W		60-62	-	-	-	-
	B - Commercial - NE		66-74	4	-	-	-
	N - Commercial - SE		66-74	4	-	-	-
Martin Place (South, Castlereagh Street)	G - Hotel - NW	70	66-69	-	-	-	-
	H - Commercial - W		76-92	22	12	7	-
	L - Commercial - S		63-66	-	-	-	-
	N - Commercial - E		76-92	22	12	7	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 44 Martin Place Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential - N	65	69-92	27	17	12	2
	B - Commercial - S	70	69-92	22	12	7	-
	C - Commercial - W	70	69-77	17	7	2	-
	D - Residential - W	65	64-68	3	-	-	-
	E - Hotel - NW	65	59-62	-	-	-	-
	F - Commercial - E	70	66-74	9	-	-	-
	G - Hotel - SW	65	60-62	-	-	-	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	65	74-83	18	8	3	-
	C - Commercial - N	70	77-82	12	5	-	-
	H - Commercial - SW	70	69-80	10	-	-	-
	I - Hotel - W	65	60-62	-	-	-	-
	B - Commercial - NE	70	66-74	4	-	-	-
	N - Commercial - SE	70	66-74	4	-	-	-
Martin Place (South, Castlereagh Street)	G – Hotel - NW	65	66-69	4	-	-	-
	H - Commercial - W	70	76-92	22	12	7	-
	L - Commercial - S	70	63-66	-	-	-	-
	N - Commercial - E	70	76-92	22	12	7	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 45 Martin Place Predicted Noise Levels - Construction - Night-time

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Martin Place (North, between Elizabeth Street and Castlereagh Street)	A - Residential - N	56	69-92	36	26	21	11
	B - Commercial - S		69-92	n/a	n/a	n/a	n/a
	C - Commercial - W		69-77	n/a	n/a	n/a	n/a
	D - Residential - W		64-68	12	2	-	-
	E - Hotel - NW		59-62	6	-	-	-
	F - Commercial - E		66-74	n/a	n/a	n/a	n/a
	G - Hotel - SW		60-62	6	-	-	-
Martin Place (In MP West of Castlereagh Street)	G - Hotel - SW	56	74-83	27	17	12	2
	C - Commercial - N		77-82	n/a	n/a	n/a	n/a
	H - Commercial - SW		69-80	n/a	n/a	n/a	n/a
	I - Hotel - W		60-62	6	-	-	-
	B - Commercial - NE		66-74	n/a	n/a	n/a	n/a
	N - Commercial - SE		66-74	n/a	n/a	n/a	n/a
Martin Place (South, Castlereagh Street)	G - Hotel - NW	56	66-69	13	3	-	-
	H - Commercial - W		76-92	n/a	n/a	n/a	n/a
	L - Commercial - S		63-66	n/a	n/a	n/a	n/a
	N - Commercial - E		76-92	n/a	n/a	n/a	n/a

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- The predicted noise levels for excavation at the Martin Place Station sites indicate significant exceedances of the NMLs for daytime operations at most sites. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. In particular there are adjacent receivers to all the sites (both commercial and residential buildings) that will require careful management. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting noise walls are effective for receivers at or near ground level (eg outdoor eating areas). The use of noise walls may also not be feasible during demolition activities, and will not offer benefit during demolition of the upper levels of the multistorey buildings. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where exceedances for construction activities are predicted using enclosures (eg residences to the north of the Elizabeth/Castlereagh Street site), the noise insulation of the enclosure element(s) facing the receiver may need to be upgraded using, for example, a double skin or masonry construction.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities.

Having considered all reasonable and feasible noise mitigation, the CBD Metro "*Construction Noise and Vibration Strategy*" would be implemented to manage the potential noise impacts.

9.4.10 Barangaroo-Wynyard Station Site

The nearest noise sensitive receivers to the Barangaroo-Wynyard Station sites are identified in **Table 46** with the receiver areas illustrated in **Figure 13**.

Figure 13 Barangaroo-Wynyard Construction Sites and Receiver Areas

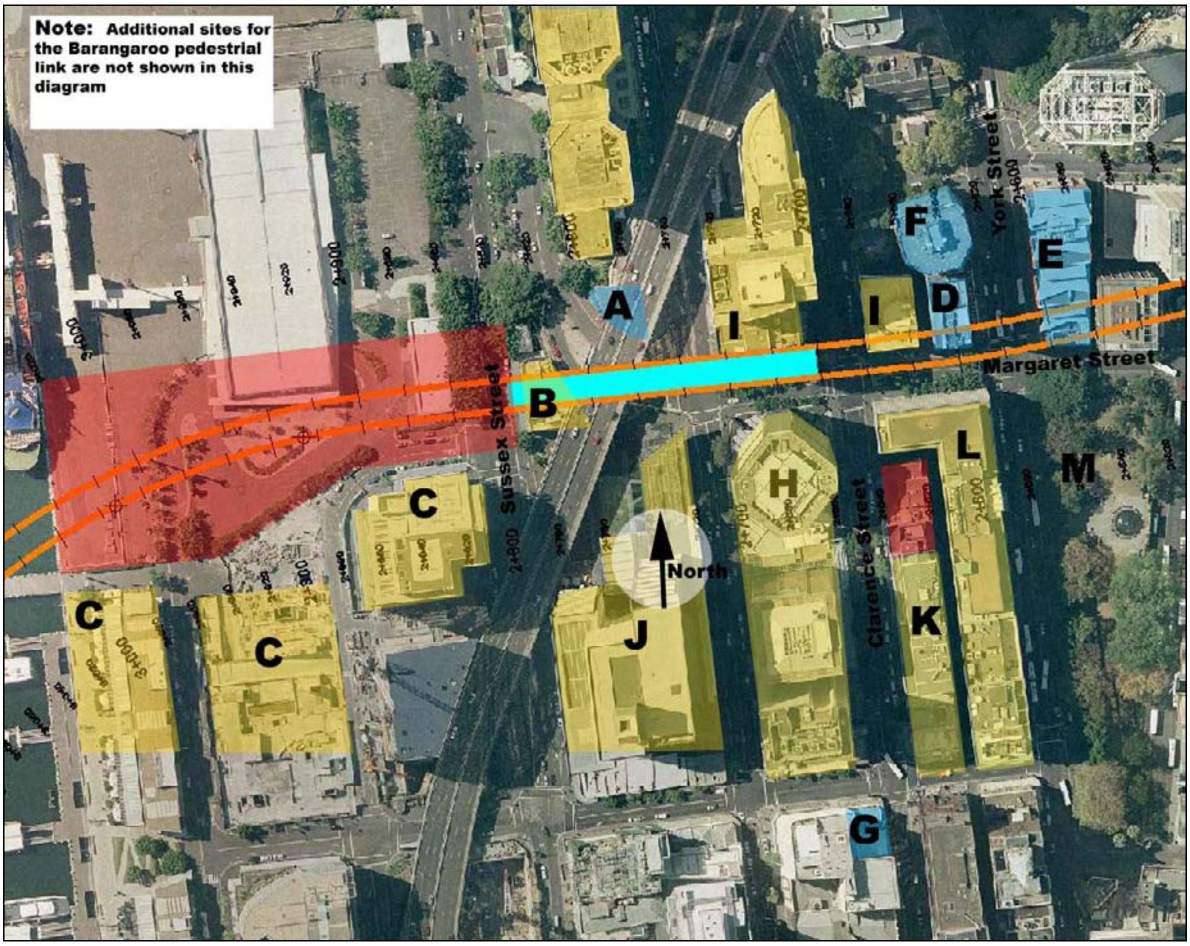


Table 46 Nearest Noise Sensitive Receivers - Barangaroo-Wynyard Station

Station Site/Excavation	Receiver	Location Relative to Works (m)
Wynyard West	A - Napoleon Apartments B - Morton Hotel C - Commercial	20 33 53
Wynyard East	D - Travelodge E - Apartments F - York Apartments G - Wynyard Hotel E - Church (Below apartments) H - Commercial W I - Commercial N L - Commercial N/E K - Commercial S M - Wynyard Park	50 75 80 120 75 20 50 7 1 50
Station Cavern	B - Morton Hotel A - Residential D - Travelodge I - Commercial H - Commercial J - Commercial	9 29 22 15 34 34

Note 1: Receivers D, E, F and M are shielded from Wynyard East by Commercial Building L to the east of York Lane.

9.4.11 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 47**.

Table 47 Barangaroo-Wynyard Station Construction NMLs.

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
Sussex Street	70	63	49

9.4.12 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 48** to **Table 53**, together with the level of exceedance with varying levels of potential noise mitigation. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Table 48 Barangaroo-Wynyard Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon	70	70-75	5	-	-	-
	Apartments		78-82	12	2	-	-
	B - Morton Hotel		80-98	28	18	13	3
	C - Commercial						
Wynyard East	D - Travelodge	70	58-63	-	-	-	-
	E - Apartments	70	46-50	-	-	-	-
	F - York Apartments	70	45-49	-	-	-	-
	G - Wynyard Hotel	70	69-70	-	-	-	-
	E - Church	50	46-50	-	-	-	-
	H - Commercial	70	80-112	42	32	27	17
	I - Commercial	70	80-95	25	15	10	-
	L - Commercial	70	80-86	16	6	1	-
	K - Commercial	70	73-78	8	-	-	-
	M - Wynyard Park	60	50-53	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 49 Barangaroo-Wynyard Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon Apartments	63	70-75	12	2	-	-
	B - Morton Hotel	63	78-82	19	9	4	-
	C - Commercial	70	80-98	35	25	20	10
Wynyard East	D - Travelodge	63	58-63	-	-	-	-
	E - Apartments	63	46-50	-	-	-	-
	F - York Apartments	63	45-49	-	-	-	-
	G - Wynyard Hotel	63	69-70	7	-	-	-
	E - Church	50	46-50	-	-	-	-
	H - Commercial	70	80-112	42	32	27	17
	I - Commercial	70	80-95	25	15	10	-
	L - Commercial	70	80-86	16	6	1	-
	K - Commercial	70	73-78	8	-	-	-
	M - Wynyard Park	60	50-53	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 50 Barangaroo-Wynyard Predicted Noise Levels - Excavation - Night-time

Station	Receiver Area	NML (dBA)	Predicted L_{Aeq} Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon Apartments	49	70-75	26	16	11	1
	B - Morton Hotel		78-82	33	23	18	8
	C - Commercial		80-98	n/a	n/a	n/a	n/a
Wynyard East	D - Travelodge	49	58-63	14	14	14	-
	E - Apartments	49	46-50	1	1	1	-
	F - York Apartments	49	45-49	-	-	-	-
	G - Wynyard Hotel	49	69-70	21	11	6	-
	E - Church		46-50	n/a	n/a	n/a	n/a
	H - Commercial		80-112	n/a	n/a	n/a	n/a
	I - Commercial		80-95	n/a	n/a	n/a	n/a
	L - Commercial		80-86	n/a	n/a	n/a	n/a
	K - Commercial		73-78	n/a	n/a	n/a	n/a
	M - Wynyard Park	60	50-53	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 51 Barangaroo-Wynyard Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted L_{Aeq} Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon Apartments	70	60-65	-	-	-	-
	B - Morton Hotel		68-72	2	-	-	-
	C - Commercial		70-88	18	8	3	-
Wynyard East	D - Travelodge	70	48-53	-	-	-	-
	E - Apartments	70	36-40	-	-	-	-
	F - York Apartments	70	35-39	-	-	-	-
	G - Wynyard Hotel	70	59-60	-	-	-	-
	E - Church	50	36-40	-	-	-	-
	H - Commercial	70	70-102	32	22	17	7
	I - Commercial	70	70-85	15	5	-	-
	L - Commercial	70	70-76	6	-	-	-
	K - Commercial	70	63-68	-	-	-	-
	M - Wynyard Park	60	40-43	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 52 Barangaroo-Wynyard Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon Apartments	63	60-65	2	-	-	-
	B - Morton Hotel	63	68-72	9	-	-	-
	C - Commercial	70	70-88	18	8	3	-
Wynyard East	D - Travelodge	63	48-53	-	-	-	-
	E - Apartments	63	36-40	-	-	-	-
	F - York Apartments	63	35-39	-	-	-	-
	G - Wynyard Hotel	63	59-60	-	-	-	-
	E - Church	50	36-40	-	-	-	-
	H - Commercial	70	70-102	32	22	17	7
	I - Commercial	70	70-85	15	5	-	-
	L - Commercial	70	70-76	6	-	-	-
	K - Commercial	70	63-68	-	-	-	-
	M - Wynyard Park	60	40-43	-	-	-	-

Note: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 53 Barangaroo-Wynyard Predicted Noise Levels - Construction - Night-time

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Wynyard West	A - Napoleon Apartments	49	60-65	16	6	1	-
	B - Morton Hotel		68-72	23	13	8	-
	C - Commercial		70-88	n/a	n/a	n/a	n/a
Wynyard East	D - Travelodge	49	48-53	4	4	4	-
	E - Apartments	49	36-40	-	13	8	-
	F - York Apartments	49	35-39	-	9	4	-
	G - Wynyard Hotel	49	59-60	11	1	-	-
	E - Church		36-40	n/a	n/a	n/a	n/a
	H - Commercial		70-102	n/a	n/a	n/a	n/a
	I - Commercial		70-85	n/a	n/a	n/a	n/a
	L - Commercial		70-76	n/a	n/a	n/a	n/a
	K - Commercial		63-68	n/a	n/a	n/a	n/a
	M - Wynyard Park	60	40-43	-	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- The predicted noise levels for excavation at the Barangaroo-Wynyard Station sites indicate significant exceedances of the NMLs for daytime operations at most sites unshielded from the sites by other buildings. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs. In particular there are immediately adjacent commercial receivers to the eastern site that will require careful management.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting noise walls are effective for receivers at or near ground level (eg outdoor eating areas). The use of noise walls may also not be feasible during demolition activities, and will not offer benefit during demolition of the upper levels of the multistorey buildings. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities.

Having considered all reasonable and feasible noise mitigation, the CBD Metro "*Construction Noise and Vibration Strategy*" would be implemented to manage the potential noise impacts.

9.4.13 Pyrmont Station Site

The nearest noise sensitive receivers to the Pyrmont Station sites are identified in **Table 54** with the receiver areas illustrated in **Figure 14**.

Figure 14 Pyrmont Construction Sites and Receiver Areas

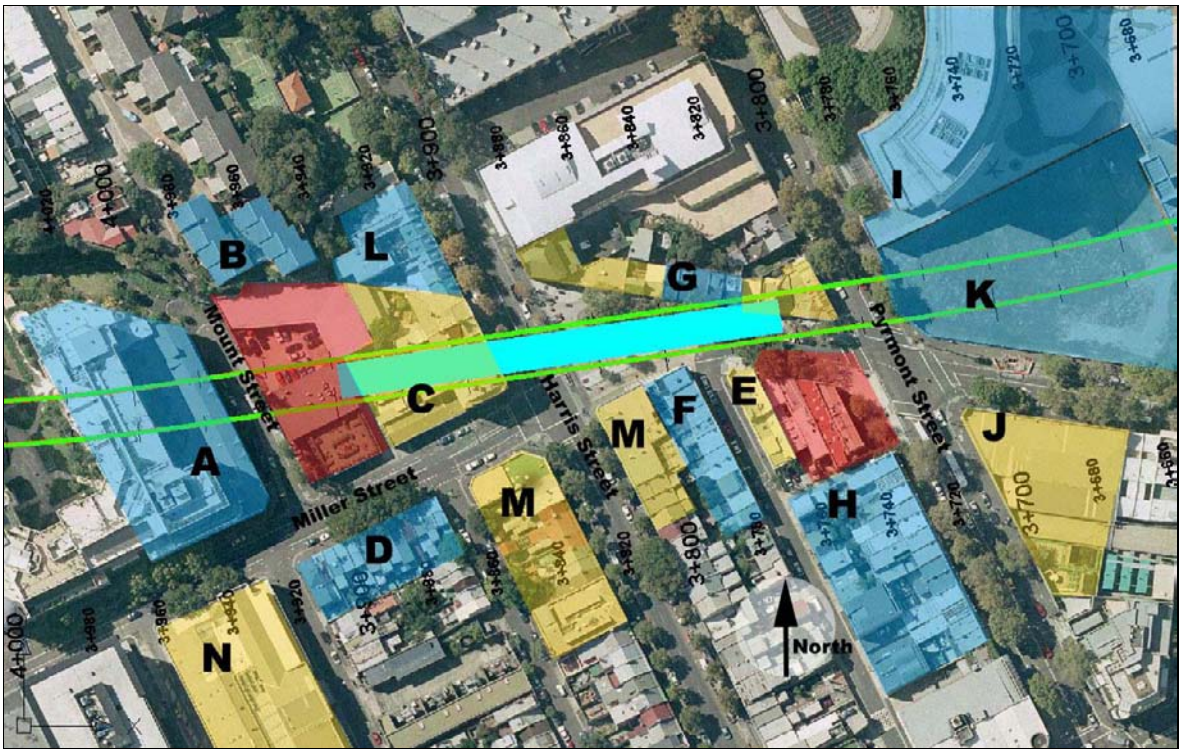


Table 54 Nearest Noise Sensitive Receivers - Pyrmont Station

Station Site/Excavation	Receiver	Location Relative to Works (m)
Miller Street/ Mount Street	A - Dwellings SW B - Dwellings N (up cliff) C - Commercial adjacent E L - Residential	10 2 0 3

Station Site/Excavation	Receiver	Location Relative to Works (m)
	D - Dwellings SE	19
Union Street/ Pyrmont Street	E - Commercial adjoining W F - Dwellings W G - Residential/Commercial N H - Dwellings adjoining E I - Casino NE J - Commercial E K - Proposed Residential	2 17 17 2 58 20 20
Station Cavern	F - Dwellings C - Commercial G - Residential E - Commercial	25 14 15 20

9.4.14 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 55**.

Table 55 Pyrmont Station Construction NMLs

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	Evening	Night-time
Near Miller Street and Mount Street	62	56	51
Near Union Street and Pyrmont Street	59	55	51

9.4.15 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 56** to **Table 61**, together with the level of exceedance with varying levels of potential noise mitigation. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 56 Pyrmont Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted L_{Aeq} Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Street/ Mount Street	Dwellings - SW	62	81-92	30	20	15	5
	B - Dwellings - N (up cliff)	62	76-90	28	18	13	3
	C - Commercial - E	70	84-88	26	16	11	1
	D - Dwellings - SE	62	75-86	24	14	9	-
	L - Residential	62	84-88	26	16	11	1
Union Street/ Pyrmont Street	E - Commercial - W	59	83-106	47	37	32	22
	F - Dwellings - W	59	79-87	28	18	13	3
	G - Residential - N	59	78-87	28	18	13	3
	H - Dwellings - E	59	82-106	47	37	32	22
	I - Casino - NE	70	75-77	17	7	2	-
	J - Commercial - E	70	76-86	16	6	-	-
	K - Proposed Residential	59	77-86	27	17	12	2

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 57 Pyrmont Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Street/ Mount Street	A - Dwellings - SW	56	81-92	36	26	21	11
	B - Dwellings - N (up cliff)	56	76-90	34	24	19	9
	C - Commercial - E	70	84-88	18	8	3	-
	D - Dwellings - SE	56	75-86	30	20	15	5
	L - Residential	56	84-88	32	22	17	7
Union Street/ Pyrmont Street	E - Commercial - W	70	83-106	36	26	21	11
	F - Dwellings - W	55	79-87	32	22	17	7
	G - Residential - N	55	78-87	32	22	17	7
	H - Dwellings - E	55	82-106	51	41	36	26
	I - Casino - NE	70	75-77	7	-	-	-
	J - Commercial - E	70	76-86	16	6	1	-
	K - Proposed Residential	55	77-86	31	21	16	6

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 58 Pyrmont Predicted Noise Levels - Excavation - Night

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Street/ Mount Street	A - Dwellings - SW	51	81-92	41	31	26	16
	B - Dwellings - N (up cliff)		76-90	39	29	24	14
	C - Commercial - E		84-88	n/a	n/a	n/a	n/a
	D - Dwellings - SE		75-86	35	25	20	10
	L - Residential		84-88	37	17	12	7
Union Street/ Pyrmont Street	E - Commercial - W	51	83-106	n/a	n/a	n/a	n/a
	F - Dwellings - W		79-87	36	26	21	11
	G - Residential - N		78-87	36	26	21	11
	H - Dwellings - E		82-106	55	45	40	30
	I - Casino - NE		75-77	n/a	n/a	n/a	n/a
	J - Commercial - E		76-86	n/a	n/a	n/a	n/a
	K - Proposed Residential		77-86	37	27	22	12

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 59 Pyrmont Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Steered/ Mount Street	A - Dwellings - SW	62	71-82	20	10	5	-
	B - Dwellings - N (up cliff)	62	66-80	18	8	3	-
	C - Commercial - E	70	74-78	8	3	-	-
	D - Dwellings - SE	62	65-76	14	4	-	-
	L - Residential	62	74-78	16	6	-	-
Union Street/ Pyrmont Street	E - Commercial - W	59	73-96	37	27	22	12
	F - Dwellings - W	59	69-77	18	8	3	-
	G - Residential - N	59	68-77	18	8	3	-
	H - Dwellings - E	59	72-96	37	27	22	12
	I - Casino - NE	70	65-67	7	-	-	-
	J - Commercial - E	70	66-76	16	6	1	-
	K - Proposed Residential	59	66-76	17	7	2	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 60 Pyrmont Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Street/ Mount Street	A - Dwellings - SW	56	71-82	26	16	11	1
	B - Dwellings - N (up cliff)	56	66-80	24	14	9	-
	C - Commercial - E	70	74-78	18	8	3	-
	D - Dwellings - SE	56	65-76	20	10	5	-
	L - Residential	56	74-78	22	12	7	-
Union Street/ Pyrmont Street	E - Commercial - W	70	73-96	41	31	26	16
	F - Dwellings - W	55	69-77	22	12	7	-
	G - Residential - N	55	68-77	22	12	7	-
	H - Dwellings - E	55	72-96	41	31	26	16
	I - Casino - NE	70	65-67	12	2	-	-
	J - Commercial - E	70	66-76	21	11	6	-
	K - Proposed Residential	55	66-76	21	11	6	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 61 Pyrmont Predicted Noise Levels - Construction - Night

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Miller Street/ Mount Street	A - Dwellings - SW	51	71-82	31	21	16	6
	B - Dwellings - N (up cliff)		66-80	29	19	14	4
	C - Commercial - E		74-78	n/a	n/a	n/a	n/a
	D - Dwellings - SE		65-76	25	15	10	0
	L - Residential		74-78	27	17	12	2
Union Street/ Pyrmont Street	E - Commercial - W	51	73-96	n/a	n/a	n/a	n/a
	F - Dwellings - W		69-77	26	16	11	1
	G - Residential - N		68-77	n/a	n/a	n/a	n/a
	H - Dwellings - E		72-96	45	35	30	20
	I - Casino - NE		65-67	n/a	n/a	n/a	n/a
	J - Commercial - E		66-76	n/a	n/a	n/a	n/a
	K - Proposed Residential		66-76	25	15	10	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- The predicted noise levels for excavation at the Pyrmont Station sites indicate significant exceedances of the NMLs for daytime operations at most receivers. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs. In particular there are immediately adjacent residential receivers to the western site, and residential and commercial receivers close to the eastern site that will require careful management.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites. Note noise walls are effective for receivers at or near ground level (eg single storey residences and outdoor eating areas). The use of noise walls may also not be feasible during demolition activities. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where exceedances for construction activities are predicted using enclosures (eg residences to the south-west of the Miller Street site, and residences adjacent to the Union Street site), the noise insulation of the enclosure element(s) facing the receiver may need to be upgraded using , for example, a double skin or masonry construction. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities.

Having considered all reasonable and feasible noise mitigation, the CBD Metro "*Construction Noise and Vibration Strategy*" would be implemented to manage the potential noise impacts.

9.4.16 Rozelle Station Site

The nearest noise sensitive receivers to the Rozelle Station sites are identified in **Table 62** with the receiver areas illustrated in **Figure 15**.

Figure 15 Rozelle Construction Sites and Receiver Areas

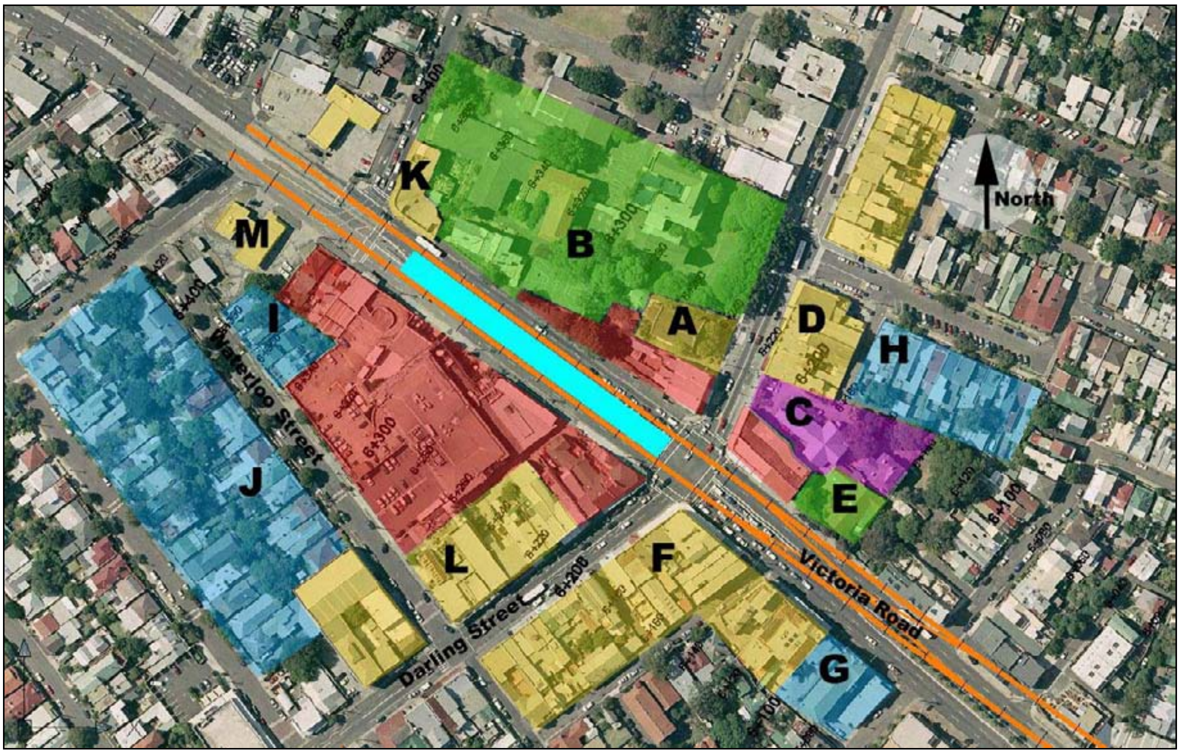


Table 62 Nearest Noise Sensitive Receivers - Rozelle Station

Station Site/Excavation	Receiver	Location Relative to Works (m)
Rozelle (north)	A - Commercial adjoining - N B - School adjoining - N C - Church - E D - Commercial - E	4 22 33 26
Rozelle (north east)	C - Church - NE E - Child Care - E D - Commercial - N F - Commercial - SW G - Residential - SE H - Residential - NE	6 14 24 34 69 50
Rozelle (south - Tigers Club)	I - Residential - W J - Residential - W K - Bridge Hotel - NE F - Commercial - SE L - Commercial - SW M - Commercial - NW	5 17 29 16 2 14
Rozelle Station Cavern	K - Hotel A - Church C - Church	25 36 36

9.4.17 Site Specific Construction Noise Goals

With reference to the project NMLs and the ambient noise survey results summarised in **Table 2**, the site specific construction NMLs are presented in **Table 63**.

Table 63 Rozelle Station Construction NMLs

Receiver Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
	Daytime	**Evening**	**Night-time**
Victoria Road	69	61	47
Waterloo Street	56	52	43

9.4.18 Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels without noise controls implemented on site, predicted at the nearest noise sensitive receivers (at ground floor level) are presented in **Table 64** to **Table 69**, together with the level of exceedance with varying levels of potential noise control. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Table 64 Rozelle Predicted Noise Levels - Demolition and Excavation - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	87-100	50	40	35	25
	B - School adjoining - N	55	82-85	30	20	15	5
	C - Church - E	50	74-82	32	22	17	7
	D - Commercial - E	70	75-84	14	4	-	-
Rozelle (northeast)	C - Church - NE	50	87-96	46	36	31	21
	E - Child Care - E	55	80-89	34	24	19	9
	D - Commercial - N	70	81-84	14	4	-	-
	F - Commercial - SW	70	79-81	11	1	-	-
	G - Residential - SE	69	73-75	6	-	-	-
	H - Residential - NE	69	76-78	9	-	-	-
Rozelle (south - Tigers Club)	I - Residential - W	56	70-98	42	32	27	17
	J - Residential - W	56	70-87	31	21	16	6
	K - Bridge Hotel - NE	69	70-83	14	4	-	-
	F - Commercial - SE	70	67-88	18	8	3	-
	L - Commercial - SW	70	70-106	36	26	21	11
	M - Commercial - NW	70	67-89	19	9	4	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Note 2: Noise mitigation may not be feasible during the demolition phase

Table 65 Rozelle Predicted Noise Levels - Excavation - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	87-100	50	40	35	25
	B - School adjoining - N	55	82-85	n/a	n/a	n/a	n/a
	C - Church - E	50	74-82	32	22	17	7
	D - Commercial - E	70	75-84	14	4	-	-
Rozelle (northeast)	C - Church - NE	50	87-96	46	25	20	10
	E - Child Care - E	55	80-89	n/a	n/a	n/a	n/a
	D - Commercial - N	70	81-84	14	4	-	-
	F - Commercial - SW	70	79-81	11	1		-
	G - Residential - SE	61	73-75	14	4	-	-
	H - Residential - NE	61	76-78	17	7	2	-
Rozelle (south - Tigers Club)	I - Residential - W	52	70-98	46	36	31	21
	J - Residential - W	52	70-87	35	25	20	10
	K - Bridge Hotel - NE	61	70-83	22	12	7	-
	F - Commercial - SE	70	67-88	18	8	3	-
	L - Commercial - SW	70	70-106	36	26	21	11
	M - Commercial - NW	70	67-89	19	9	4	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 66 Rozelle Predicted Noise Levels - Excavation - Night

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	87-100	n/a	n/a	n/a	n/a
	B - School adjoining - N	55	82-85	n/a	n/a	n/a	n/a
	C - Church - E	50	74-82	n/a	n/a	n/a	n/a
	D - Commercial - E	70	75-84	n/a	n/a	n/a	n/a
Rozelle (northeast)	C - Church - NE	50	87-96	n/a	n/a	n/a	n/a
	E - Child Care - E	55	80-89	n/a	n/a	n/a	n/a
	D - Commercial - N	70	81-84	n/a	n/a	n/a	n/a
	F - Commercial - SW	70	79-81	n/a	n/a	n/a	n/a
	G - Residential - SE	47	73-75	28	18	13	3
	H - Residential - NE	47	76-78	31	21	16	6
Rozelle (south - Tigers Club)	I - Residential - W	43	70-98	55	45	40	30
	J - Residential - W	43	70-87	44	34	29	19
	K - Bridge Hotel - NE	47	70-83	36	26	21	11
	F - Commercial - SE	70	67-88	n/a	n/a	n/a	n/a
	L - Commercial - SW	70	70-106	n/a	n/a	n/a	n/a
	M - Commercial - NW	70	67-89	n/a	n/a	n/a	n/a

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 67 Rozelle Predicted Noise Levels - Construction - Daytime

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	77-90	40	30	25	15
	B - School adjoining - N	55	72-75	22	12	7	-
	C - Church - E	50	64-72	22	12	7	-
	D - Commercial - E	70	65-74	4	-	-	-
Rozelle (north east)	C - Church - NE	50	77-86	36	26	21	11
	E - Child Care - E	55	70-79	24	14	19	9
	D - Commercial - N	70	71-74	4	-	-	-
	F - Commercial - SW	70	69-71	1	-	-	-
	G - Residential - SE	69	63-65	-	-	-	-
	H - Residential - NE	69	66-68	-	-	-	-
Rozelle (south - Tigers Club)	I - Residential - W	56	60-88	32	22	17	7
	J - Residential - W	56	60-77	21	11	6	-
	K - Bridge Hotel - NE	69	60-73	4	-	-	-
	F - Commercial - SE	70	57-78	8	-	-	-
	L - Commercial - SW	70	60-96	26	16	11	1
	M - Commercial - NW	70	57-79	9	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 68 Rozelle Predicted Noise Levels - Construction - Evening

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	77-90	40	30	25	15
	B - School adjoining - N	55	72-75	20	10	5	-
	C - Church - E	50	64-72	22	12	7	-
	D - Commercial - E	70	65-74	4	-	-	-
Rozelle (northeast)	C - Church - NE	50	77-86	36	26	21	11
	E - Child Care - E	55	70-79	24	14	19	9
	D - Commercial - N	70	71-74	4	-	-	-
	F - Commercial - SW	70	69-71	1	-	-	-
	G - Residential - SE	61	63-65	4	-	-	-
	H - Residential - NE	61	66-68	-	-	-	-
Rozelle (south - Tigers Club)	I - Residential - W	52	60-88	36	26	21	11
	J - Residential - W	52	60-77	25	15	-	-
	K - Bridge Hotel - NE	61	60-73	12	2	-	-
	F - Commercial - SE	70	57-78	8	-	-	-
	L - Commercial - SW	70	60-96	26	16	11	11
	M - Commercial - NW	70	57-79	9	-	-	-

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Table 69 Rozelle Predicted Noise Levels - Construction - Night

Station	Receiver Area	NML (dBA)	Predicted LAeq Noise Level (dBA)[1]	NML Exceedance with Level of Noise Mitigation (dBA)			
				None	3 m Hoarding	6 m Hoarding	Enclosure
Rozelle (north)	A - Commercial - N	50	77-90	n/a	n/a	n/a	n/a
	B - School adjoining - N	55	72-75	n/a	n/a	n/a	n/a
	C - Church - E	50	64-72	n/a	n/a	n/a	n/a
	D - Commercial - E	70	65-74	n/a	n/a	n/a	n/a
Rozelle (northeast)	C - Church - NE	50	77-86	n/a	n/a	n/a	n/a
	E - Child Care - E	55	70-79	n/a	n/a	n/a	n/a
	D - Commercial - N	70	71-74	n/a	n/a	n/a	n/a
	F - Commercial - SW	70	69-71	n/a	n/a	n/a	n/a
	G - Residential - SE	47	63-65	18	8	3	-
	H - Residential - NE	47	66-68	21	11	6	-
Rozelle (south - Tigers Club)	I - Residential - W	43	60-88	45	35	30	20
	J - Residential - W	43	60-77	34	24	19	9
	K - Bridge Hotel - NE	47	60-73	26	16	11	1
	F - Commercial - SE	70	57-78	n/a	n/a	n/a	n/a
	L - Commercial - SW	70	60-96	n/a	n/a	n/a	n/a
	M - Commercial - NW	70	57-79	n/a	n/a	n/a	n/a

Note 1: Predicted noise levels (ranges) have been determined based on equipment working at various locations on the site.

Discussion

- The predicted noise levels for excavation at the Rozelle Station sites indicate significant exceedances of the NMLs for daytime operations at most receivers. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs. In particular there are immediately adjacent commercial and residential receivers to the south of the Tigers site, and on the northern side of Victoria Road a church, a school and a child care centre. At all these receivers, due to close proximity, significant exceedances are predicted. Careful management will be required at these receivers.

- To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites noting noise walls are effective for receivers at or near ground level (eg single storey residences). The use of noise walls may also not be feasible during demolition activities. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. Indicatively, the enclosure construction could consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where exceedances for construction activities are predicted using enclosures (eg residences to the west of the Tigers site), the noise insulation of the enclosure element(s) facing the receiver may need to be upgraded using, for example, a double skin or masonry construction. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project.
- Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities.

Having considered all reasonable and feasible noise mitigation, the CBD Metro "*Construction Noise and Vibration Strategy*" would be implemented to manage the potential noise impacts.

9.5 Station Sites - Ground-borne Noise Assessment - Evening and Night-time

Ground-borne noise impacts from excavation using conventional construction techniques (including rockbreaking) are presented in the following sections.

Ground-borne noise in buildings is caused by the transmission of ground-borne vibration rather than the direct transmission of noise through air. Vibration may be generated by construction equipment such as rockbreakers, roadheaders, drilling rigs and excavators and can be transmitted through the ground into the adjacent building structures. After entering a building, this vibration may cause the walls and floors to faintly vibrate and hence to radiate noise.

Attenuation with distance occurs due to the geometric spreading of the wave front and due to other losses within the ground material, known as "damping". In addition, losses occur with the transfer of vibration from floor-to-floor within buildings (typically 2 dBA per floor).

The ground-borne internal $L_{Aeq(15minute)}$ noise goal objective associated with the construction works for residential receivers is 40 dBA during the evening between 6.00 pm and 10.00 pm, and 35 dBA between the night-time hours of 10.00 pm to 7.00 am.

9.5.1 Ground-borne Noise from Rockbreakers

Table 70 and **Appendix H** present indicative complying working distances for heavy, medium and light rockbreakers (indicated in orange, yellow and green respectively in **Appendix H)**. The complying working distance has been determined for the predicted vibration at the third floor of a residential dwelling. Actual distances at each site would need to be confirmed at the commencement of rockbreaking activities if night-time works are required.

Table 70 Indicative Night-time Regenerated Complying Working Distances

Rockbreaker	Complying Distance
Heavy (eg 1600 kg)	70 m
Medium (eg 900kg)	60 m
Light (eg 300 kg)	50 m

Note 1: These ground-borne complying working distances (inside buildings) are indicative only. Actual levels are dependent on other factors such as geotechnical conditions, rock hardness, intensity of use of the machinery, etc.

The results in **Appendix H** show that due to the relative close proximity of sensitive receivers to all sites (closer than the complying distances), the ground-borne noise goal will be exceeded. Therefore, whilst airborne noise impacts can potentially be controlled using a suitably designed acoustic enclosure the resultant ground-borne noise is likely to exceed the design goal.

9.5.2 Alternative Methods - Penetrating Cone Fracture

Penetrating Cone Fracture (PCF) involves the energy efficient breakage of rock using a high-pressure gas pulse. The rock is fractured by the introduction of a gas pulse at the base of a short drill hole (usually less than 1.5 m). This technique has successfully been utilised on a number of construction sites in Sydney, including at the Westfield site in Bondi Junction.

PCF potentially offers the ability to conduct excavation works with a reduced impact on the surrounding area when compared to more conventional techniques. The impact of using PCF during the more sensitive night-time period is contained in this section.

Potential Airborne Noise Sleep Disturbance Impacts for Night-time PCF Works

When assessing night-time PCF works, the current sleep disturbance criterion used in NSW should be considered (refer **Section 7.2.1**). Where the screening criterion is not met, a more detailed analysis is required which should cover the maximum noise level and the number of times this happens during the night-time period.

Table 71 presents calculated indicative complying working distances for a 60 g charge weight based on the sleep disturbance targets for each respective construction site. The distances have been calculated assuming the works occur inside an enclosure. Actual distances at each site would need to be confirmed at the commencement of PCF activities if night-time works are required.

Table 71 Indicative Night-time Complying Working Distances to Avoid Sleep Disturbance - PCF 60 g Charge

Location	Complying Working Distance (m)
Rozelle	30
Pyrmont	20
Wynyard	15
Martin Place	5
Town Hall	5
Central	10

The indicative complying working distance to avoid sleep disturbance for a 60 g charge weight is indicated in pink in **Appendix H**.

The results in **Appendix H** show that the airborne sleep disturbance (using a suitably designed enclosure) is expected to be complied (using a 60 g charge) for PCF operations during the night-time.

Indicative Vibration Related Complying Working Distances for Night-time PCF Works

As a guide, based on the DECCW's "*Assessing Vibration: a technical guideline*", complying working distances have been calculated for various charge weights. The calculated preferred complying working distance is based on the DECCW's preferred RMS velocity of 2 mm/s. The nearest allowable complying working distance is based on the DECCW's maximum allowable RMS velocity of 4 mm/s. A summary of the indicative separation distances is presented in **Table 72**. The preferred complying working distance for a 60 g charge weight is also indicated in blue in **Appendix H**.

Table 72 Indicative Complying Working Distances - PCF

Charge Weight (g)	Preferred Complying Working Distance (m)[1]	Nearest Allowable Complying Working Distance (m)[2]
10	8	5
30	13	8
60	18	11
100	24	14
200	33	20
300	41	25

Note 1: Based on the DECCW's preferred RMS velocity of 2 mm/s.

Note 2: Based on the DECCW's maximum allowable RMS velocity of 4 mm/s.

The results in **Appendix H** show that the DECCW's guideline for maximum allowable vibration from an impulsive event is expected to be complied (using a 60 g charge) for PCF operations during the night-time.

Similarly to PCF, drill and blast techniques are anticipated to be able to offer the ability to conduct excavation works with a reduced impact on the surrounding area when compared to more conventional techniques such as rockbreakers. The same techniques of limiting the charge mass to control the ground vibration, and the use of a suitable acoustic enclosure to control overpressure would be required to be employed.

9.5.3 Ground-borne Noise from Roadheaders

Roadheaders will be used for the station caverns, cross tunnels, the main tunnels from White Bay to Rozelle stations, the stub tunnels at Rozelle, and the turnback and stub tunnels at Central.

From **Section 7.2.2,** internal noise goals of L_{Aeq} 45 dBA during the daytime, 40 dBA during the evening and 35 dBA during the night-time have been adopted as assessment goals for these activities at residential receivers.

The nearest receivers to the station caverns, the main tunnels and the stabling depot connection tunnels have been identified and the ground-borne noise levels predicted as well as the anticipated number of days of impact. The results are presented in **Table 73**.

Table 73 Predicted Noise Levels from Roadheader Operation

Station Site / Excavation	Receiver	Location Relative to Works (m)	Predicted Noise Level in dBA	Predicted Number of Days Exceeding Night-time Noise Trigger Level 35 dBA
Rozelle Station Cavern	Hotel Church	25 36	36 33	Up to 10 days 0 days
Pyrmont Station Cavern	Commercial Commercial Residential Union Square Residential	15 14 24 15	41 42 36 41	n/a n/a Up to 11 days Up to 22 days
Wynyard Station Cavern	Morton Hotel Residential Travelodge Commercial	9 29 22 15	46 35 37 41	n/a 0 days Up to 16 days n/a
Martin Place Cavern	CTA - residence	26	36	Up to 7 days
Town Hall Cavern	Criterion Hotel Commercial	24 24	37 37	Up to 12 days n/a
Central Cavern	Wake-up Hostel Central Station Commercial	55 11	29 44	0 days n/a
Rozelle to White Bay	Residential Commercial	16 25	40 36	12 days n/a
Rozelle to Stabling Yards	Residences: 22-36 Lilyfield Rd 19 Lilyfield Road 2-6 Hornsey Street 3 Hornsey Street 4 Quirk Street 5 Quirk Street	 7 15 19 22 22 23	 48 41 39 37 37 37	 14 days 12 days 10 days 9 days 9 days 8 days

Discussion

The results presented in **Table 73** show only marginal exceedances of up to 2 dBA of the night-time noise goals at all the nearest residences, except those above the depot connection tunnels in Rozelle. Exceedances are up to 4 dBA at 2 to 6 Hornsey Street, and 6 dBA to 13 dBA at Lilyfield Road. Where feasible, it may be necessary to maximise the distance between the roadheader and receivers at these locations during night-time periods. If this is not feasible, and ground-borne noise levels remain above the design goals during night-time periods, there may be a requirement to offer affected residents alternative temporary accommodation during these works. This process will be described in Sydney Metro's "*Construction Noise and Vibration Strategy*".

9.5.4 Ground-bourne Noise from Tunnel Boring Machines (TBM)

Tunnel Boring Machines (TBM) will be used to excavate the main tunnels from Central to White Bay. From **Section 7.2.2** internal noise goals of L_{Aeq} 40 dBA during the evening and 35 dBA during the night-time have been adopted as assessment goals for these activities at residential receivers.

The nearest receivers from the tunnels have been identified and the corresponding ground-bourne noise levels have been predicted. **Figure 16** and **Figure 17** provide a summary of the predicted ground-borne noise levels versus track chainage.

Figure 16 presents the maximum anticipated noise levels occurring when the TBM is located below the receiver location. While **Figure 17** represents the noise levels five days before and after the TBM arrival to the receiver location (assuming a TBM advancement rate of typically 300 m per month).

Figure 16 Summary of TBM Regenerated Noise Levels at the Nearest Point to Receiver

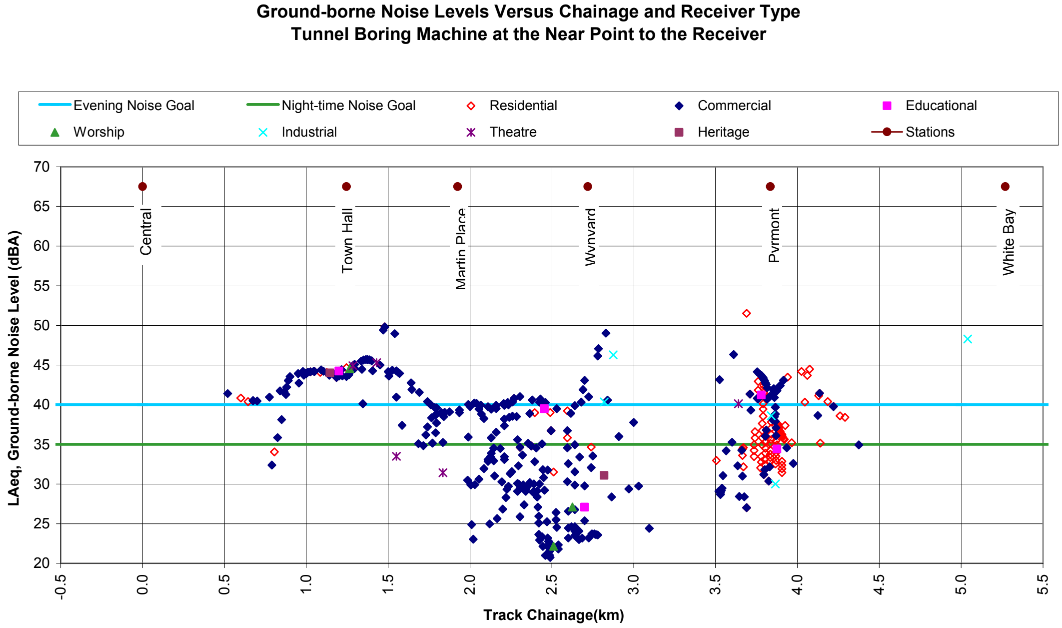
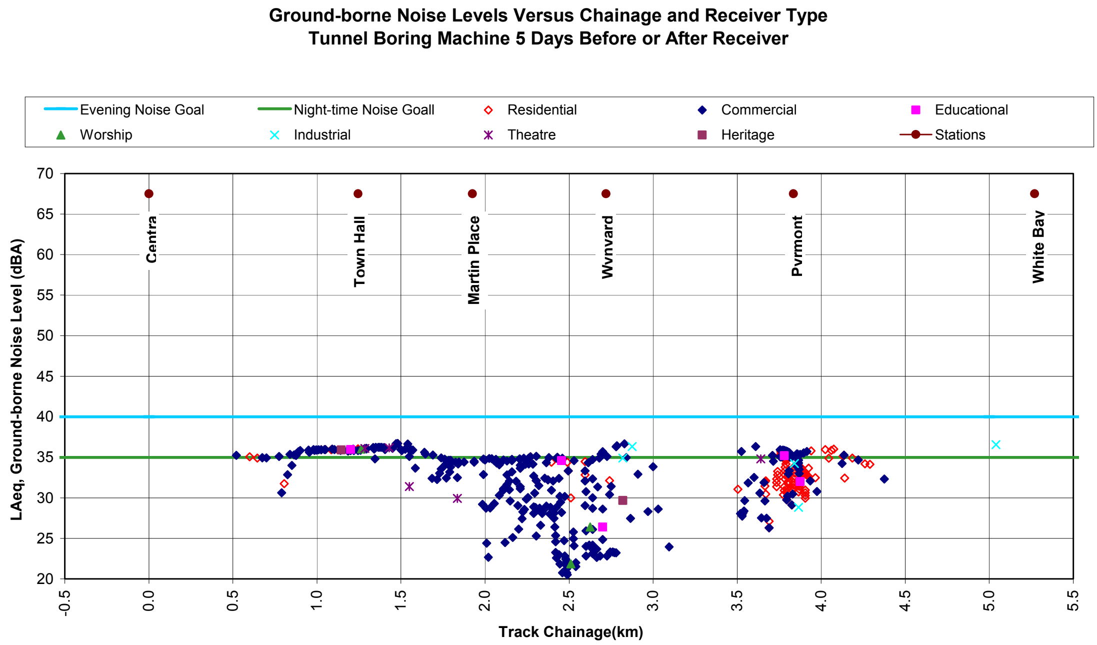


Figure 17 Summary of TBM Regenerated Noise Levels 5 days Before and After Nearest Point to Receiver



If the receiver is located directly above the tunnel, the ground-borne noise levels are anticipated to exceed the recommended residential night-time noise goal of 35 dBA for a period up to approximately 10 days. As depicted in **Figure 16** and **Figure 17** most of the receivers are commercial. **Table 74** presents the predicted noise levels for the affected residential receivers during TBM operations as well as the anticipated number of days of impact.

Table 74 Predicted Noise Levels at Critical Residential Receivers for TBM Operations

Street Address	Receiver	Predicted Maximum Noise Level, LAeq (dBA)	Predicted Number of Days Exceeding Night-time Noise Trigger Level, 35 dBA
303-307, 317-321 Castlereagh Street, Haymarket	Regis Apartments	41	4 days
300 Pitt Street, Sydney	Metro Hotel	44	6 days
329 Pitt Street, Sydney	Meriton Apartments	43	6 days
255-259 Pitt Street, Sydney	Hilton Hotel	50	8 days
27 O'Connell Street, Sydney	Radisson Hotel	41	3 days
7-9 York Street, Sydney	Travelodge	39	2 days
24 Union Street, Pyrmont	Proposed Star City Hotel	52	4 days
20 Pyrmont Street, Pyrmont	Star City Casino Apartment	41	4 days
91-93 Pyrmont Street, Pyrmont	Residential	43	9 days
1-19 Paternoster Road, Pyrmont	Residential	40 to 43	9 days

Street Address	Receiver	Predicted Maximum Noise Level, LAeq (dBA)	Predicted Number of Days Exceeding Night-time Noise Trigger Level, 35 dBA
102-104 Miller Street, Pyrmont	Residential	43	9 days
13-15 Jones Street, Pyrmont	Residential	44	9 days
14 Quarter Master Drive, Pyrmont	Residential	41	9 days

Note 1: The number of days exceeding the night-time noise trigger level has been determined based on predicted noise levels on the 2nd floor of multi-story hotels/city apartments and ground floor residential houses.

Note 2: The predicted maximum noise levels are predicted for the ground floor. Noise levels will decrease at upper levels in the building by typically 2 dBA per floor.

Given the TBM(s) follow a predefined path, where ground-borne noise levels remain above the design goals during night time periods, there may be a requirement to offer affected residents alternative temporary accommodation during these works. This process will be described in Sydney Metro's "*Construction Noise and Vibration Strategy*".

9.6 Construction Noise Traffic Assessment

This section provides an assessment of the construction traffic noise that would be generated by the heavy vehicles which would be required to service each site.

For this assessment, the maximum number of hourly vehicle movements used is 10 heavy vehicles (spoil and/or delivery vehicle combination) during the daytime and 5 heavy vehicles during the night-time.

Daytime Impacts

Heggies has been provided with indicative daytime vehicle movements and percentage of heavy vehicles on the access roads to the respective sites. For the major CBD arterial and collector roads such as George Street, Pitt Street and Bathurst Street, which are site access routes, typical flows are 800 to 1300 vehicles per hour. For the CBD collector, roads such as Castlereagh Street, Clarence Street, Phillip Street, Erskine Street the typical flows are 160 to 500 vehicles per hour. For Victoria Road at Rozelle, the indicative daytime flow is 3,000 vehicles per hour.

For receivers located in the CBD and on Victoria Road at Rozelle, based on the low (in the context of existing road traffic volumes) daytime volume of heavy vehicle movements during construction, the project is not expected to result in traffic noise increases that exceed 2 dBA at the receivers on access roads close to the station construction sites. It is predicted that construction related traffic activity will generally result in noise increases of less than 1 dBA.

Heggies has also been provided with indicative daytime vehicle movements and percentage of heavy vehicles on the access roads to the Pyrmont station sites. For the access roads of Miller Street and Pyrmont Street the indicative hourly flows are 140 vehicles per hour. Here, it is predicted that construction related traffic activity will generally result in noise increases of less than 2 dBA.

In summary, on the construction vehicle arterial and collector access roads to the station sites, due to relatively high existing vehicle flows, daytime noise levels are expected to exceed the ECRTN 60 dBA. The increase in traffic noise as a result of construction vehicles is therefore not expected to exceed the 2 dBA allowance increase.

Night-time Impacts

Based on the indicative daytime traffic flows provided and the expected daytime and night-time split of 85 percent and 15 percent night-time hourly flows have been estimated to be typically 200 to 700 for the major arterial and collector roads, and in the order of 80 to 200 vehicles per hour on the minor collector roads.

Based on the potential project night-time heavy vehicle movements of 5 per hour, increases in the $L_{Aeq(1hour)}$ noise level have been predicted, and are presented in **Table 75**. For the CBD, compliance with the 2 dBA allowance increase is achieved at all locations, with the exception of the Criterion Hotel on Pitt Street and the Sofitel Wentworth Hotel on Bligh Street.

For receivers on the access routes to the Pyrmont Station sites the $L_{Aeq(1hour)}$ noise level has been predicted to increase by 2.6 dBA, which is a very minor exceedance of the 2 dBA allowance increase.

For receivers on the Victoria Road access routes to the Rozelle Station sites the $L_{Aeq(1hour)}$ noise level has been predicted to increase by less than 1 dBA, which complies with the 2 dBA allowance increase.

Sleep Disturbance

The nearest receivers on the access routes to the station sites, where night-time spoil removal is proposed, have been identified and maximum heavy vehicle passby noise levels have been predicted. The predicted noise levels have been compared to "external window" criterion based on the maximum internal noise level of 55 dBA which is not expected to cause awakening reactions. The external (window) screening level is 10 dBA above the 55 dBA level for open windows (eg a residence) and 20 dBA above 55 dBA for closed windows (eg a hotel). The assessment results are presented in **Table 75**, together with the ambient background +15 dBA screening level guideline noise level for general sleep disturbance.

Table 75 Receivers on Station Access Routes and Predicted Night-time Noise Level Increases and Heavy Vehicle Passby Noise Levels

Station and Construction Site Access[1]	Access Street	Receiver	Predicted Traffic Noise Increase	Background (+15 dBA)	External Screening Noise Level[2]	Predicted Noise Level L_{Amax}
Central						
Belmore Park (in)	Pitt Street	Sydney Central YHA	< 2 dBA	52 (67)	65	63
Central Station (in)	Pitt Street	Wake up Hostel	< 1 dBA		75	71
		Sydney Central YHA	< 1 dBA		65	69
Central Station (out)	Lee Street	Medina Hotel	< 2 dBA		75	77
Town Hall Square						
Bathurst St (in)	Bathurst Street	Meriton Apartments	< 2 dBA	61 (76)	65	73
Bathurst St (out)	Bathurst Street	Euro Towers	< 2 dBA		65	77
Pitt & Park St and Pitt St (in)	Bathurst Street	Meriton Apartments	< 2 dBA		65	76
	Pitt Street	Criterion Hotel	3 to 4 dBA		75	78
Pitt & Park (out)	-	-	-	-	-	-
Pitt St (out)	Pitt Street	Hilton Hotel	3 to 4 dBA		75	72

Station and Construction Site Access[1]	Access Street	Receiver	Predicted Traffic Noise Increase	Background (+15 dBA)	External Screening Noise Level[2]	Predicted Noise Level LAmax
Martin Place						
Martin Place (in)	Bligh Street	Sofitel Wentworth	10 to 11 dBA	56 (71)	75	75
	Castlereagh Street	CTA Business Club	2 to 3 dBA		75	77
Martin Place (out)	Castlereagh Street	CTA Business Club	2 to 3 dBA		75	77
	Elizabeth Street	Travel Lodge			75	71
	Phillip Street	Sofitel Wentworth	< 2 dBA		75	78
Wynyard						
York Street (in)	Clarence Street	Wynyard Hotel	2 to 3 dBA	49 (64)	75	78
York Street (out)	Erskine Street	Wynyard Hotel	3 to 4 dBA		75	78
	Erskine Street	Occidental Hotel	5 to 6 dBA		75	77
Sussex Street (in)	Sussex Street	Moreton's Hotel	< 2 dBA		75	72
Sussex Street (out)	Sussex Street	Moreton's Hotel	< 2 dBA		75	75
Pyrmont						
Pyrmont Mount Street (in)	Miller Street	Residential 81-105 Miller	5 to 6 dBA	51 (66)	65	78
	Miller Street	Residential Cnr Mount & Miller	5 to 6 dBA		65	84
Pyrmont Mount Street (out)	Miller Street	Residential 81-105 Miller	5 to 6 dBA		65	84
	Miller Street	Residential Cnr Mount & Miller	5 to 6 dBA		65	77
Pyrmont Union Street (in)	Miller Street	Residential 81-105 Miller	5 to 6 dBA		65	78
	Miller Street	Residential Cnr Mount & Miller	5 to 6 dBA		65	84
	Union Street	Residential 1 Paternoster Road	16 to 17 dBA		65	79
Pyrmont Union Street (out)	Pyrmont Street	Residential 103-127 Pyrmont	5 to 6 dBA		65	79
Rozelle						
Rozelle (in/out)	Victoria Road	Residential Victoria Road	< 1 dBA	47 (62)	65	83

Note 1: "in" refers to inbound traffic entering construction site and "out" refers to outbound traffic leaving construction site

Note 2: External Criteria is based on the 55 dBA internal criterion plus 10 dBA for a sensitive receiver with openable windows and plus 20 dBA for a sensitive receiver with fixed windows (eg Hotel)

Discussion of Sleep Disturbance Screening Criterion and Predictions

In the CBD, for sensitive receivers with fixed glazing, such as air-conditioned hotel suites and apartments, the 55 dBA based external sleep disturbance screening criterion is either complied with or marginally exceeded (by up to 3 dBA), at all receivers. Sleep disturbance is therefore considered marginally acceptable. It is also noted the design of CBD buildings for accommodation generally includes a high degree of external noise insulation due to prevailing high levels of ambient traffic noise. It would be recommended at the locations where the exceedances exist further, investigation be conducted during the construction planning and site establishment phases of the project to confirm the external to internal noise reduction achieved at these locations. A significant traffic increase is predicted for the Sofitel Wentworth for the Martin Place site exit route via Bligh Street and alternative access via Hunter Street should be considered. Furthermore, using Hunter Street for the site entrance route (currently via Phillip) would reduce impacts at the Sofitel Hotel Phillip Street façade.

In the CBD, for sensitive receivers with openable windows, exceedances range from 4 dBA at the Sydney City YHA to 8 dBA to 12 dBA at apartments near Town Hall. Sleep disturbance potential is marginal at the Sydney City YHA, whilst the "external criterion" is significantly exceeded near Town Hall. However at this location the Background + 15 dBA is complied with. On this basis, sleep disturbance is considered marginally acceptable, and it would be recommended that further investigation be conducted during the construction planning and site establishment phases of the project to confirm the number of existing sleep disturbing events that occur as well as the external to internal noise reduction achieved at these locations.

At the Pyrmont receivers, the openable window external criterion applies. It is also noted that this sleep disturbance screening criterion is similar to the Background + 15 dBA level. Exceedances at Pyrmont range from 13 dBA to 19 dBA, due to the location of receivers adjacent to the access routes and consequently the potential for significant sleep disturbance exists. Furthermore, the existing heavy night-time traffic flow volumes in Pyrmont are low. It is therefore recommended that heavy vehicle movements for the Pyrmont sites be restricted to the daytime and evening periods.

At receivers on Victoria Road, the openable window external criterion applies, and exceedances of the sleep disturbance screening criterion of 8 dBA are predicted. Whilst this is significant, indicative existing hourly heavy night-time traffic flow volumes on Victoria Road are much higher than the 5 movements associated with the station site.

9.7 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. For construction noise, a summary of the SoC's is provided in the main body of the Environmental Assessment.

10 CONSTRUCTION VIBRATION ASSESSMENT

During construction activities, the major potential sources of vibration include rockbreakers, other excavation plant and equipment, vibratory pile drivers, vibratory rollers and potentially Penetrating Cone Fracture (PCF) operations.

Vibration goals have been provided in **Section 7.3** of this report, with a vibration level of 7.5 mm/s at a building or vibration sensitive receiver being set as a cosmetic damage threshold for further assessment and/or monitoring. For commercial receivers 4 mm/s has been set as a threshold for further assessment.

10.1 Safe Working Distances for Vibration Intensive Plant

For the purpose of this assessment a "safe distance" would correspond to the nearest distance at which the maximum vibration level generated by the operation of a subject plant item is predicted not to exceed the 7.5 mm/s cosmetic damage threshold (noting that higher vibration levels may be permitted for typical building constructions - refer **Section 7.3**). **Table 76** presents indicative "safe distances" for the plant items likely to be used at the White Bay, Rozelle depot and the various station sites.

Table 76 Safe Working Distances - Cosmetic Damage

Plant Items	Safe Working Distance (m)
Hydraulic Impact Hammer - Small	1
Hydraulic Impact Hammer - Medium	4
Hydraulic Impact Hammer - Large	15
Vibratory Roller - 10 Tonne	6
Vibratory Trench Roller - 3 Tonne	1

10.2 General Comments

The following general comments are made:

- Vibration levels at services (especially critical infrastructure ie fibre optics, gas pipelines) will be below 2 mm/s.
- Use of rockbreakers would need to be carefully managed in the vicinity of residences due to potential noise impacts. Co-ordination may also be required with schools for rockbreaking.
- The use of impact-driven piles should be avoided where reasonable and feasible.

10.3 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. For construction vibration, a summary of the SoC's is provided in the main body of the Environmental Assessment.

11 NOISE AND VIBRATION MITIGATION STRATEGIES

The Director-General's Requirements for the project recognise that there are likely to be potential noise and vibration impacts associated with the proposed construction works. An extract from the Director-General's Requirements is provided below:

*"**General Construction Impacts** - [The Environmental Assessment must] consider the potential impacts associated with the construction of the project, and present a management framework for construction works to ensure that impacts are mitigated, monitored and managed. The EA must include consideration of, and a management framework for:*

* *construction noise and vibration, including a considered approach to scheduling construction works having regard to the nature of construction activities (including transport, blasting and tonal or impulsive noise-generating works), the intensity and duration of noise and vibration impacts, the nature, sensitivity and impact to potentially-affected human receivers and structures, the need to balance timely conclusion of noise and vibration-generating works with periods of receiver respite, and other factors that may influence the timing and duration of construction activities (such as traffic or spoil management). The EA must also present a strategy for monitoring and mitigating construction noise and vibration, with a particular focus placed on those activities identified as having the greatest potential for adverse noise or vibration impacts, and a broader, more generic approach developed for lower-risk activities"*

11.1 Construction Noise and Vibration Strategy Framework

Sydney Metro is in the process of developing a *'Construction Noise and Vibration Strategy'* that will be adopted by all contractors to address the above requirements. In preparing this strategy, consideration has been given to several guideline documents including the DECCW's '*Interim Construction Guideline'*, Transport Infrastructure Development Corporation's *'Construction Noise Strategy (Rail Projects)'* and Australian Standard AS 2436-1981 *'Guide to noise control on construction, maintenance and demolition sites'.*

The framework for the Sydney Metro *'Construction Noise and Vibration Strategy'* is provided in the following sections.

11.1.1 The Specific Objectives of the Construction Noise and Vibration Strategy

The Specific Objectives of the Construction Noise and Vibration Strategy are as follows:

- To provide minimum noise and vibration mitigation and management requirements for all Sydney Metro projects.
- To provide guidance on minimising air-borne and ground-borne noise and vibration impacts.
- Focus on applying 'feasible' and 'reasonable' work practices to minimise construction noise and vibration impacts.
- To assist in ensuring that noise emissions during the subject demolition, excavation and construction ("construction") works comply with the repetitive noise and vibration performance objectives for the works.
- To assist in ensuring that vibration emissions during the subject excavation works comply with appropriate structural damage criteria and to manage the potential vibration impacts on vibration sensitive receivers.
- To define the roles, responsibilities, and the tasks to be performed, in relation to the control and monitoring of noise and vibration emissions.
- To compile relevant information in a manner which will provide ongoing guidance to all parties regarding work planning and noise and vibration emissions control.

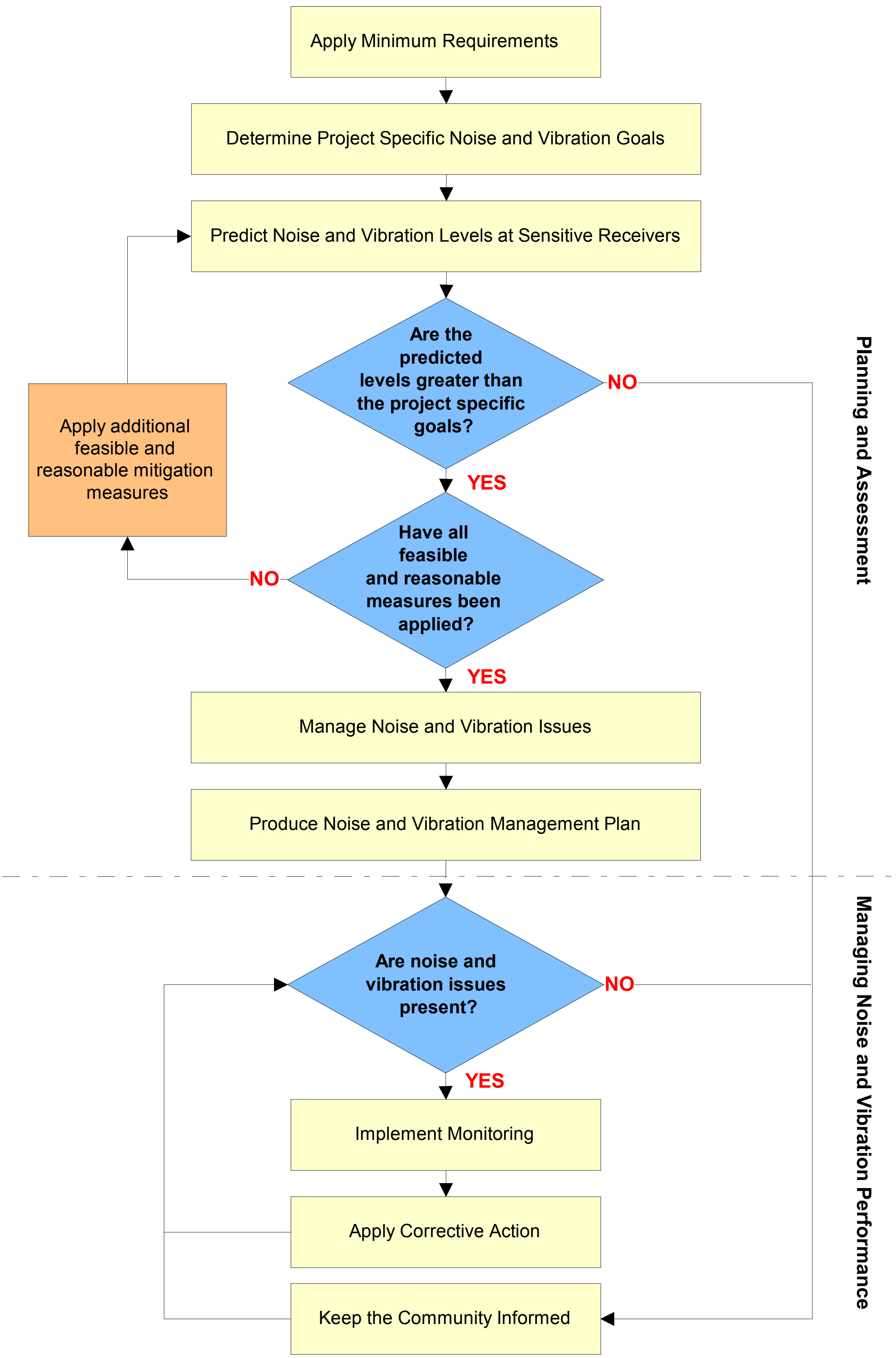
11.1.2 Responsibility

Responsibility for implementation of the Strategy rests with the Sydney Metro Project Manager, supported by the construction contractor and the noise and vibration consultant. Areas of responsibility include overall implementation, co-ordination of records of complaints and responses, non-conformances, reports and community liaison.

11.1.3 Strategy Overview and Review

The strategy recognises the exact construction methodologies would only be determined when the relevant construction contractors are appointed. The construction contractors on Sydney Metro projects would be required to comply with the strategy. The strategy will be reviewed annually to ensure that it meets the needs of the community, the regulators, Sydney Metro and the contractors engaged on Sydney Metro projects.

Application of the Strategy is shown in the following flow diagram:


Apply Minimum Requirements
Determine Project Specific Noise and Vibration Goals
Predict Noise and Vibration Levels at Sensitive Receivers
Are the predicted levels greater than the project specific goals?
NO
YES
Apply additional feasible and reasonable mitigation measures
Have all feasible and reasonable measures been applied?
NO
YES
Manage Noise and Vibration Issues
Produce Noise and Vibration Management Plan
Are noise and vibration issues present?
NO
YES
Implement Monitoring
Apply Corrective Action
Keep the Community Informed
Planning and Assessment
Managing Noise and Vibration Performance

11.1.4 Standard Mitigation Measures

Standard mitigation measures to reduce construction noise and vibration on Sydney Metro projects include:

- Management Methods
  - Project specific mitigation measures identified in the environmental assessment documentation (e.g. EA, REF, submissions or representations report) or approval or licence conditions;
  - Community consultative measures, ie periodic notification (monthly letterbox drop), website, infoline, construction response line, email distribution list, place managers.
  - A register of all noise and vibration sensitive receivers (NSRs) would be kept on site.
  - All employees, contractors and subcontractors would receive an environmental induction. The induction must include relevant project specific and standard noise and vibration mitigation measures, licence and approval conditions, permissible hours of work, limitations on high noise generating activities, location of nearest sensitive receivers, construction employee parking areas, designated loading/unloading areas and procedures, site opening/closing times (including deliveries), environmental incident procedures.
  - Behavioral practices such as no unnecessary shouting, and general practices to minimise noise (eg no dropping of materials from height; throwing of metal items; and slamming of doors)
  - Noise monitoring at sensitive receivers during critical periods (ie times when noise emissions are expected to be at their highest - eg piling and hammering) to identify and assist in managing high risk noise events. A noise monitoring program is to be carried out for the duration of the works in accordance with the Construction Noise and Vibration Management Plan and any approval and licence conditions.
  - Attended vibration measurements would be undertaken at the commencement of vibration generating activities to confirm that vibration levels are within the acceptable range to prevent cosmetic building damage.
- Source controls
  - Where feasible and reasonable, construction would be carried out during the standard daytime working hours. Work generating high noise and/or vibration levels would be scheduled during less sensitive time periods.
  - Respite for high noise and vibration generating activities in consultation with affected receivers.
  - Use of quieter and less vibration emitting construction methods where feasible and reasonable.
  - The offset distance between noisy plant and adjacent sensitive receivers is to be maximized. Noise-emitting plant to be directed away from sensitive receivers. Plant used intermittently to be throttled down or shut down.
  - Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site. Dedicated loading/unloading areas to be shielded if close to sensitive receivers.
- Path Controls
  - Stationary noise sources should be enclosed or shielded whilst ensuring that the occupational health and safety of workers is maintained

- 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.

11.1.5 Maximum Allowable Plant Sound Power Levels

The strategy contains a comprehensive list specifying maximum allowable sound power levels (SWL) for equipment likely to be used on all Sydney Metro projects. Plant and equipment with SWLs higher than those presented in the list would be deemed to be emitting an excessive level of noise and would not be permitted to operate Sydney Metro project construction sites.

11.1.6 Noise and Vibration Sensitive Receivers

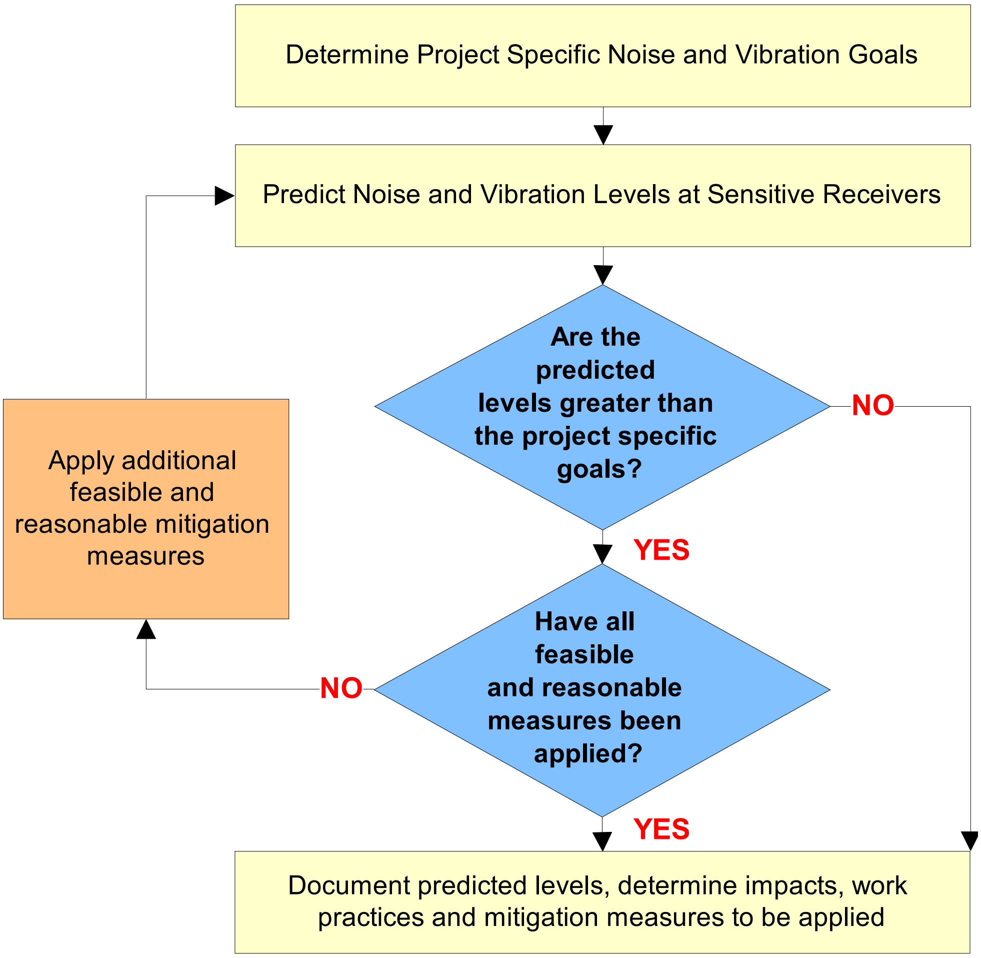
The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. Specific noise and vibration sensitive receivers relevant to individual construction sites should be identified and addressed in the Environmental Assessment and CNIS of each Sydney Metro project.

11.1.7 Noise and Vibration Guidelines

The strategy contains the same construction noise and vibration guidelines as specified in **Section 7**.

11.1.8 Construction Noise Assessment and Construction Noise Impact Statements (CNIS)

CNIS are to be developed to assess the potential impact of noise on NSRs as a result of a Sydney Metro project's construction activities prior to the commencement of construction components. The noise impact assessment procedure to be followed is shown in the following flow diagram:



11.1.9 Managing Exceedances of Construction Noise and Vibration Objectives

The following management measures would be applied as determined through the application of additional mitigation via a matrix based on the time (eg daytime or night-time), duration (eg one day or one week), and level of exceedance of the project specific noise and vibration management levels:

- Noise and Vibration Monitoring
- Individual Briefings
- General letter box drops and specific letters to identified residents
- Project specific respite offers
- Direct phone calls to affected residents
- Alternative accommodation

11.1.10 Noise and Vibration Management Plans

Where noise and/or vibration issues have been identified after all feasible and reasonable mitigation measures have been implemented, a noise and vibration management plan would be produced to include:

- Identification of nearby residences

- Description of the monitoring auditing and reporting procedures
- Procedure for reviewing performance and implementing corrective action
- Description of the complaints handling process
- Procedure of community consultation and liaison
- Liaison with DECCW

11.1.11 Monitoring, Auditing and Reporting

Guidance and procedures are provided to conduct:

- Plant noise auditing, compliance evaluation and reporting
- Noise monitoring at affected receivers
- Vibration monitoring at affected receivers
- PCF and Blast monitoring, including vibration and overpressure

11.1.12 Equipment Performance Review and Corrective Action

Procedures to ensure plant complies with specified noise emission levels including:

- Plant noise corrective action (eg maintenance or mitigation)

11.1.13 Complaint Handling

Procedures to ensure enquiries and complaints are dealt with in a responsive manner so that stakeholders' concerns are managed effectively and promptly:

- Utilisation of a 24 hour toll free Construction Response Line
- Verbal response within two hours
- Written response within seven days and ongoing communication if required
- Identifying, advising and delegating any required actions to appropriate team managers including the project manager
- Ensure details of the issue and all stakeholder contacts and associated actions are updated in a database

12 GROUND-BORNE VIBRATION ASSESSMENT - TRAIN OPERATIONS

12.1 Introduction

Railway vibration is generated by dynamic forces at the wheel-rail interface and occurs, to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness and elastic deformation of the surfaces). Higher vibration levels occur in the presence of rail and wheel surface irregularities.

This vibration propagates via the rail mounts into the ground or track support structures. It then travels through the ground or structures and may sometimes be felt as tactile vibration by the occupants of buildings. If the levels of vibration are sufficiently high (ie in buildings very close to rail tracks), then rattling or visible movement of loose objects (crockery, plants, etc) may also sometimes occur.

The effects of vibration in buildings can be divided into three main categories:

- Those in which the occupants or users of the building are inconvenienced or possibly disturbed (human perception or human comfort vibration)
- Those where the building contents may be affected
- Those in which the integrity of the building or the structure itself may be prejudiced

A fourth effect is the noise generated within buildings as a result of the vibration. This is termed "ground-borne noise" and is discussed further in **Section 13**.

For this project, the potential ground-borne vibration impacts would be limited to receivers located within an approximate 50 m wide corridor above the centre-line of the proposed tunnels.

12.1.1 Human Perception of Vibration

As discussed in **Section 7.4.1**, an individual's response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration.

Although people are able to perceive relatively low vibration levels, it is not appropriate to set vibration emission limits requiring "no vibration", since there will always be some measurable vibration in any environment. Realistic design goals should therefore be set to minimise disturbance and adverse impacts on amenity. The recommended approach is discussed in **Section 12.2**.

12.1.2 Effects of Vibration on Building Contents

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment. As such, the controlling vibration design goals during operations will be the human comfort goals, and it is therefore not necessary to set separate design goals for this EA in relation to the effect of railway vibration on common building contents.

Some scientific equipment (eg electron microscopes and microelectronics manufacturing equipment) can however require more stringent design goals than those applicable to human comfort. In such cases, vibration design goals should be obtained from the specific equipment manufacturers. If specific vibration design goals are not available, recommended vibration levels are provided in the ANC Guidelines (2001) and Ungar (1990).

12.1.3 Effects of Vibration on Structures

The levels of vibration required to cause damage to buildings tend to be at least an order of magnitude (10 times) higher than those at which people may consider the vibration to be intrusive. It is not necessary therefore to set separate design goals for this project in relation to building damage from railway vibration. Construction vibration goals to prevent potential building damage are discussed in **Section 7.3**.

12.2 Ground-borne Vibration Goals

On the basis of the above discussion, the vibration design goals adopted for this project are based on human comfort considerations, rather than the less stringent building damage risk criteria or potential effects on building contents.

There are several sources from which vibration goals may be drawn. These include:

- Australian Standard AS 2670.2 1990 "*Evaluation of Human Exposure to Whole Body Vibration - Part 2: Continuous and Shock Induced Vibration in Buildings (1 Hz to 80 Hz)*".
- The United States Federal Transit Administration (FTA) guideline "*Transit Noise and Vibration Impact Assessment*".
- British Standard BS 6472-1992 "*Evaluation of Human Exposure Vibration in Buildings (1 Hz to 80 Hz)*".
- The NSW Department of Environment, Climate Change and Water document "*Assessing Vibration: A Technical Guideline*".

The following discussion expresses vibration levels in terms of decibels (dB_V re 10^{-9} m/s). A level of 100 dB corresponds to 0.1 mm/s (rms) and a level of 120 dB corresponds to 1 mm/s (rms).

AS 2670.2 provides recommended vibration levels corresponding to 106 dB_V (0.2 mm/s) to 112 dB_V (0.4 mm/s) for residential buildings during the daytime, reducing to 103 dB_V (0.14 mm/s) during the night-time. These levels apply to both continuous and intermittent vibration. For office and industrial buildings, the recommended vibration levels are 112 dB_V (0.4 mm/s) and 118 dB_V (0.8 mm/s) respectively, independent of the time of day. Much higher vibration levels are permitted for transient events with only a few occurrences per day.

For residential buildings, the US FTA guideline recommends a vibration level of 100 dB_V (0.1 mm/s) for frequent events (ie more than 70 per day), 103 dB_V (0.14 mm/s) for occasional events (ie between 30 and 70 per day) and 108 dB_V (0.25 mm/s) for infrequent events (ie less than 30 per day). For schools, churches, quiet offices, etc, the recommended vibration levels are 3 dB higher than residential receivers.

BS 6472 has similar vibration level goals for continuous vibration, but also includes a vibration dose relationship for intermittent events such as trains, which for a "low probability of adverse comment" would permit vibration levels of up to approximately 110 dB_V (0.32 mm/s) on the basis of frequent nature of the proposed CBD Metro operations.

The DECCW's "*Assessing Vibration: A Technical Guideline*" is based on the guidelines contained in BS 6472. The acceptable values for intermittent vibration are the same as detailed above (namely 110 dB_V).

12.2.1 Proposed Vibration Design Goals

The proposed vibration design goal for residential receivers is based on the lower daytime value in AS 2670, namely 106 dB_V (0.2 mm/s). This level is recommended for both the daytime and night-time periods, recognising that the intermittent nature of train vibration events and that the frequency of train passby events will be lower during the night-time period.

The recommended level of 106 dB_V for residential receivers is 3 dB_V higher than the 103 dB_V night-time level (for continuous vibration) in AS 2670, but 4 dB_V lower than the DECCW guideline referred to in the Director-General's requirements for the EA.

For other sensitive receiver categories, the proposed design goals are listed in **Table 77**. For design purposes, these goals may be regarded as applicable to the maximum 1 second rms vibration level, not to be exceeded by more than 5% of train passbys.

Table 77 Human Comfort Vibration Design Goals

Receiver Type	Period	Vibration Design Goal[1]
Residential	Day/Night	106 dB_V (0.2 mm/s)
Commercial (including schools and places of worship)	When in use	112 dB_V (0.4 mm/s)
Industrial	When in use	118 dB_V (0.8 mm/s)

Note 1: The vibration design goals are based on the maximum 1 second rms vibration level, not to be exceeded by more than 5% of train passbys.

In the case of railway tunnels, the ground-borne noise design goals, presented in **Section 13**, almost always dictate lower vibration levels than the vibration goals indicated in **Table 77**. Hence other than at specific facilities with particularly high sensitivity to vibration, compliance with the ground-borne noise design goals should ensure that the vibration design goals will also be achieved.

12.3 Ground-borne Vibration Modelling Methodology

12.3.1 Ground-borne Vibration Modelling

International Standard ISO 14837-1 2005 "*Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance*" provides useful guidance in relation to the extent of assessment that is normally required for new rail systems including:

- **Scoping Model** at the very earliest stages
- **Environmental Assessment Model** during planning process and preliminary design
- **Detailed Design Model** to finalise extent and form of mitigation for construction

At this stage of the CBD Metro Project, a combined Environmental Assessment / Detailed Design Model has been adopted to assess the potential impact of ground-borne noise and vibration levels and identify, in-principle, the extent of likely mitigation measures. A brief description of the modelling options is provided in **Figure 18**.

Figure 18 Ground-borne Vibration/Noise Modelling Approaches (from ISO 14837-1:2005(E))

A single model may be used for all stages with appropriate selection of input parameters (e.g. worst case for scoping assessment). Otherwise, three types of ground-borne vibration and/or ground-borne noise prediction model should be considered, as follows.

a) **Scoping model**: to be used at the very earliest stages of development of a rail system to identify whether ground-borne vibration and/or ground-borne noise is an issue and, if so, where the "hot spots" along the length of the system's alignment are located. This type of model should be used to generate input to either environmental comparative frameworks (as part of the selection of a mode of transport) or the scoping stage of an environmental assessment.

b) **Environmental assessment model**: to be used to quantify more accurately the location and severity of ground-borne vibration and/or ground-borne noise effects for a rail system and the generic form and extent of mitigation required to reduce or to remove the effects. This type of model should form part of the planning process for a scheme, developing the environmental statement where required and supporting preliminary design.

c) **Detailed design model**: to be used to support the detailed design and specification of the generic mitigation identified as being required by the environmental assessment model. This type of model should form part of the design and construction stages of a scheme, with particular focus on the rolling stock and permanent-way design.

In accordance with the ISO standard, the ground-borne noise and vibration modelling considers all of the parameters that are critical to determine the absolute levels of ground-borne noise and vibration, and the benefits (or otherwise) of different design and mitigation options. The key parameters are listed under the following headings:

- **Source** - route alignment, rolling stock design, rail type, trackform design, tunnel design, construction tolerances, operations and maintenance
- **Propagation Path** - ground type and vibration propagation wave types
- **Receiver** - Building construction

The following sections provide a brief summary of the modelling algorithms that have been adopted for the CBD Metro assessment.

12.3.2 Modelling Approach

The prediction of ground-borne vibration from rail systems is a complex and developing technical field. Whilst much research has been undertaken into various aspects associated with ground-borne noise and vibration from metro systems, there are currently no commercially available modelling software packages.

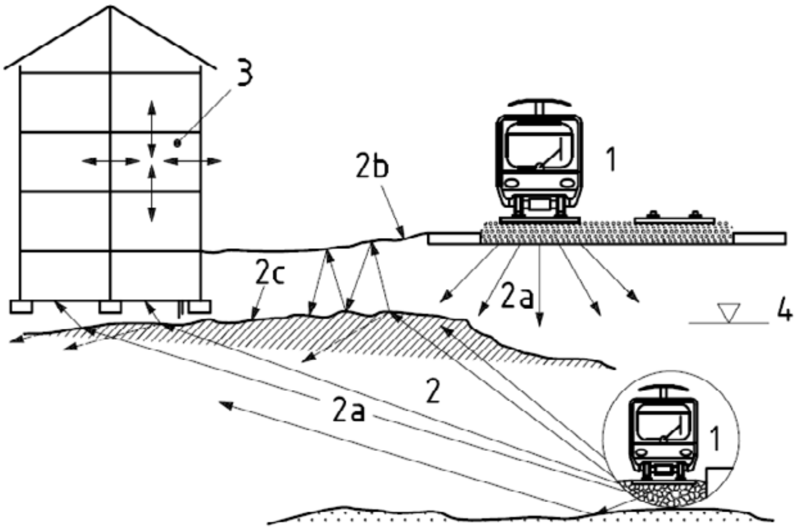
The modelling for the CBD Metro was therefore carried out using a Heggies-developed modelling process for the core calculations. The algorithms incorporated into the in-house model are well documented in authoritative references and are widely used within the acoustical consulting profession, both in Australia and internationally.

Furthermore, as part of the Epping to Chatswood Railway Line (ECRL) project, ground-borne noise and vibration measurements have been undertaken by Heggies whilst a test train was operated in the tunnel under controlled conditions. As part of this testing, Heggies undertook ground-borne noise and vibration measurements on the surface and within the tunnel at a number of locations. The results from this testing have been used to validate and refine the ground-borne noise and vibration modelling algorithms for the CBD Metro assessment.

The ECRL and proposed CBD Metro projects share similar design characteristics in relation to a circular tunnel cross-section, similar ground conditions and slab track design. Where differences exist between the ECRL and CBD Metro (eg rolling stock and maintenance practices), these have been accounted for in the ground-borne noise and vibration predictions.

The modelling approach is illustrated in **Figure 19** and takes into account the source vibration levels, the vibration propagation between the tunnel and nearby building foundations, and the propagation of vibration within the building elements. A summary of the key modelling assumptions are provided in the following sections.

Figure 19 Example of Source, Propagation and Receiver System (ISO 14837)



Key

1 source

2 propagation:
- 2 a body waves (compression, shear)
- 2 b surface waves (e.g. Rayleigh, Love)
- 2 c interface waves (e.g. Stoneley)

3 receiver (vibration, re-radiated noise)

4 water table

NOTE The components of the system comprising source, propagation and receiver are interdependent.

12.3.3 Source Vibration Levels

Source vibration levels within tunnels are dependent on a number of factors including the track design, train type, train speed, wheel condition, ground conditions and tunnel design.

As new single-deck trains are proposed to operate on the CBD Metro, it has been necessary to undertake a desktop assessment of similar rail projects to determine the typical source vibration levels to be used as a starting point for the modelling.

In undertaking this desktop assessment, it is noted that the proposed CBD Metro trains are smaller and lighter than the double-deck trains that currently operate in Sydney, resulting in comparatively lower source vibration levels.

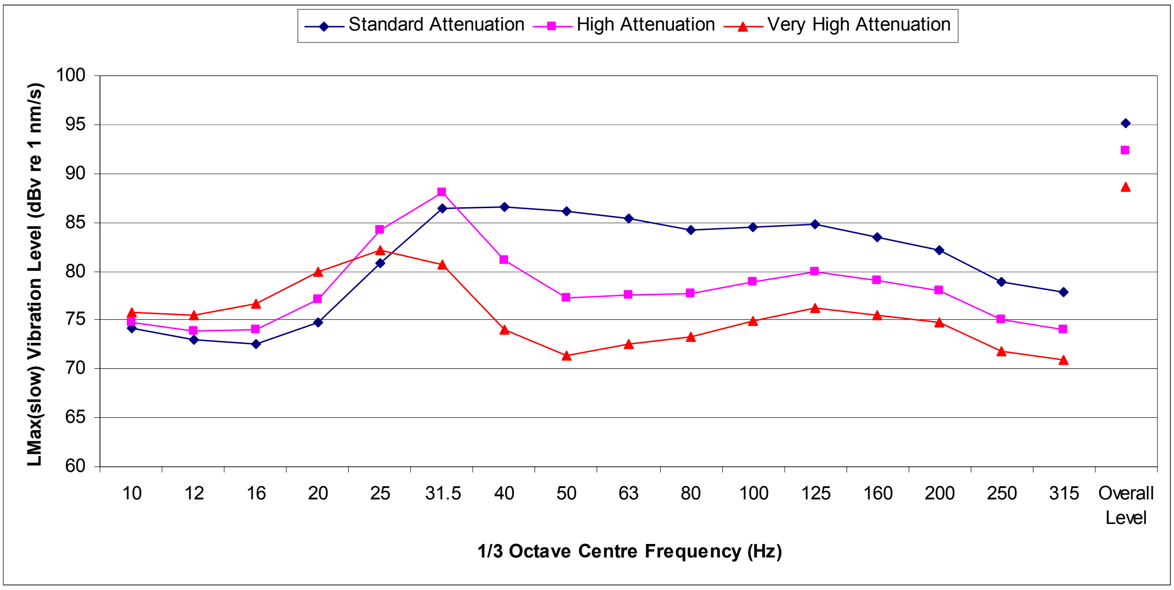
Standards will also be adopted to ensure that the condition of the train wheels and rails are maintained within the specified roughness limits (relating to source noise and vibration levels). These limits are more stringent than what is applied on existing lines in Sydney and will therefore result in lower source vibration levels.

A summary of the reference vibration levels for three forms of track are provided in **Table 78** and **Figure 20**. These trackforms are CBD Metro specific, taking into account the relevant design factors, and are described below under the "trackform design" heading.

Table 78 Reference Source Vibration Levels for CBD Metro Trains (Tunnel Wall Vibration Levels at reference speed of 80 km/h) - Lmax Slow Response

Track Type	1/3 Octave Vibration Levels (dB_V re 1 nm/s)																Overall Level
	10 Hz	*12 Hz*	*16 Hz*	*20 Hz*	*25 Hz*	*31.5 Hz*	*40 Hz*	*50 Hz*	*63 Hz*	*80 Hz*	*100 Hz*	*125 Hz*	*160 Hz*	*200 Hz*	*250 Hz*	*315 Hz*	
Standard Attenuation	74	73	72	75	81	86	87	86	85	84	84	85	83	82	79	78	95
High Attenuation	75	74	74	77	84	88	81	77	78	78	79	80	79	78	75	74	92
Very High Attenuation	76	76	77	80	82	81	74	71	72	73	75	76	76	75	72	71	89

Figure 20 Reference Source Vibration Levels for CBD Metro Trains (Tunnel Wall Vibration Levels at Reference Speed of 80 km/h) - Lmax Slow Response



Route Alignment

For much of the CBD Metro alignment, the tunnels are located below major roads including Pitt Street, Castlereagh Street, Margaret Street, and Victoria Road. From a ground-borne noise and vibration perspective, this is advantageous because in many areas, the nearest receptors are of a commercial or industrial nature and are therefore not highly susceptible to ground-borne noise and vibration emissions.

Furthermore, as the background noise levels from road traffic are likely to be relatively high adjacent to major roads, the potential impact of ground-borne noise from train operations is reduced compared to quiet suburban locations. In areas where background noise levels from road traffic are lower, the potential impact of ground-borne noise levels from train operations would be greater for the same noise levels.

On curved track, wear patterns and vehicle steering characteristics can affect the source vibration emissions at the wheel rail interface. The risk of poor rail condition (such as corrugation) is also greater on curves than on straights, as is the risk of other effects, such as heavy flanging.

For track radii less than approximately 600 m, measurements undertaken by Heggies on the Singapore Circle Line indicated that there is a general increase in source vibration levels of approximately 5 dB. On this basis, 5 dB has been added to the source vibration levels at the locations identified in **Table 79**.

Table 79 Location of Curve Radii 600 m or Less

Down Track			**Up Track**		
Start of Curve (km)	**End of Curve (km)**	**Curve Radius (m)**	**Start of Curve (km)**	**End of Curve (km)**	**Curve Radius (m)**
Main Line					
-0.32	0.22	300	-0.32	0.22	300
0.20	0.58	390	0.20	2.59	403
0.70	0.78	300	0.71	0.79	313
0.91	0.99	350	0.92	1.10	336
1.36	1.40	880	1.36	1.39	520
1.49	1.64	230	1.49	1.66	230
1.68	1.82	230	1.70	1.83	230
2.04	2.45	230	2.05	2.49	243
2.58	2.61	500	2.62	2.65	513
2.88	3.12	340	2.92	3.17	353
3.29	3.68	540	3.34	3.72	527
3.99	4.24	500	4.03	4.26	465
4.41	4.46	570	4.44	4.49	587
5.57	5.66	500			
5.80	5.84	300			
Depot Connection					
Towards Rozelle			**From White Bay**		
0.00	0.39	190	0.00	0.22	190
			0.29	0.39	190

Note 1: Positive values represent locations north of Central Metro Station. Negative Values represent locations south of Central Station.

Rolling Stock Design

The proposed trains are approximately 135 m long[1] in a 6-car[2] configuration with a maximum axle load of approximately 15 tonnes. The proposed CBD Metro trains will incorporate regenerative brakes, friction disc brakes (at low speeds) and anti-skid systems to ensure that the wheel running profile remains smooth.

On the basis that the Singapore Northeast trains have been provided as a reference, the ground-borne noise modelling assumes an unsprung axle load of 1941 kg/axle.

Other rolling stock variables such as wheel diameter, wheel tread profile, axle spacing, bogie spacing, suspension stiffness and the modal properties of the train body will need to be considered in more detail when information on the proposed rolling stock is available. At this stage in the assessment process, these variables are not considered to be significant.

Rail Type

The proposed rail type for CBD Metro Project is 60 kg/m rail.

Trackform Design

The trackform design and its interaction with the rolling stock under consideration is one of the primary ways in which ground-borne noise and vibration can be minimised on new underground railway lines.

The broad principles of vibration isolation of railways consist of the reduction of the dynamic stiffness of the track support, and further, the introduction of (or increase in the mass of) elements of the track support, plus adjustments to damping. In general, the lower the natural frequency of the track support system, the better the vibration isolation. Low natural frequency is achieved by increased mass and reduced dynamic stiffness.[3]

A ballastless (concrete slab) trackform is proposed. The Reference Design notes that there are many types of trackforms available, however a standard booted sleeper design is proposed as standard. High attenuation booted sleepers would be provided for more sensitive areas where the standard design is not sufficient to achieve the noise design goals.

For the purpose of the Reference Design, generic performance data has been obtained for the Sonneville booted embedded sleeper options. A summary of the dynamic stiffness properties of the "Standard" and "High Attenuation" versions of the Sonneville system is provided in **Table 80**. Also included in **Table 80** are the equivalent dynamic stiffness properties for the Delkor fasteners used on the ECRL and the Pandrol fasteners used in the Perth Metro.

The dynamic stiffness values in **Table 80** indicate that the Sonneville Standard and ECRL Alt 1 fasteners have similar dynamic stiffness values. The Sonneville High Attenuation and ECRL Egg fasteners also have similar dynamic stiffness values.

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1 Trains proposed to be 137 m long, but have been rounded to the nearest 5 m for modelling purposes.

2 The project has been designed to accommodate 6-car rolling stock, however it is likely that only a 5-car configuration would be required upon commissioning in 2015. The number of cars per metro train would increase as demand for the metro also increases.

3 Association of Noise Consultants (ANC Guidelines), 2001, "*Measurement and Assessment of Groundborne Noise & Vibration"*, Page132

For the current assessment, it is assumed that the vibration attenuation provided by the above systems is similar on the basis of the equivalent dynamic stiffness values. In practice, the vibration attenuation performance will also be affected by other parameters including the loss factor (damping), mass and dynamic interaction with the tunnel and rolling stock. Furthermore, various testing methods are employed in order to calculate the static and dynamic stiffness values of different systems which makes a direct like for like comparison difficult. These other factors will be investigated as part of the detailed design.

Care also needs to be exercised during the detailed design stage to ensure that a low stiffness track design does not give rise to excessive passenger comfort vibration levels or unacceptable reliability, availability, maintainability and safety (RAMS) implications.

For the ground-borne vibration modelling undertaken for CBD Metro Project, the source vibration levels with ECRL Egg fasteners have been adopted as a reference, on the basis of attended measurements undertaken by Heggies on the ECRL (refer to **Section 12.3.2**). The Sonneville High Attenuation system is assumed to provide an equivalent acoustic performance on the basis that the dynamic stiffness of the rail fastening system is similar.

For the Sonneville Standard and Pandrol Vanguard fastening system, the relative performance (compared with Sonneville High Attenuation) has been evaluated using a Single Degree of Freedom (SDoF) analysis including the unsprung axle mass of the rolling stock and rail pad stiffness per track metre. The Reference Design assumes a rail fastener spacing of 700 mm for all trackform options.

In the ground-borne vibration assessment, the following three trackform options have been evaluated:

- **Standard Attenuation Track** - Ground-borne noise performance equivalent to Sonneville Standard Attenuation Low Vibration Track System (Booted Sleepers) - or equivalent from other suppliers/systems. Assumed dynamic stiffness of 28 kN/mm.
- **High Attenuation Track** - Ground-borne noise performance equivalent to Sonneville High Attenuation Low Vibration Track System (Booted Sleepers) - or equivalent from other suppliers/systems. Assumed dynamic stiffness of 12 kN/mm.
- **Very High Attenuation Track** - Ground-borne noise performance equivalent to the Pandrol Vanguard Direct Fix Track System - or equivalent from other suppliers/systems. Assumed dynamic stiffness of 6 kN/mm.

The source vibration levels for the above trackforms are provided in **Table 78**.

Table 80 Stiffness Properties of Sonneville, Delkor and Pandrol Rail Fasteners

Fastener Type	Static Stiffness[1,2]	Dynamic Stiffness[1,2]	Dyn/Stat Ratio	Comments
Standard Rail Fasteners				
Sonneville Standard	18 kN/mm	27 kN/mm	1.5	Mass of Block 100 kg
ECRL Alt 1	20 kN/mm	28 kN/mm	1.4	As installed on ECRL
Delkor Alt 1	12 - 30 kN/mm	17-42 kN/mm	1.4	Stiffness options can be varied to suit
Pandrol Vipa	17 - 20 kN/mm	17-21 kN/mm	1.05	-
High Attenuation Rail Fasteners				
Sonneville High Attenuation	8 - 9 kN/mm	12 - 13 kN/mm	1.5	Mass of Block 127 kg
ECRL Delkor Egg	10 kN/mm	12 kN/mm	1.2	As installed on ECRL
Delkor Egg	6 - 15 kN/mm	8 - 20 kN/mm	1.3	Stiffness options can be varied to suit
Very High Attenuation Rail Fasteners				
Pandrol Vanguard	3 - 5 kN/mm	5 - 7.5 kN/mm	1.5	Assume Dynamic Stiffness of 6 kN/mm for Modelling
Low Profile Delkor Egg	6 kN/mm	7.2 kN/mm	1.2	Stiffness options can be varied to suit

Note 1: The Static and Dynamic stiffness values have been obtained from product brochures (for Delkor and Pandrol products), from the ECRL 100% Design Report (for the ECRL Alt 1 and Egg products) and via e-mail correspondence with the manufacturer (for the Sonneville products).

Note 2: Various testing methods are employed in order to calculate the static and dynamic stiffness values of different systems. This makes a direct like for like comparison of the different systems difficult.

Turnouts

The Reference Design alignment has turnouts at a number of locations. As there is a discontinuity in the rail running surface at these locations, vibration levels will be higher than on smooth continuous track. Turnout locations are provided in **Table 81**.

Table 81 Turnout Locations

Turnout Chainage (km)	
Down Track	**Up Track**
-0.17	-0.17
0.03	-0.03
5.16	5.08
5.4	6.06
5.74	6.19
6.03	
6.17	

References such as the US FTA "*Transit Noise and Vibration Impact Assessment*" indicate that vibration levels are typically 10 dB higher adjacent to turnouts, which is in accordance with Heggies experience on similar projects. This adjustment has been incorporated into the model for a 10 m track increment at each turnout. Increases in overall vibration levels at receiver locations are less than 10 dB, as the 10 m track increment represents only a portion of the total train vibration emission.

The increase in vibration levels can be significantly reduced by the installation of swing nose or spring wing crossings in lieu of standard crossings. Crossings of these types do not include a discontinuity at the frog (crossing point), thus significantly reduce the impulsive vibration levels. For the swing nose crossings installed in the Chatswood Rail Enclosure Structure, Heggies has observed a reduction in the ground-borne vibration levels compared with standard crossings. The degree of ground-borne noise and vibration reduction has however not been quantified through measurements.

For the Reference Design, the location of the proposed turnouts are not sufficiently close to sensitive receivers to warrant the installation of swing nose crossings. This would need to be assessed in further detail if the location of the proposed turnouts change during detailed design.

Tunnel Design

The design properties of the tunnel including the diameter, wall thickness and material properties influence the vibration energy transmitted into the surrounding ground. An inside diameter of 5.7 m and tunnel lining of 275 mm has been evaluated for the CBD Metro design.

Construction Tolerances

Construction tolerances refer to factors such as the variation in stiffness values between rail fasteners, the quality of the track construction and any change in stiffness values with time.

The potential effect of construction tolerances has not been evaluated as part of CBD Metro assessment and will be addressed in detailed design. These effects are not anticipated to be significant.

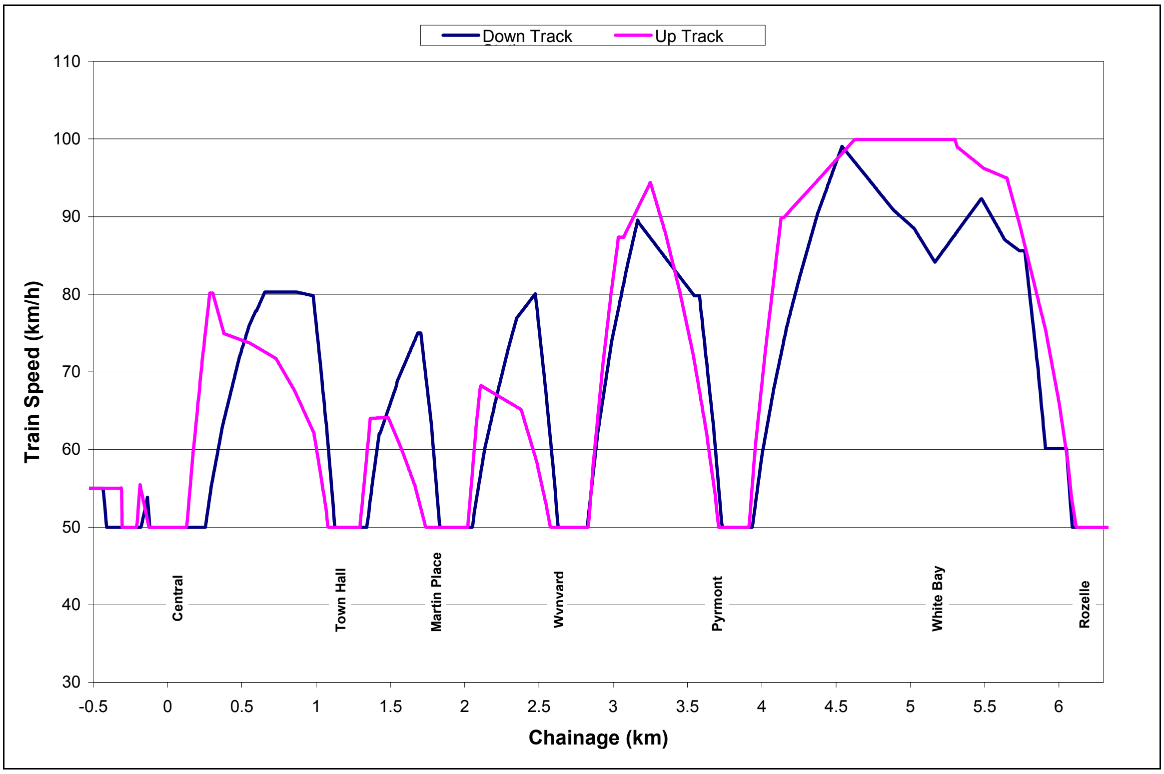
Operations

The main factors associated with operational patterns are the train speeds and timetabling.

The speed profile for the Reference Design is provided in **Figure 21**. For the purpose of the ground-borne noise and vibration modelling, the minimum speed was capped at 50 km/h at the stations.

A maximum train speed of 35 km/h is anticipated for the section of track between the main alignment and the maintenance and stabling facility.

Figure 21 Speed Profile for CBD Metro



For train operations in tunnels, the vibration levels typically increase by 6 dB for each doubling of train speed. This relationship has been observed by Heggies on other projects (including ECRL) and has therefore been adopted for the CBD Metro modelling.

The reference vibration levels adopted in the modelling process are for a train speed of 80 km/h (refer **Table 78**). **Figure 21** shows that for the CBD Metro, train speeds are expected to range up to 100 km/h. Speed adjustment of the 80 km/h reference vibration levels have therefore been made using the following formula on a 1/3 octave frequency basis:

$$V(speed\_adjusted) = V(reference) + 20\log_{10}\left(\frac{speed}{80}\right)$$

For automated train operations, it is possible that trains could be timetabled to cross in separate directions below the same receiver location on a regular basis. The maximum increase in ground-borne noise and vibration levels would be up to 3 dB in the worst case situation. In most cases, the increase in ground-borne noise levels would be 1 dB or 2 dB.

The potential impact of passing trains at particular receiver locations on a regular basis has not been evaluated as part of CBD Metro. Should such events occur during operations and the resulting ground-borne noise or vibration levels exceed the design goals, consideration will need to be given to scheduling trains to cross at less sensitive locations.

As the proposed CBD Metro will incorporate a captive fleet, the variation in source vibration levels from train to train is anticipated to be much smaller than an equivalent system with a variety of different rolling stock (such as the CityRail network). As such, the ground-borne vibration modelling assumes that the source vibration levels of the rolling stock will vary in accordance with a normal distribution having a standard deviation of 2 dB. This results in a 95th percentile vibration level approximately 3 dB higher than the mean or 50th percentile level. This factor is incorporated into the source vibration levels in **Table 78**.

Maintenance

The maintenance of the track and rolling stock can have a significant influence on the ground-borne noise and vibration levels. For modelling purposes, a correction of 3 dB has been applied to account for progressive deterioration in wheel and track condition between maintenance activities. This is incorporated into the source vibration levels in **Table 78**.

In the case of poor track condition, it is assumed that rail grinding would be undertaken if the surface roughness values of the track are outside the permitted tolerances. Furthermore, it is also assumed that the condition of the track would be monitored on a regular basis using on-car or hand-held monitoring equipment.

In the case of poor wheel condition, it is assumed that the potential for wheel flats would be minimised through design. If wheel flats or other wheel defects do occur however, it is assumed that these would be identified by a permanent monitoring station and rectified using a wheel lathe or other measures to return the wheel condition to an acceptable degree of smoothness.

12.3.4 Propagation Path

The propagation of vibration through the ground is a complex phenomenon. Even for a simple source, the received vibration at any point includes the combined effects of several different wave types, plus reflections and other effects caused by changes in ground conditions along the propagation path.

Attenuation with distance occurs due to the geometric spreading of the wave front and due to other losses within the ground material, known as “damping”. The attenuation due to geometric spreading occurs equally for all frequencies, whereas the damping component is frequency dependent, with greater loss per metre occurring at high frequencies than at low frequencies.

In the modelling process, the various vibration wave contributions are not sufficiently defined to allow them to be calculated separately. Analytical techniques such as finite element analysis and boundary element analysis would require the ground and buildings to be modelled in great detail to represent the propagation path over the required frequency range. Otherwise, the modelling process could introduce large inaccuracies that may be difficult to trace.

Given the extensive land area along the proposed alignment, such an approach at this stage of the assessment is not feasible (and would only be undertaken at critical locations during detailed design). As such, the CBD Metro modelling was carried out using a combination of theoretical and empirical relationships to determine the attenuation and/or amplification of the ground-borne vibration levels.

Vibration Attenuation due to Geometric Spreading

For geometric spreading, the 135 m long train was modelled as a cylindrical line source based on the estimated tunnel wall vibration levels at a distance of 2 m from the track centreline. For this project, the trains were represented by point sources spaced at 2 m intervals, with the distance attenuation from each point calculated according to the following formula:

$$V(spreading) = 10\log_{10}\left(\frac{2}{Distance}\right)$$

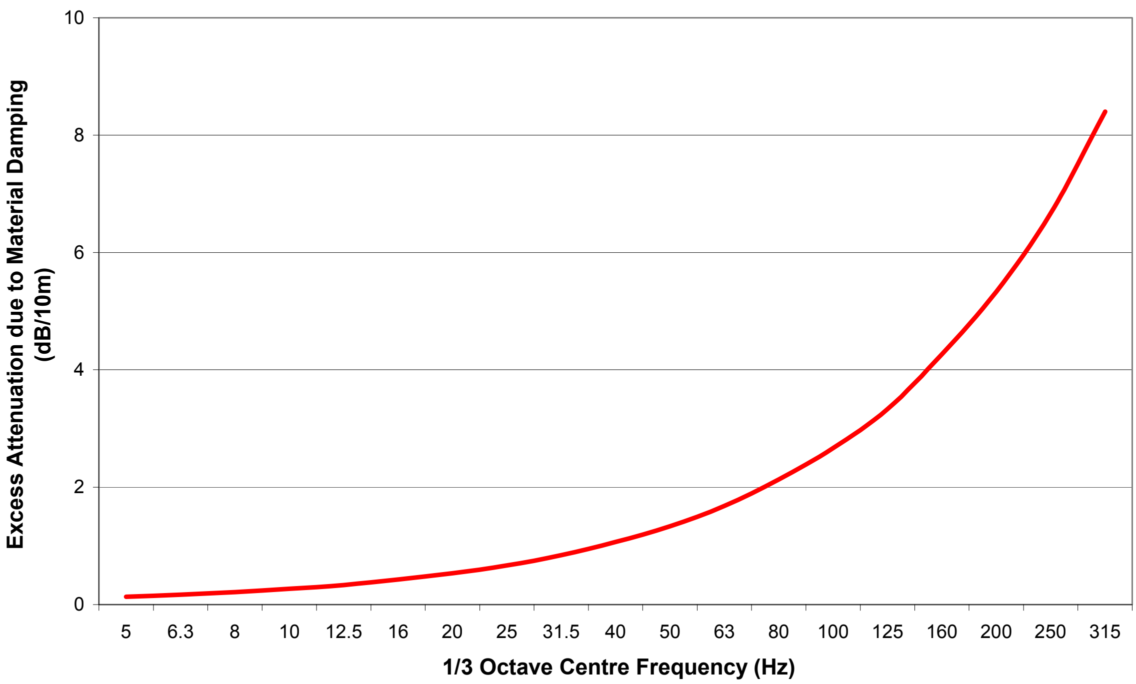
where;

> *V(spreading)* is the change in vibration level (in dB), distance is the slant distance between the point source and the receiver location and 2 m is the reference distance of the source vibration spectrum.

Vibration Attenuation due to Material Damping

The excess attenuation due to material damping was based on force transmissibility measurements undertaken by Wilkinson Murray Pty Ltd for the ECRL. These levels (refer **Figure 22**) were adopted on the basis that the predicted results provided a good estimate of the measured damping values at the majority of test locations across the ECRL project area. Geological surveys indicate that the predominant ground type in the project area is Hawkesbury Sandstone. This is consistent with geology for the ECRL. On this basis, it is reasonable to assume that the ground conditions on the CBD Metro will be similar to the ECRL.

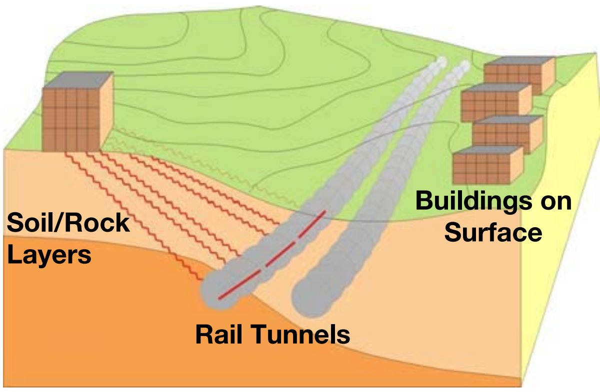
Figure 22 Excess Attenuation Due to Material Damping



Three-Dimensional Modelling

The importance of undertaking three-dimensional modelling is illustrated using the graphical representation in **Figure 23**. For a 135 m long vibration source, changes in trackform or train speed, crossovers, curves and other local characteristics can result in variations in vibration emissions within the zone of influence of a given building. Hence, it is desirable for modelling to represent the train over its full length. In other words, it is necessary to model the tunnel in three dimensions, rather than as a simple cross section as illustrated in **Figure 19**.

Figure 23 Graphical Representation Indicating Possible Propagation Paths from a Train in a Tunnel



12.3.5 Receiver

Propagation of Vibration into Buildings

With many types of building, a coupling loss occurs at the ground/footing interface, resulting in lower levels of vibration in the building's footings than in the surrounding ground. The model permits assessment with a variety of coupling loss categories, or, alternatively, zero coupling loss can be specified.

For several buildings within the CBD, it is likely that the building footings will be founded on the underlying sandstone. On this basis, a conservative coupling loss midway between zero and that for a single level building has been assumed in the ground-borne noise and vibration modelling for all buildings.

Table 82 Coupling Loss Values (dB)

Building Type	Coupling Loss (dB) in 1/3 Octave Bands																		
	5 Hz	6.3 Hz	8 Hz	10 Hz	12 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz
Values adopted for CBD Metro	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2
Large Masonry on Piles	6	6	6	6	7	7	7	8	9	10	11	12	13	13	14	14	15	15	15
Large Masonry on Spread Footings	11	11	11	11	12	13	14	14	15	15	15	15	14	14	14	14	13	12	11
2-4 Storey Masonry on Spread Footings	5	6	6	7	9	11	11	12	13	13	13	13	13	12	12	11	10	9	8
1-2 Storey Commercial	4	5	5	6	7	8	8	9	9	9	9	9	9	8	8	8	7	6	5
Single Residential	3	3	4	4	5	5	6	6	6	6	6	6	6	5	5	5	4	4	4

Note: Coupling loss values have been obtained from Nelson[4] and have been extrapolated to include frequency bands below 16 Hz.

Propagation of Vibration within Buildings

Losses also occur with the transfer of vibration from floor-to-floor within buildings. The model incorporates the losses listed in **Table 83**, which are based on data presented by Nelson (1987), extrapolated to include frequency bands below 16 Hz. The ground-borne noise and vibration levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter.

Table 83 Floor-to-Floor Loss Values

Floor Level Above Grade	Floor to Floor Loss (dB) in 1/3 Octave Bands																		
	5 Hz	6.3 Hz	8 Hz	10 Hz	12 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz
1	1	1	1	1	1.5	1.5	1.5	2	2	2	3	3	3	2	2	2	3	3	3
2	1	1	1	1	1.5	1.5	1.5	2	2	2	2	2	2	3	3	3	3	3	3

Note: The floor to floor losses in this table are additive (ie for assessment on the second level above ground, the loss at 50 Hz would be 5 dB).

Low frequency vibration can be amplified within buildings by resonances in floors and walls. On the basis of data presented by Nelson (1987), the amplification spectrum presented in **Table 84** has been adopted. Nelson indicates that amplification values found in practice are typically within ±3 dB of these values. Slightly lower values are assumed for the ground-borne noise calculations as the ANC Guidelines indicate that using the full floor amplification values can result in over-estimation of the resultant noise.

The values in **Table 84** have been adopted in the CBD Metro model for all receivers.

4 Nelson, J. - Transportation Noise Reference Book (1987)

Table 84 Amplification within Buildings

Calculation Type	Amplification (dB) in 1/3 Octave Bands																		
	5 Hz	6.3 Hz	8 Hz	10 Hz	12 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz	250 Hz	315 Hz
Floor Vibration	10	10	10	10	10	10	10	11	11	11	10	9	9	-	-	-	-	-	-
Ground-borne Noise	-	-	-	-	-	-	6	7	7	7	6	6	5	5	4	3	2	1	1

Note: Note that the frequency range used for vibration assessment is 5 Hz to 80 Hz and the frequency range for ground-borne noise assessment is 20 Hz to 315 Hz.

12.4 Ground-borne Vibration Predictions

On the basis of the ground-borne vibration modelling assumptions discussed above, **Figure 24** and **Figure 25** present a summary of the predicted ground-borne vibration levels for buildings located above or near the proposed rail alignment.

The predicted ground-borne vibration levels represent the maximum mid-floor vibration levels within multi-storey buildings. For a building with a slab on ground construction, the highest vibration levels would be expected to occur on level 2, due the amplification resulting from the suspended slab. Calculations are based on the Standard Attenuation trackform.

Figure 24 Main Line Predicted Ground-borne Vibration Levels (Standard Attenuation Track)

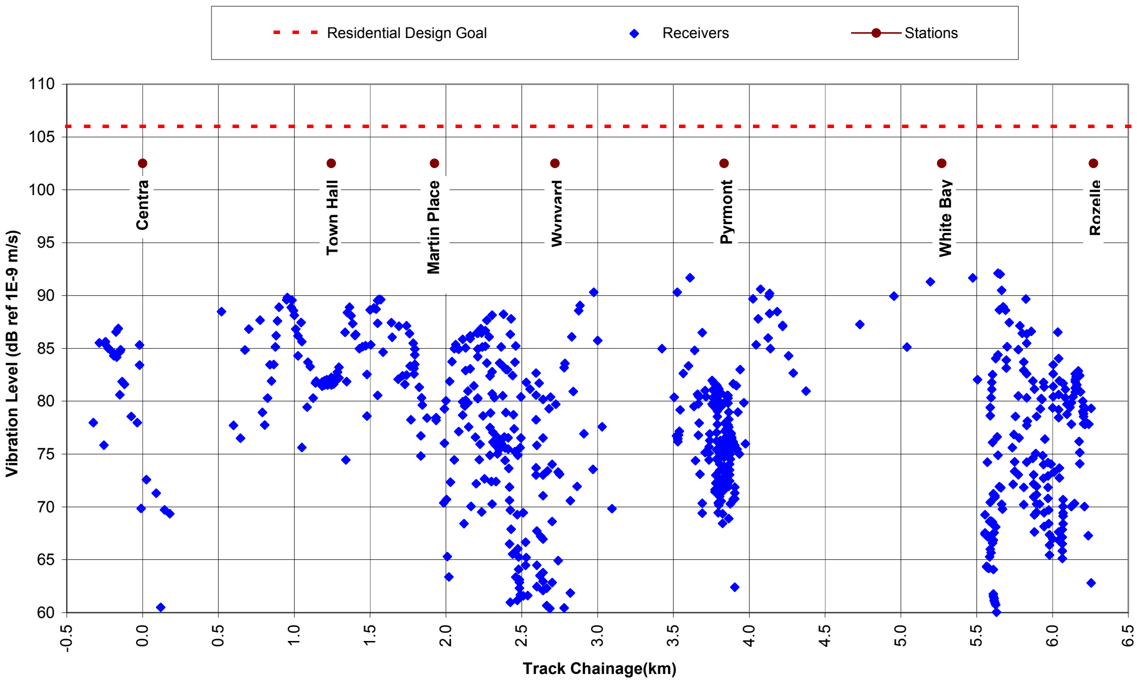
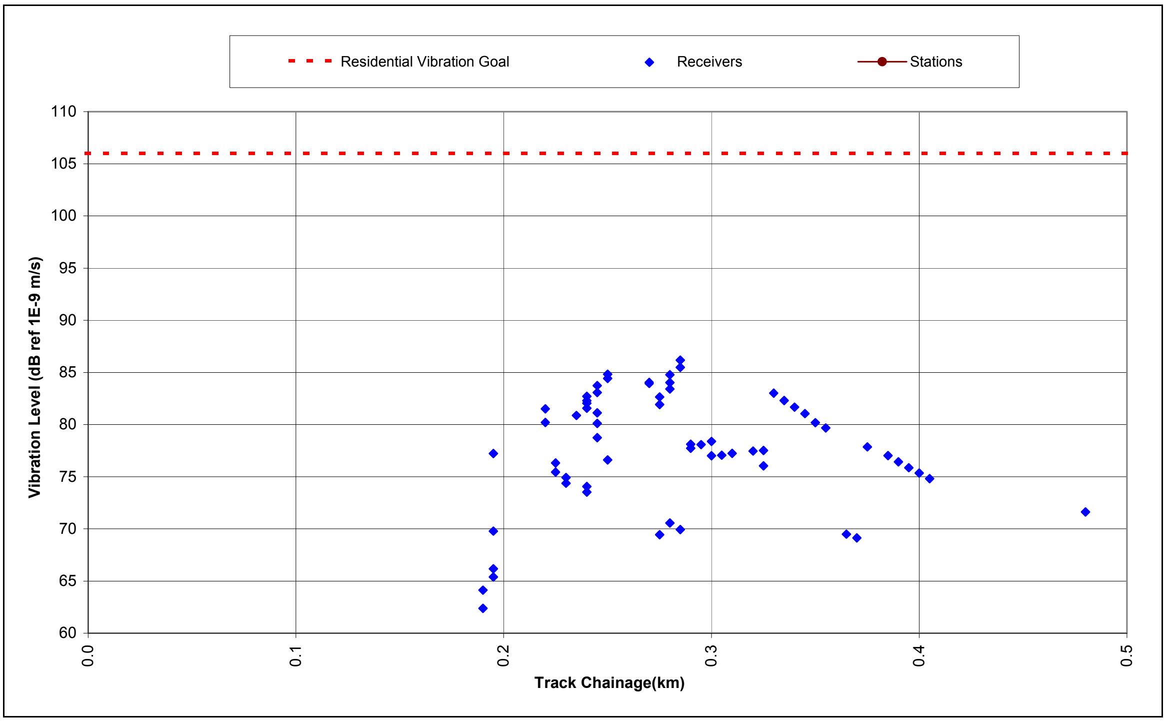


Figure 25 Maintenance Depot Connection Ground-borne Vibration Levels



12.5 Ground-borne Vibration Assessment

As discussed in **Section 12.2**, the human comfort (perception) goals for ground-borne vibration tend to be more stringent than other possible design goals relating to building damage risk or the potential effects on building contents. The most stringent ground-borne vibration design goal is 106 dB_V for residential buildings (refer **Table 77**).

On the basis of the speed profile for the CBD Metro (refer **Figure 21**) and on the proposed vertical alignment and the modelling assumptions described in the previous sections, compliance with the ground-borne vibration goals is predicted for all sensitive receiver locations above or near the proposed alignments.

Heritage Structures

The DG's requirements require an assessment of the potential vibration impacts to heritage structures. As discussed in **Section 7.3**, a conservative vibration damage screening level of 7.5 mm/s (138 dB_V) has been adopted for assessment purposes. This is applicable to all buildings including heritage structures.

The predicted vibration levels associated with train operations are approximately two orders of magnitude (100 times) lower than the vibration damage screening level at the nearest buildings and therefore the risk of damage is negligible. Similarly, the potential for damage to other key utilities/ infrastructure is also negligible on the basis that the tunnel wall vibration levels are anticipated to be less than 100 dB_V.

12.6 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. **Table 85** details the draft SoC associated with the ground-borne vibration assessment for the CBD Metro.

Table 85 Draft Statement of Commitments - Ground-borne Vibration Assessment - Train Operations

Report Section	Measure Type	Commitment	Desired Environmental Outcome
12.2	Manage	A ground-borne vibration level of 106 dB_V (0.2 mm/s rms) has been adopted as a design goal. This goal is based on residential receivers with higher levels being applicable for commercial and industrial buildings.	Ensure that vibration levels during train passbys do not cause disturbance to building occupants

13 GROUND-BORNE NOISE ASSESSMENT - TRAIN OPERATIONS

13.1 Introduction

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. The vibration is initially generated by wheel/rail interaction (by the mechanisms described in **Section 12.3**) and is transmitted from the trackbed, through the tunnel structure, via the ground and into the adjacent building structures (as illustrated in **Figure 19**). After entering a building, this vibration causes the walls and floors to vibrate faintly and hence to radiate noise (commonly termed "ground-borne noise").

If it is of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be experienced in buildings adjacent to many urban underground rail systems, including several buildings close to the existing CityRail tunnels in the Sydney CBD.

In some CBD buildings, the rumbling noise can sometimes be heard several storeys above ground level where no precautions have been taken in the tunnel or building design to limit ground-borne noise and vibration effects. For most new railway lines (including the ECRL and the CBD Metro), the standard track design usually incorporates resilient rail fasteners to reduce the dynamic forces that occur at the wheel-rail interface. This resilience also serves to provide some isolation of ground-borne vibration, which in turn reduces the ground-borne noise levels in buildings near the railway tunnel.

The fact that ground-borne train noise may be audible does not necessarily indicate that it is offensive or disturbing. In many cases, the train noise may pass unnoticed due to the "masking" effect of other ambient noise sources, activities or distractions.

Some especially sensitive spaces and activities, such as theatres, cinemas, studios and sleeping areas are more prone to disturbance from ground–borne noise than others, such as shopping areas, office spaces or industrial premises.

13.2 Ground-borne Noise Goals

The ground-borne noise and vibration assessment is required to be undertaken in accordance with the requirements of the Department of Environment, Climate Change and Water's (DECCW's) "*Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects*" (IGANRIP). The noise design goals contained within this guideline are expressed as non-mandatory "trigger levels", which if exceeded will trigger the need to consider feasible and reasonable mitigation measures.

A summary of the ground-borne noise trigger levels is provided in **Table 86**.

Table 86 IGANRIP Ground-borne Noise Trigger Levels for Sensitive Receivers

Receiver	Time of day	Noise trigger levels dB(A)
		Development increases existing rail noise levels by 3 dB(A) or more ***and*** resulting rail noise levels exceed:
Residential	Day (7 am–10 pm)	40 L_{Amax} (slow)
	Night (10 pm–7 am)	35 L_{Amax} (slow)
Schools, educational institutions, places of worship	When in use	40–45 L_{Amax} (slow)

The ground-borne noise levels in **Table 86** refer to noise contributed from the proposed rail operations only and do not include ambient noise from other sources such as major roads and industry. The train noise levels are evaluated inside buildings at the centre of the most affected habitable room.

"Residential" typically means any residential premises located in a zone as defined in a planning instrument that permits new residential land use as a primary use. The L_{Amax} noise level refers to the 95th percentile train passby event (ie 5% of train passbys are permitted to exceed the trigger levels). The absolute maximum event is not used for design, as it cannot be precisely defined and would be a highly infrequent event. The ground-borne noise level of the "average" or median train event would typically be approximately 3 dB lower than the 95th percentile event.

For new rail projects, the noise trigger levels apply immediately after operations commence and for projected traffic volumes over an indicative period into the future that represents the expected typical level of rail traffic usage (eg 10 years or a similar period into the future).

For schools, educational institutions and places of worship, the lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.

The guideline also states:

> *"It appears reasonable to conclude that ground-borne noise at or below 30 dB LAmax will not result in adverse reactions, even where the source of noise is new and occurs in areas with low ambient noise levels. Levels of 35–40 LAmax are more typically applied and likely to be sufficient for most urban residential situations, even where there are large numbers of noisy events.*
>
> *The noise trigger levels … are aimed at providing a reasonable basis for triggering the assessment of impacts from ground-borne noise. They are necessarily set to the lower end of the range of possible trigger values so that potential impacts on quieter suburban locations are addressed. In practice, higher levels of ground-borne noise than the trigger level for assessing impacts may be suitable for urban areas where background noise levels are relatively high."*

As the CBD Metro represents an entirely new rail infrastructure project incorporating new rolling stock and trackform designs, the noise trigger levels should be viewed as "design goals" which are to be achieved at all locations where this is considered to be feasible and reasonable.

For residential receivers, this results in a ground-borne noise design goal of 35 dBA $L_{Amax,slow}$. For schools, educational institutions and places of worship, this results in a noise design goal of 40 dBA to 45 dBA $L_{Amax,slow}$.

For commercial receivers, shopping centres and industrial buildings, IGANRIP does not provide guidance on acceptable levels. On other projects, Heggies has applied ground-borne noise goals of 45 dBA for general office areas and 50 dBA to 55 dBA for retail areas depending on the particular sensitivity of the receiver. A ground-borne noise design goal of 40 dBA is desirable for commercial receivers with private offices or conference rooms.

Provided in **Table 87** is a summary of the proposed ground-borne noise goals for the CBD Metro incorporating these receiver types.

Table 87 CBD Metro Ground-borne Noise Design Goals for Sensitive Receivers

Receiver	Time of Day	Noise Trigger Level (dBA)
Residential	Day (7.00 am to 10.00 pm)	40 dBA
	Night (10.00 pm to 7.00 am)	35 dBA
Schools, educational institutions, places of worship[1]	When in use	40 dBA to 45 dBA
Retail Areas	When in use	50 dBA to 55 dBA
General Office Areas	When in use	45 dBA
Private Offices and Conference Rooms	When in use	40 dBA
Theatres	When in use	35 dBA

Note 1: The lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.

13.3 Ground-borne Noise Modelling Methodology

The ground-borne noise modelling methodology followed the same calculation procedure discussed in **Section 12.3** for the ground-borne vibration modelling, with the addition of two final steps to account for the conversion of surface vibration into noise.

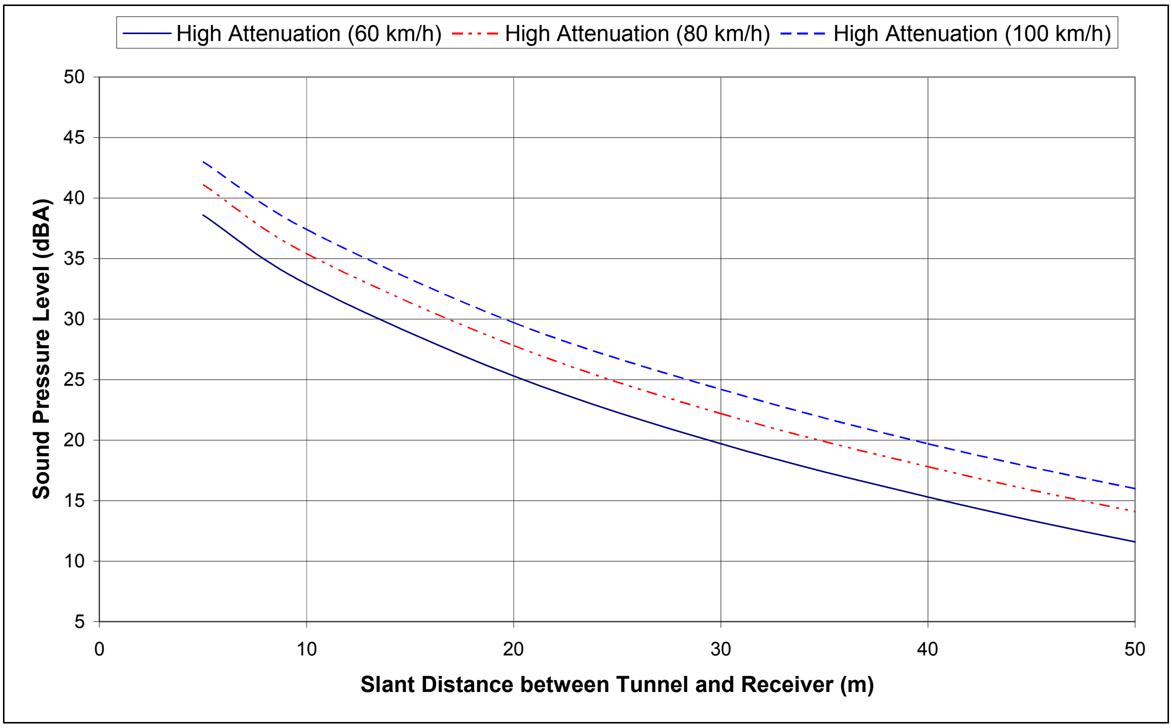
In accordance with Nelson (1987) and the ANC Guidelines (2001), an adjustment of -27 dB was used in the model to convert each 1/3 octave band vibration level (dB_V re 1E-9 m/s) to a sound pressure level (dB re 20 μPa). The 1/3 octave band sound pressure levels were then A-weighted and logarithmically summed to provide the overall $L_{Amax(slow\ response)}$ noise level predictions.

13.3.1 Ground-borne Noise Prediction Curve

On the basis of the ground-borne noise and vibration modelling assumptions discussed in **Sections 12.3** and **13.3**, **Figure 26** presents a summary of the predicted ground-borne noise levels at various distances from the proposed railway tunnel for train speeds of 60 km/h, 80 km/h and 100 km/h, assuming a "High Attenuation" trackform design.

This figure is illustrative only and its purpose is to show how ground-borne noise levels are dependent on speed and reduce as the distance between the tunnel (rail level) and receiver increases. The distances are slant distances, and are therefore dependent on the depth of the tunnel (rail level) as well as the horizontal offset distance. For the modelling results presented in the following section, the ground-borne noise level predictions are based on the 3-dimensional track layout, actual train speeds, track features, etc, which are not included in **Figure 26**.

Figure 26 Ground-borne Noise Level Versus Slant Distance
Illustrative Only - Not to be used for Assessment



Note: The distance refers to the slant distance between the receiver location (on the surface) and the track (within the tunnel). For example, if the track is located 20 m below ground and the receiver is located 30 m to the side of the tunnel, the receiver would be located at a slant distance of 36 m from the track.

13.4 Ground-borne Noise Predictions (With Standard Attenuation Track)

On the basis of the speed profile for the CBD Metro (shown in **Figure 21**), the proposed vertical alignment and the modelling assumptions described in the previous sections, **Figure 27** provides a summary of the predicted ground-borne noise levels for buildings located above or close to the proposed rail alignments. These calculations have been performed for the standard attenuation trackform incorporating moderately resilient rail fasteners.

Figure 27 Predicted Ground-borne Noise Levels (Standard Attenuation Track)

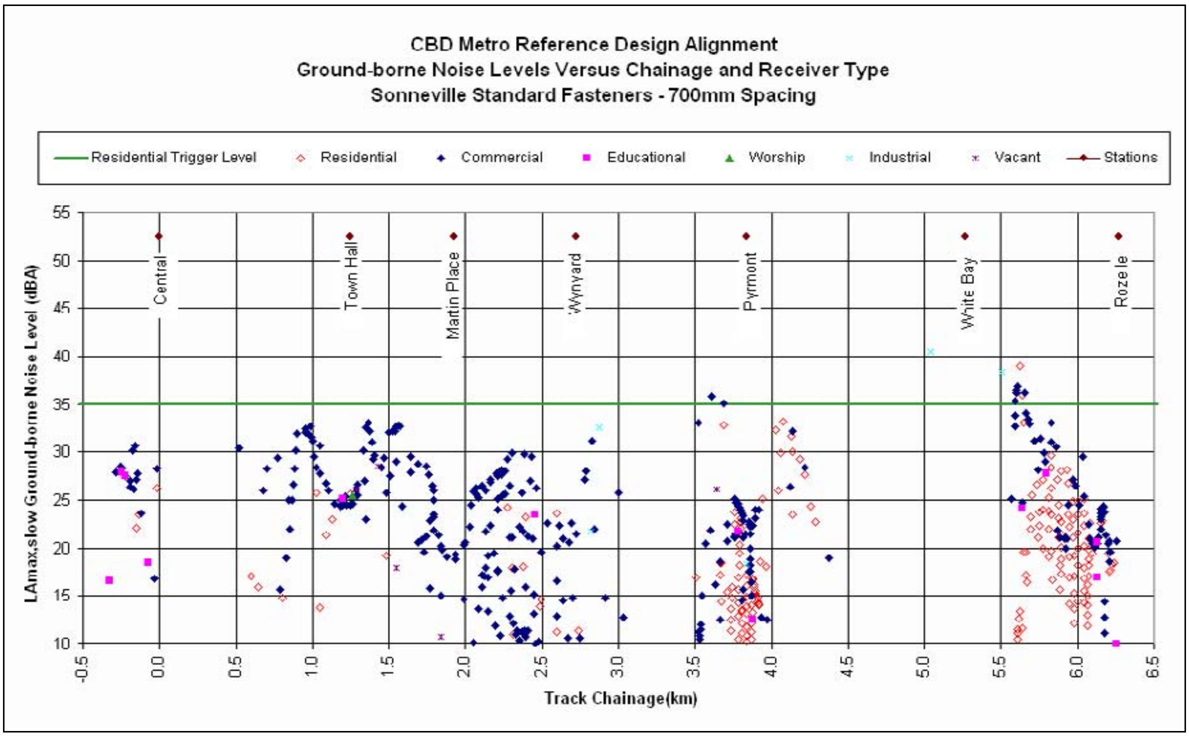


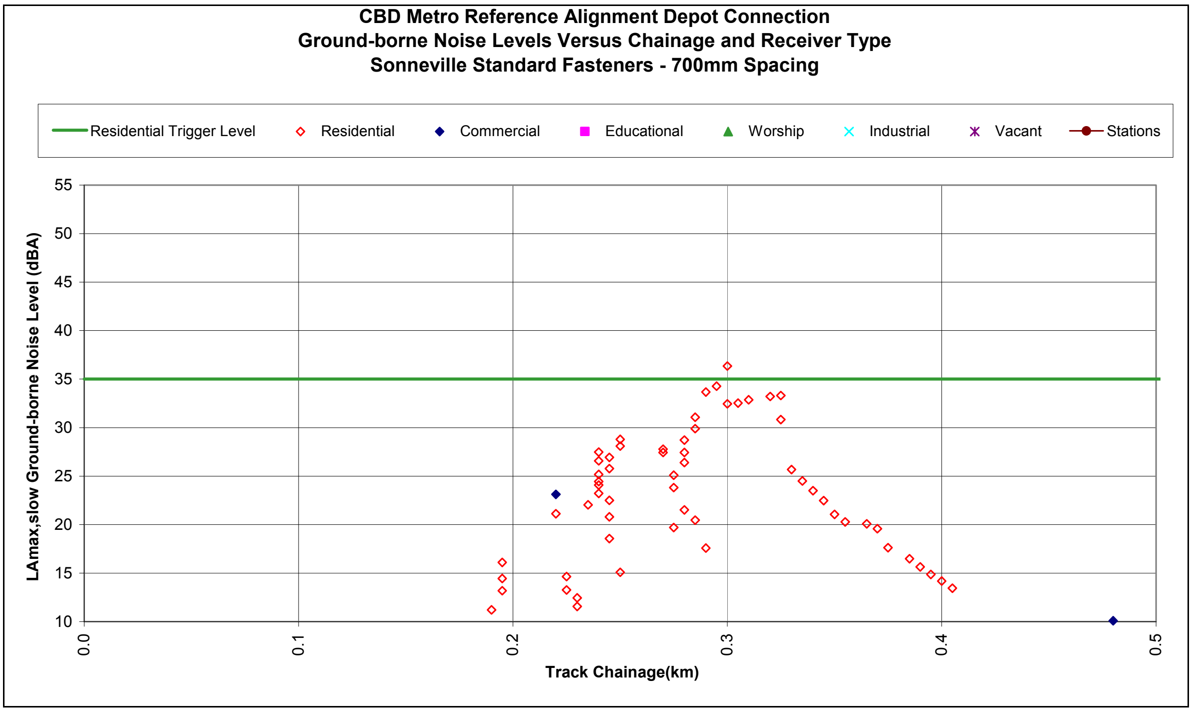
Figure 27 indicates that for residential receivers, the predicted ground-borne noise levels exceed the 35 dBA design goal at several locations near track chainage 5.5 km (three houses in Crescent Street, Rozelle). At all other residential receivers, the predicted ground-borne noise levels comply with the 35 dBA design goal.

For commercial receivers, the predicted ground-borne noise levels comply with the 40 dBA design goal at all locations.

The highest ground-borne noise level of 39 dBA is predicted in the vicinity of track chainage 5.5 km, where the train speed on the Up track is approximately 90 km/h and the distance between the ground surface and the top of rail level is approximately 18 m.

The predicted ground-borne noise levels for the depot connections are provided in **Figure 28**. The predicted ground-borne noise levels exceed the 35 dBA design goal at one residential receiver in Lilyfield Road. At this location, the maximum train speed is 35 km/h and the distance between the ground surface and the top of rail level is approximately 12 m.

Figure 28 Predicted Ground-borne Noise Levels at Depot Connection (Standard Attenuation Track)



13.5 Ground-borne Noise Mitigation Options

The potential ground-borne noise mitigation options for a new railway line include the following:

- Operational measures such as reduced train speeds or allowing system access only to trains with wheels in "good" condition.
- Track design measures including the provision of resilient rail fasteners, booted sleepers or floating slab track to reduce the vibration energy transferred to the tunnel footing, foundation, surrounding ground and nearby buildings.
- Track maintenance / rolling stock measures such as maintenance to keep rail and wheel roughness within required tolerances, maintaining existing rolling stock to ensure "good" wheel condition and / or implementing long-term measures to improve wheel condition over time.
- Receiver controls at existing or proposed developments such as full or partial vibration isolation of the building using springs or rubber bearings.
- Planning measures such as locating sensitive developments at an acceptable distance from the tunnel alignment.

The alignment has been designed to avoid major buildings insofar as possible by running the route in-line with existing roads. The vertical alignment (tunnel depth) has also been maximised where possible to reduce potential noise and vibration impacts.

Further approaches to mitigation therefore focus on operational measures, track design, maintenance regimes and source control measures. These options are likely to be far more cost effective than receiver controls such as full or partial vibration isolation of buildings above the railway tunnel (which are also usually impractical for most existing buildings).

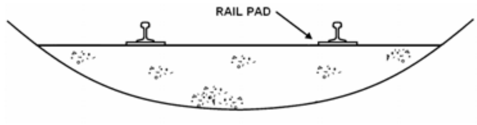
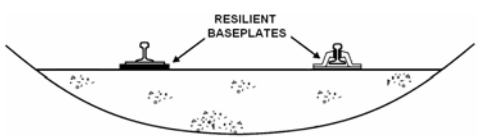
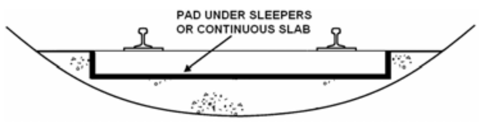
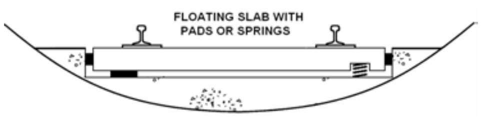
Operational measures such as improved wheel and rail condition would provide ground-borne noise and vibration benefits across the whole project area, whilst track design measures and a reduction in train speeds could provide benefits in specific areas.

For the CBD Metro, the ground-borne noise and vibration modelling assumed that the condition of the wheels and rails would be maintained within specified limits and that a monitoring program would be implemented by the operators to identify and repair track and wheels in poor condition.

In order to reduce the potential for ground-borne noise impacts at sensitive receivers without impacting operations via speed reductions, mitigation measures would need to focus on improving the vibration isolation characteristics of the track.

In order to reduce ground-borne noise and vibration levels within buildings located close to railway lines, a range of alternative track designs are available. These generally include the insertion of a resilient layer between the rail and tunnel foundation, either in the form of a resilient rail fastener, booted sleeper, floating track slab or a combination of approaches. The resilience is usually in the form of elastic/resilient pads or mats (or moulded rubber elements in the resilient baseplates/fasteners). **Table 88** presents the principal features of generic designs for slab tracks and the location of the resilient components in each case.

Table 88 Generic Trackforms to Mitigate Ground-borne Noise and Vibration on Slab Track

Generic Trackform Layouts	*Acoustic Performance*	*Description*
		*Direct fixation with standard rail foot pads (eg HDPE)*
	*Increasing Ground-borne Noise and Vibration Reduction*	*"Hard" resilient baseplates (eg, Delkor Alt 1, Pandrol Vipa, Pandrol Double Fastclip)*
		"Soft" resilient baseplates (eg, Delkor Egg or Pandrol Vanguard)
		*Resiliently supported sleepers/blocks or continuously supported slabs (eg slab on ballast mat)*
		*Floating Slab Track (FST) systems using short, long or continuous slabs with rubber or spring elements*

13.5.1 Resilient Baseplates

The use of resilient baseplates is the most widespread approach to minimising ground-borne noise and vibration from underground railways.

Resilient baseplates are available from a range of suppliers including ATP, CDM, Delkor, Getzner, Hilti, Lord, Pandrol, Schwihag and Vossloh. The dynamic stiffness of resilient baseplates varies significantly, ranging from approximately 5 kN/mm to 40 kN/mm. The softer baseplates have a lower dynamic stiffness and provide a reduction in ground-borne noise levels.

Examples of moderately resilient and highly resilient baseplates from two manufacturers (Delkor and Pandrol) are provided in **Figure 29** and **Figure 30**.

Figure 29 Moderately Resilient Baseplates (Delkor Alt 1 and Pandrol Vipa)

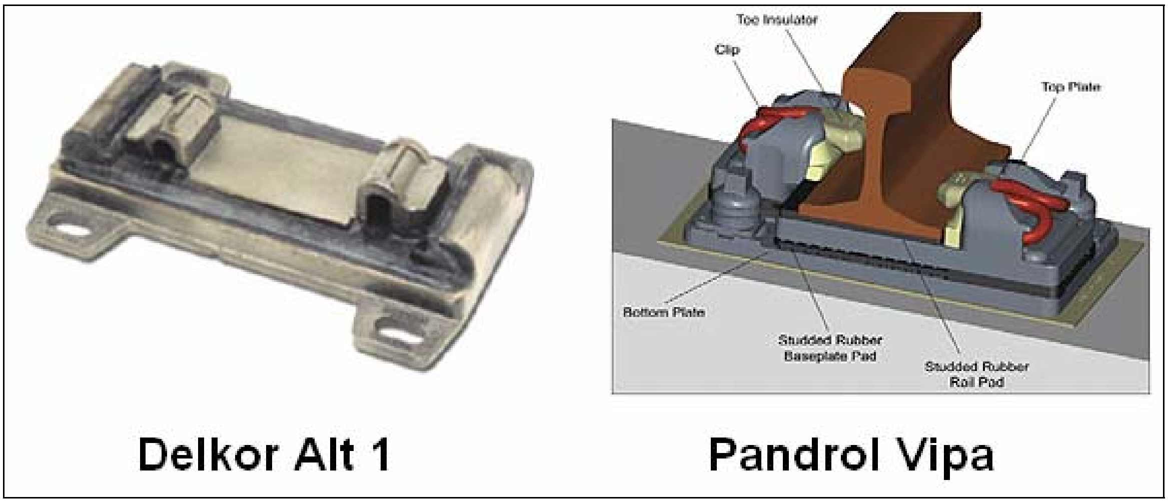
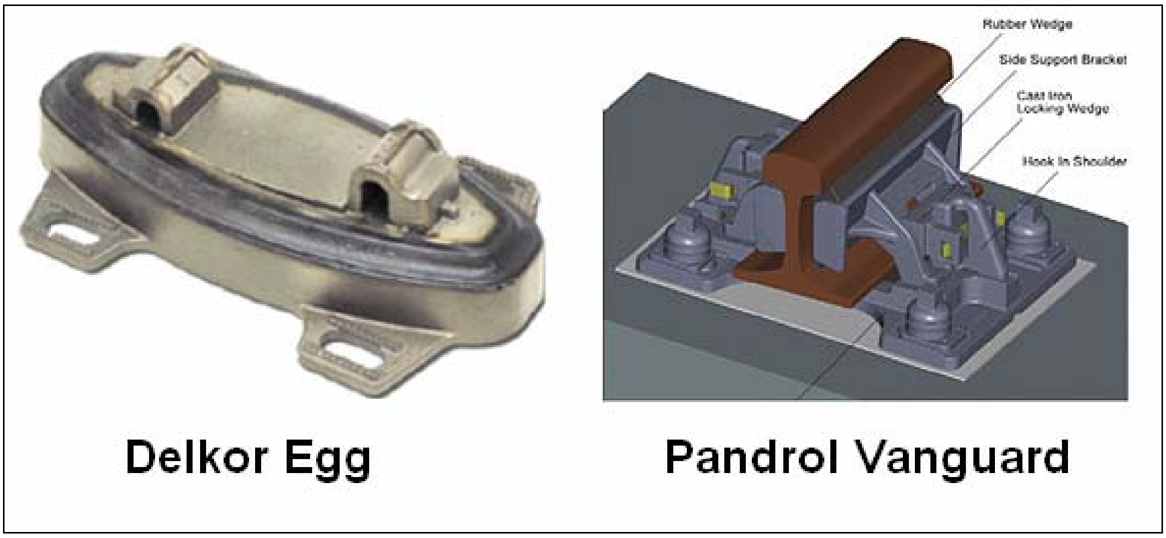


Figure 30 Highly Resilient Baseplates (Delkor Egg and Pandrol Vanguard)



Low stiffness baseplates can significantly reduce the level of ground-borne noise and vibration; however the following important factors should be noted:

- Careful attention is needed during detailed design to ensure that the loaded natural frequency of the resilient rail fastener does not coincide with other frequencies associated with the fastener spacing, wheel diameter, bogie passing frequency, etc. If this occurs, the performance of the system will be impaired.
- An increase in the fastener spacing and decrease in the static stiffness of the resilient rail fasteners will increase the maximum rail deflection (and rail stress).

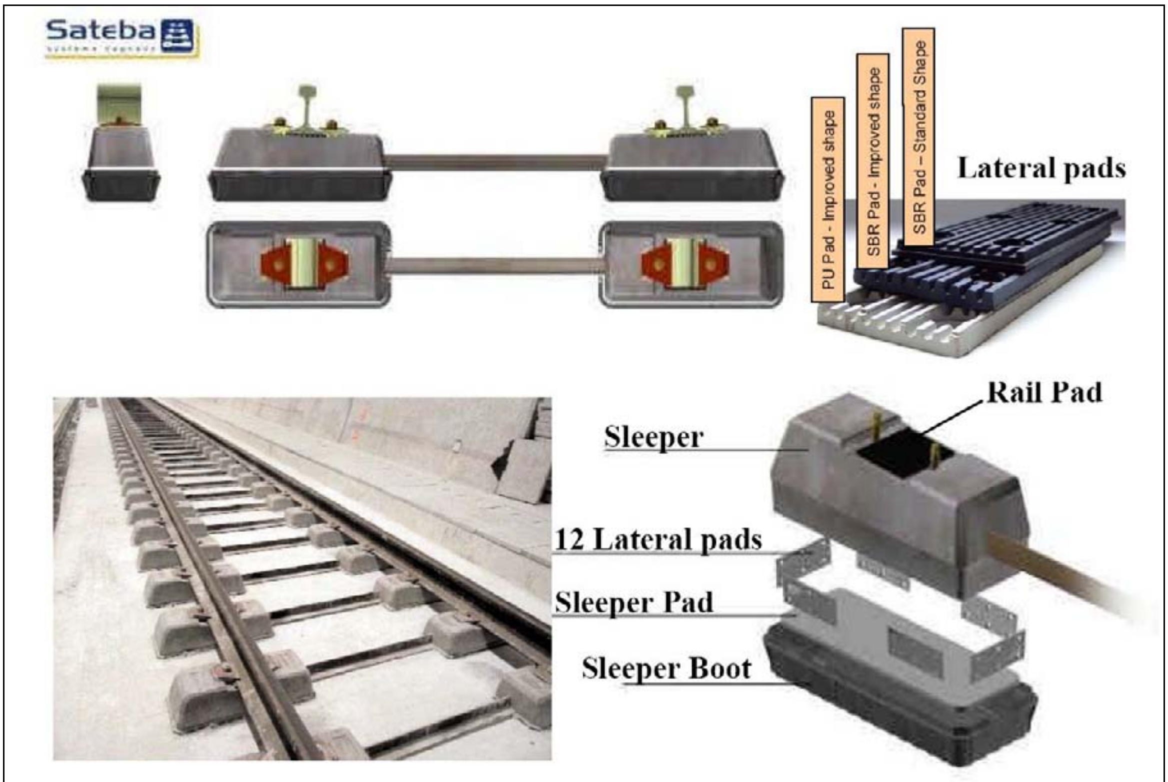
13.5.2 Booted Sleepers

Booted sleepers / booted block systems have been used in various forms over the past 40 years. An example of a recent installation on the Channel Tunnel Rail Link (CTRL) is illustrated in **Figure 31**.

Booted block systems generally consist of separate concrete blocks under each rail at normal "sleeper spacing". Each block sits on a resilient pad, with a rubber "boot" encasing the sides and base of the block and pad. Construction is by a "top down" method, whereby the tracks are assembled and aligned using jigs, which hold them in place while a concrete topping slab is poured around the booted blocks.

The original Sonneville LVT track design is understood to provide little vibration isolation, and should not be regarded as equivalent to the resilient baseplate systems. Over recent years, the system has been further developed to provide improved vibration isolation, particularly at audible frequencies.

Figure 31 Booted Sleeper Design on Channel Tunnel Rail Link (UK)



13.6 Ground-borne Noise Levels (With High Attenuation Track)

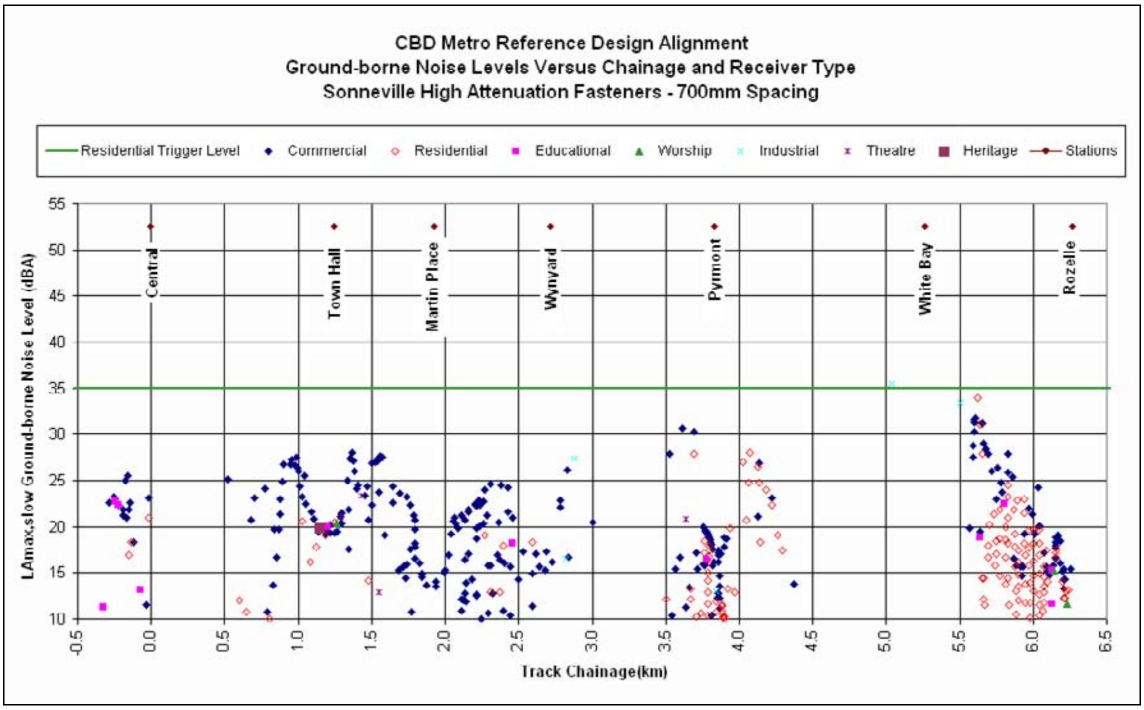
13.6.1 Residential and Commercial Receivers

As discussed in **Section 13.4**, the predicted ground-borne noise levels with the standard attenuation trackform exceed the noise trigger levels at three houses in Crescent Street, Rozelle and one house in Lilyfield Road. At several other residential and commercial locations, the predicted ground-borne noise levels are within 5 dBA of the relevant design goals.

Additional calculations have therefore been undertaken using a high attenuation trackform. The high attenuation trackform consists of softer baseplates with a dynamic stiffness of 12 kN/mm at the same fastener spacing of 700 mm. Such fasteners would be expected to provide an overall reduction in ground-borne noise levels in the order of 5 dBA.

Figure 32 provides a summary of the predicted ground-borne noise levels, assuming a high attenuation trackform.

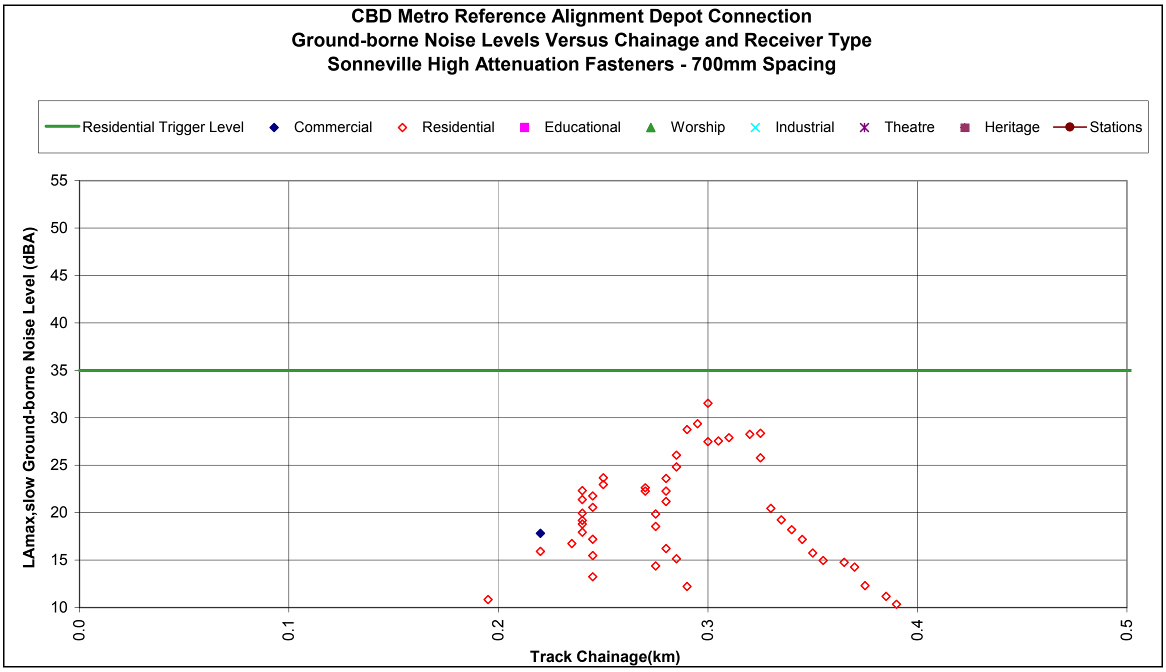
Figure 32 Predicted Ground-borne Noise Levels (High Attenuation Track)



For the high attenuation track, ground-borne noise levels are predicted to comply with the 35 dBA design goal at the residential receiver locations in Crescent Street, Rozelle. Furthermore, at other sensitive residential and commercial receivers, the predicted noise levels comply with the relevant ground-borne noise goals with an acceptable margin of safety.

The predicted ground-borne noise levels for the depot connection are provided in **Figure 33**. The predicted ground-borne noise levels comply with the 35 dBA design goal with an acceptable margin of safety.

Figure 33 Predicted Ground-borne Noise Levels at Depot Connection (High Attenuation Track)



13.7 Summary of Ground-borne Noise Assessment

The ground-borne noise modelling indicates that a trackform design which uses a combination of standard attenuation and high attenuation rail fasteners will be sufficient to achieve compliance with the ground-borne noise goals at all sensitive receiver locations adjacent to the project area.

At this stage in the assessment process, it has been necessary to undertake a best estimate of several parameters that form part of the ground-borne noise and vibration modelling. These parameters include the source vibration levels of the proposed rolling stock, vehicle/track interaction and ground conditions.

For these reasons, it is considered prudent to incorporate a high attenuation trackform in several areas where marginal compliance is predicted with the standard attenuation trackform.

Table 89 provides a summary of the locations where standard attenuation and high attenuation trackforms are proposed. For this assessment, it is assumed that the extent of the proposed trackforms will be identical for each tunnel. A graphical summary of the proposed trackform extents is provided in **Figure 34**.

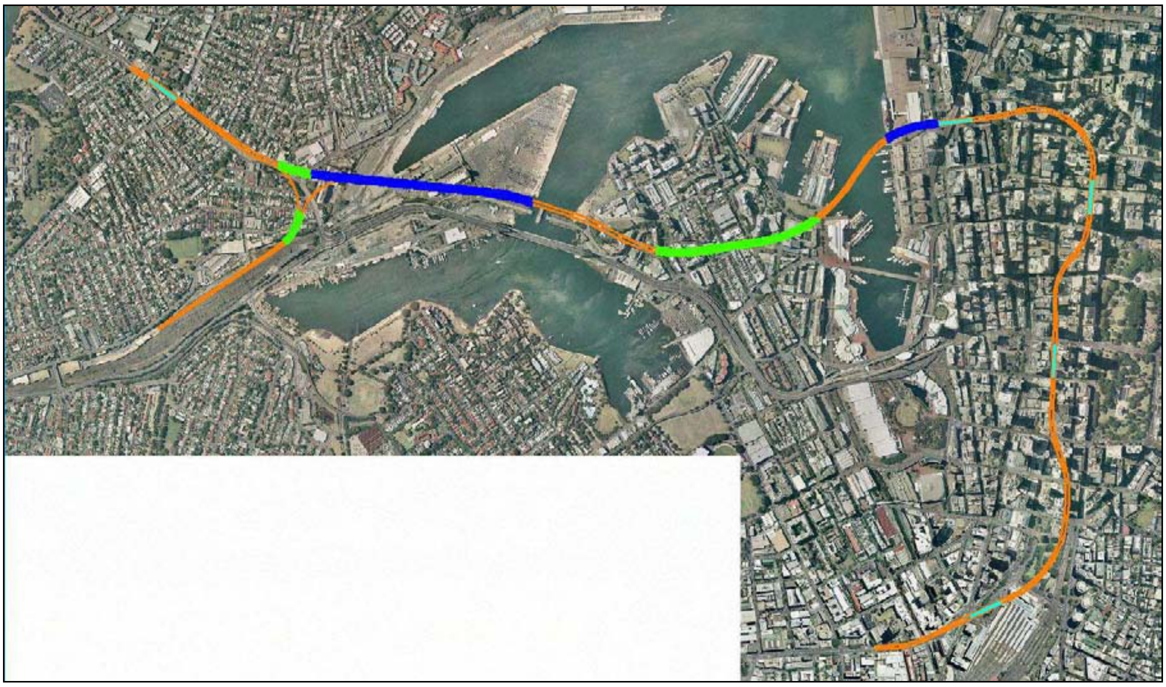
At the proposed Barangaroo and White Bay development sites, the track is located approximately 20 m to 15 m below the existing ground surface respectively. At these locations, it is likely that the future land use will incorporate mixed use residential/commercial developments. On the basis of the likely train speeds, alignment and other relevant parameters, a High Attenuation trackform should be considered in these areas in order to avoid the potential need to mitigate ground-borne noise levels as part of the building design.

A summary of the updated ground-borne noise predictions for the main alignment (with the proposed trackform) is provided in **Figure 35**. For the depot connections, the predicted ground-borne noise levels are as per **Figure 33**.

Table 89 Extent of Proposed Trackforms

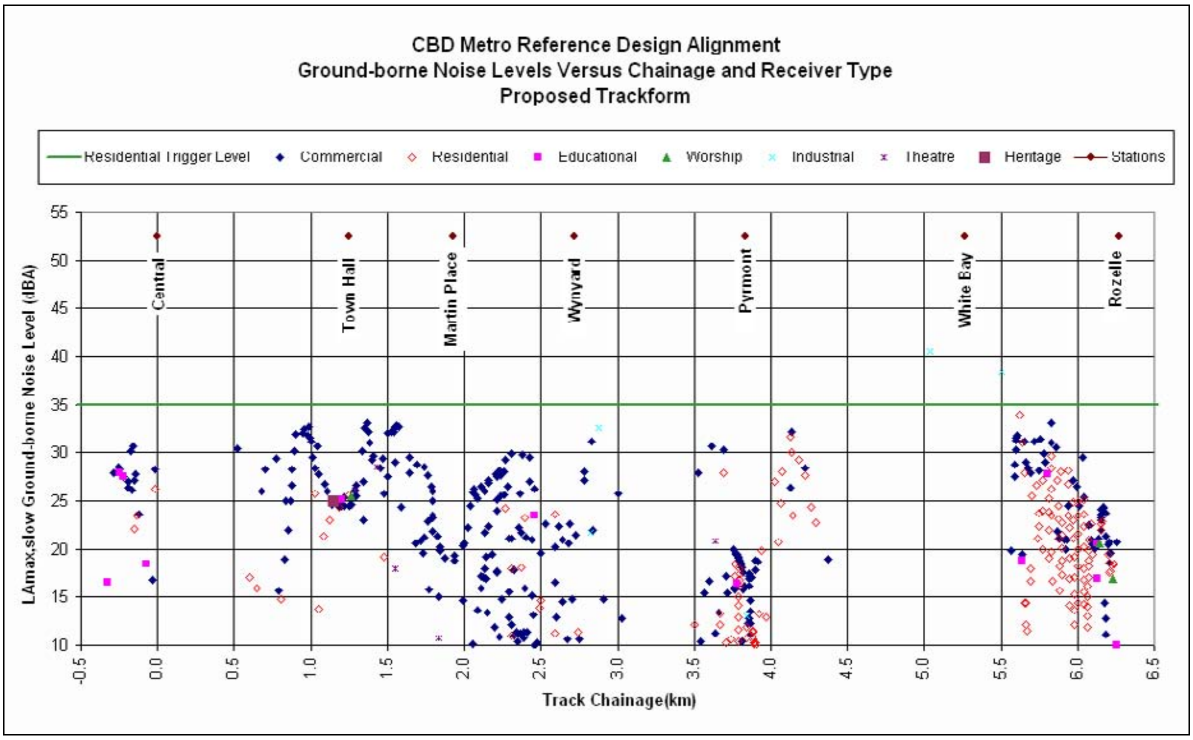
Track Chainage (km)	Extent of Proposed Trackforms (km)	
	Sonneville Standard	**Sonneville High Attenuation**
Main Line (Down Line Chainage)		
-0.4 to 3.44	3.94	
3.44 to 4.12		0.68
4.12 to 5.56	1.44	
5.56 to 5.70		0.14
5.70 to 6.42	0.72	
Total	**6.09**	**0.82**
Depot Connections (Up Connection Chainage)		
0.00 to 0.24	0.24	
0.24 To 0.38		0.14
0.38 to 0.99	0.61	
Total	**0.85**	**0.14**

Figure 34 Extent of Proposed Trackforms



Note: The orange lines represent Standard Attenuation Track, the green lines represent High Attenuation Track and the blue lines indicate areas where High Attenuation track may be required for future mixed use residential and commercial development sites at Barangaroo and White Bay.

Figure 35 Predicted Ground-borne Noise Levels (Proposed Trackform)



13.8 Other Sensitive Receivers

A summary of the sensitive receivers (excluding residences) above or close to the proposed alignment is provided in **Table 4**.

On the basis of the speed profile for the CBD Metro (shown in **Figure 21**), the proposed vertical alignment, the modelling assumptions described in the previous sections and the proposed trackform in **Table 89**, ground-borne noise levels are predicted to comply with the design goals at all locations.

13.9 Compliance Monitoring

The IGANRIP guideline recommends the selection of representative noise monitoring locations in order to later assess compliance with the design goals. For this project, the following representative receiver locations are proposed:

- 45-47 Crescent Street, Rozelle
- 10-22 Lillyfield Road, Rozelle
- 102 Miller Street, Pyrmont
- Star City Development
- Pilgrim Theatre - 262 Pitt Street

It is anticipated that compliance monitoring at the above locations would need to be based on operator-attended measurements for a minimum of 20 train passbys at each monitoring location. These measurements should be undertaken at the commencement of train operations and on a yearly basis thereafter.

13.10 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. **Table 90** details the draft SoC associated with the Ground-borne Noise Assessment for the CBD Metro.

Table 90 Draft Statement of Commitments - Ground-borne Noise Assessment - Train Operations

Report Section	Measure Type	Commitment	Desired Environmental Outcome
13.2	Manage	For residential receivers, schools, educational institutions and places of worship, adopt the "noise trigger" levels in the DECCW's "*Interim Guideline for the Assessment of Noise from rail Infrastructure Projects*" as design goals.	Minimise ground-borne noise levels at nearby sensitive receivers.
13.2	Manage	For other sensitive receivers, adopt the ground-borne noise design goals in Table 87.	Minimise ground-borne noise levels at nearby sensitive receivers.
13.5	Mitigate	The track design will incorporate moderately resilient and/or highly resilient rail support systems to achieve compliance with the ground-borne noise design goals.	Minimise ground-borne noise levels at nearby sensitive receivers
12.3.3	Manage	Wheel and track maintenance procedures will be adopted to ensure that source vibration levels are within the specified limits. Monitoring systems will be implemented to measure the condition of the wheels and track. A wheel lathe and track grinding machine will be used to restore the track condition to specified limits when required. If wheel flats or other wheel defects do occur, these would be identified by a permanent monitoring station and rectified using a wheel lathe or other measures to return the wheel condition to an acceptable degree of smoothness.	Ensure that the ground-borne noise goals remain within the design goals on a long-term basis.
13.9	Manage	Compliance monitoring will be undertaken at the commencement of train operations at selected receiver locations.	Assess compliance with the ground-borne noise design goals and determine if any additional feasible and reasonable mitigation measures are required.

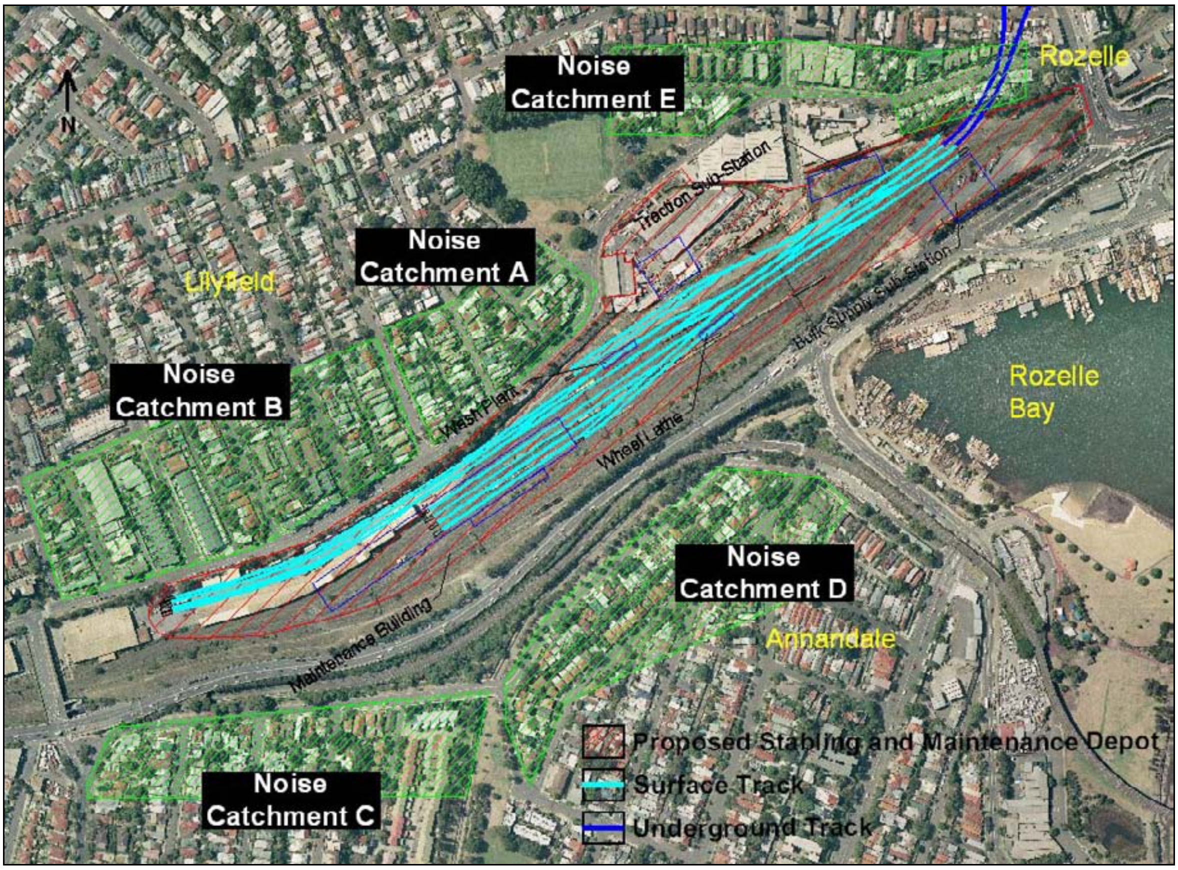
14 AIRBORNE NOISE ASSESSMENT - TRAIN OPERATIONS

14.1 Introduction

The majority of the proposed CBD Metro alignment comprises underground sections of track within tunnels. There is however a section of surface track between the tunnel portals and the Rozelle stabling and maintenance depot (refer **Figure 36**).

The assessment in this chapter therefore deals with the airborne noise emissions associated with train movements on the surface track between the tunnel portals and the stabling area. The assessment of noise from stabled trains (and from maintenance activities) is detailed in **Section 15**.

Figure 36 Rozelle Stabling and Maintenance Depot Layout (Indicative)



The assessment of airborne operational noise from the proposed Rozelle stabling and maintenance depot has been undertaken with reference to the site layout as described in the Environmental Assessment (a description of the surrounding areas to the site, along with the definitions of the noise catchment areas illustrated in **Figure 36**, are presented in **Sections 15.2.1** and **15.2.2** respectively).

The main sources of airborne noise from moving electric passenger trains originate at the wheel-rail interface as a result of surface irregularities on the wheel and/or rail running surfaces and interaction forces. During a train passby, the wheel, bogies, rail and rail support system vibrate and hence radiate airborne noise.

As the maximum train speed within the stabling and maintenance facility will be limited to 40 km/h, other noise sources on electric metro trains, (such as air conditioning plant and air compressors) will also contribute to the overall noise levels. These noise sources are normally insignificant when trains travel at speeds greater than 50 km/h where wheel/rail noise becomes dominant.

The key parameters influencing the level of airborne noise are train speed, wheel condition, rail condition, train length, number of trains, track design and at low speeds, the source noise levels from air conditioning plant and compressors on the trains. Receiver distance and the presence of natural or man-made barriers located between the railway line and receivers (to break line-of-sight noise propagation) will also influence noise levels at receivers.

Impact noise from rail discontinuities such as turnouts and mechanical joints or uneven welded joints also has an effect on the level of wheel-rail noise emission, as impulsive noise is emitted as each wheel of the train impacts the discontinuity.

In track sections having tight radius curves, flanging noise or curve squeal may also increase the levels of noise emission.

All relevant factors are taken into consideration as part of the noise modelling.

14.2 Airborne Noise Goals

The airborne noise assessment is required to be undertaken in accordance with the requirements of the Department of Environment, Climate Change and Water's (DECCW's) "*Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects*" (IGANRIP). The noise design goals contained within this guideline are expressed as non-mandatory "trigger levels", which if exceeded will trigger the need to consider feasible and reasonable mitigation measures.

A summary of the noise trigger levels for residential receivers is provided in **Figure 37**.

Figure 37 Airborne Noise Trigger Levels for Residential Receivers (IGANRIP)

Table 1: Airborne rail traffic noise trigger levels for residential land uses

Type of development	Noise trigger levels dB(A)		
	Day (7 am–10 pm)	**Night (10 pm–7 am)**	**Comment**
New rail line development	Development increases existing rail noise levels *and* resulting rail noise levels exceed:		These numbers represent external levels of noise that trigger the need for an assessment of the potential noise impacts from a rail infrastructure project. An 'increase' in existing rail noise levels is taken to be an increase of 2 dB(A) or more in L_{Aeq} in any hour or an increase of 3 dB(A) or more in L_{Amax}.
	60 $L_{Aeq(15h)}$ 80 L_{Amax}	55 $L_{Aeq(9h)}$ 80 L_{Amax}	
Redevelopment of existing rail line	Development increases existing rail noise levels *and* resulting rail noise levels exceed:		
	65 $L_{Aeq(15h)}$ 85 L_{Amax}	60 $L_{Aeq(9h)}$ 85 L_{Amax}	

The IGANRIP also specifies noise goals for sensitive land uses such as educational facilities, places of worship, areas of active/passive recreation, etc. Although two areas of active recreation (Easton Park and Whites Creek Valley) are situated in the vicinity of the Rozelle stabling and maintenance depot, they are both at a sufficient distance not to require assessment. It is further noted that the "active recreation" noise trigger level of $L_{Aeq(24hour)}$ 65 dBA is less stringent than the trigger levels applicable to "residential land uses", as shown in **Figure 37**.

The noise trigger levels in **Figure 37** refer to noise from the proposed rail operations only and do not include ambient noise from other sources such as major roads and industry. The noise levels are evaluated externally at a distance of 1 m from the most affected building façade. "Residential" typically means any residential premises located in a zone as defined in a planning instrument that permits new residential land use as a primary use.

The L_{Amax} noise level refers to the 95th percentile train passby event (ie, 5% of train passbys are permitted to exceed the noise trigger levels). The absolute maximum event is not used for design, as it cannot be precisely defined and would be a highly infrequent event.

For new rail projects, the noise trigger levels apply immediately after operations commence and for projected traffic volumes to a period over an indicative period into the future that represents the expected typical level of rail traffic usage (eg 10 years or a similar period into the future).

The guideline also states:

> *"Where noise above the noise trigger levels continues even after all feasible and reasonable mitigation measures have been applied to a project, other long-term strategies need to be applied to minimise impacts. These include reducing noise emissions from rolling stock by applying noise standards to new rolling stock; managing noise emissions from rolling stock already in use; and improved planning, design and construction of adjoining land-use developments."*

As the CBD Metro represents an entirely new rail infrastructure project incorporating new rolling stock and trackform designs, the noise trigger levels should be viewed as "design goals" which are to be achieved at all locations where feasible and reasonable mitigation design measures are available.

14.3 Airborne Noise Modelling Methodology

SoundPLAN Version 6.5 has been used to calculate railway airborne noise emission levels for this part of the study. Of the train noise prediction models available within SoundPLAN, the Nordic Rail Traffic Noise Prediction Method (Kilde 1984) has been used, since it is capable of efficiently and reliably calculating both the L_{Amax} and L_{Aeq} noise levels.

The calculation procedure involves a 360° scan from each receiver point (using fixed angular steps), with the contributions from each angular increment summed to determine the total received noise level. The calculation procedure takes into account the direct noise, the noise diffracting over obstacles or barriers and the noise reflected off buildings.

A separate model run was also carried out using a fixed calculation grid with a spacing of 10 m to produce noise contours. The resultant contours were interpolated between the grid points.

14.3.1 Rolling Stock Noise Levels

Noise emission limits from new trains are normally specified in terms of the L_{Amax} (fast) noise level at a particular speed, measured at a distance of 7.5 m, 15 m or 25 m from the track centreline. The reference noise levels are typically expressed for straight ballast and sleepered track, with measurements being undertaken at grade or on low embankment.

Heggies has undertaken a desktop review of the guideline levels applied in Europe and the USA, supplemented by measurement data obtained for Tangara Rolling stock in Sydney. On the basis of this information, the following reference noise levels have been adopted for the airborne noise modelling, evaluated at a reference speed of 40 km/h and measurement distance of 15 m from the track centreline. As the stabling and maintenance depot will be constructed using a slab track design, the source noise levels incorporate a +3 dBA correction to account for additional reflected noise which does not occur on ballast track.

- L_{Amax} 79 dBA (at 40 km/h and 15 m distance)
- L_{AE} 85 dBA (at 40 km/h and 15m distance)

The L_{Amax} noise level is representative of the 95th percentile as required by IGANRIP. The L_{AE} is the "sound exposure level", which is used to indicate the total acoustic energy of an individual noise event. This parameter is used in the calculation of the $L_{Aeq(15hour)}$ daytime and $L_{Aeq(9hour)}$ night-time noise levels from individual noise events.

14.3.2 Train Speeds

A maximum speed of 30 km/h has been assumed for train movements within the stabling depot, with a maximum of 40 km/h for the main roads to/from the tunnel portals.

14.3.3 Train Numbers and Stabling Operations

The stabling depot has capacity to stable a maximum of 11 CBD Metro trains. All trains are expected to depart the facility from 5.30 am to 6.30 am for the morning peak hour with about half of the fleet returning at about 9.00 am. These trains would then depart again for the afternoon peak and return to the depot at about 7.00 pm. The remaining trains would return to stabling around midnight.

Infrastructure maintenance trains would leave the depot around midnight and return around 5.00 am. Three daily maintenance train movements have been assumed.

14.3.4 Tunnel Portal Extensions

To ensure operational noise impacts at sensitive receiver locations in the vicinity of the tunnel portals are minimised, the portals are proposed to be extended in length by enclosed concrete structures. At this stage in the assessment the details of the tunnel portal extensions has not been finalised. It is anticipated that a noise barrier and/or full enclosure will be required in the area of the portals if the detailed assessment indicates a curving noise is likely.

14.3.5 Rail Surface Discontinuities

Discontinuities in the rail running surface occur at turnouts, crossings, track defects, etc. For this assessment, the modelled location of turnouts and crossovers has been based on the information in the depot drawing supplied. Within SoundPLAN, these have been modelled over a track length of 10 m, with a +6 dBA correction being applied to both the L_{Amax} and L_{AE}.

14.3.6 Miscellaneous Noise Modelling Inputs

The following data and inputs have also been used within the modelling process of airborne noise:

- Ground Terrain and Track Alignment Strings - this was supplied to Heggies in 3D AutoCAD format (a minimum relative level (RL) of 4.5 m has been used for the ground contours)
- Stabling Depot Layout - the layout of the proposed facility has been taken from drawing CBD-2100-SK-0800-TR-0036 (consistent with the layout described in the EA).

- Buildings and Receiver Locations - the location of buildings and their representation within the noise model has been derived from aerial photography. The various uses of the nearby buildings were determined during a detailed site inspection.
- Road Traffic Noise Barrier - there is an existing 1.5 m to 2.5 m high noise barrier situated on the edge of the southern carriageway of the City-West Link Road. This has been included in the noise model.

14.3.7 Noise Modelling Scenarios

Noise contour plots have been predicted at calculation heights of 2.0 m and 4.8 m above ground level, representing first and second floor receivers respectively. Separate noise contour plots have been provided for the $L_{Aeq(15hour)}$, $L_{Aeq(9hour)}$ and L_{Amax} noise parameters at both heights. All plots are shown within **Appendix I**.

14.4 Predicted Noise Levels

The data in **Table 91** together with the noise contour plots in **Appendix I** detail the results of the noise modelling completed for the surface track between the tunnel portals and the Rozelle stabling and maintenance depot.

Table 91 Airborne Operational Noise Assessment – Nearest Receiver Predicted Façade Noise Levels

Noise Catchment Area	Noise Design Goals (dBA)			Predicted Noise Levels (dBA)		
	LAeq(15 hour)	LAeq(9 hour)	LAmax	LAeq(15 hour)	LAeq(9 hour)	LAmax
Area A	60	55	80	44	47	72
Area B				45	48	74
Area C				29	32	56
Area D				34	37	62
Area E				47	50	76

Reference to the above table indicates compliance with the noise goals at the nearest sensitive receivers to the Rozelle stabling and maintenance depot (the various noise catchment areas are illustrated in **Figure 36**).

The above assessment considers the stabling and daily movements of up to 11 CBD Metro trains. As the proposed stabling and maintenance facility may facilitate up to 30 trains as part of a possible expansion, additional noise modelling has been undertaken to estimate the increase in L_{Aeq} noise levels from these additional train movements (L_{Amax} noise levels would remain unchanged).

The potential increase in L_{Aeq} noise levels associated with the additional trains is approximately 3 dBA to 4 dBA. On this basis, it is anticipated that the airborne noise levels would remain compliant with the design goals should the proposed stabling facility be expanded to accommodate additional Metro trains.

14.5 Conclusions

Based on the assumptions detailed above, the assessment of airborne operational noise indicates that noise levels are predicted to comply with the appropriate noise goals at all locations surrounding the Rozelle stabling and maintenance yard. On this basis, it is unlikely that further noise mitigation measures would be required.

During the detailed design stage, careful attention will need to be taken to ensure that the risk of curve flanging and curve squeal do not occur at locations where the curve radius is less than approximately 300 m. It is anticipated that gauge face lubrication and top of rail friction modification may be required near the tunnel portals to minimise the risk of curving noise. It is anticipated that absorptive acoustic panels will also be required within the tunnel dive and inside the tunnels at the depot connections to absorb the additional noise associated with the tight radius curve and reverberant noise environment.

The risk of curve squeal is reduced when the bogies steer correctly around small radius curves without flange contact. This outcome can only be achieved if the wheel and rail profiles are maintained within tight tolerances through regular wheel truing and rail grinding.

14.6 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. **Table 92** details the draft SoC associated with the Airborne Noise Assessment for the CBD Metro.

Table 92 Draft Statement of Commitments - Airborne Noise Assessment - Train Operations

Report Section	Measure Type	Commitment	Desired Environmental Outcome
14.2	Manage	For residential receivers, schools, educational institutions and places of worship, adopt the "noise trigger" levels in the DECCW's "*Interim Guideline for the Assessment of Noise from rail Infrastructure Projects"* as design goals.	Minimise airborne noise levels at nearby sensitive receivers
14.3.4	Mitigate	For the tunnel portals, noise barriers and/or portal extensions may be required if the detailed assessment indicates a curving noise is likely.	Minimise general train noise and any curve squeal noise which may be generated from the curved underground sections.
14.5	Mitigate	During the detailed design stage, careful attention will need to be taken to ensure that the risk of curve flanging and curve squeal do not occur at locations where the curve radius is less than approximately 300 m. It is anticipated that gauge face lubrication and top of rail friction modification may be required near the tunnel portals to minimise the risk of curving noise.	Minimise general train noise and any curve squeal noise which may be generated from the curved underground sections.

15 AIRBORNE NOISE ASSESSMENT - TRAIN STABLING AND MAINTENANCE

15.1 Introduction

The Rozelle stabling and maintenance depot is proposed to be situated at the former Rozelle Marshalling Yard. The proposed Rozelle stabling and maintenance depot would operate on a 24 hour basis and provide an area for train stabling and maintenance to be performed.

For the CBD Metro, up to 11 trains are proposed to be located at the stabling and maintenance depot. It is likely that one additional train would be stabled overnight at both Central Station and Rozelle Station to allow for efficient early morning start-up operations.

The current CBD Metro schedule details that all trains are expected to depart the facility from 5.30 am to 6.30 am for the morning peak hour with about half of the fleet returning at about 9.00 am. These trains would then depart again for the afternoon peak and return to the depot at about 7.00 pm. The remaining trains would return to stabling around midnight, when the Infrastructure Maintenance Operations Period would commence. Infrastructure maintenance trains would leave the depot around midnight and return about 5.00 am.

Maintenance of the CBD Metro rolling stock fleet will be performed within the proposed depot. The majority of the noise intensive maintenance works would most likely be carried out within dedicated on-site maintenance buildings during daytime and evening periods. These activities would include major overhauls and general routine maintenance of all train sets, wheel profile correction using an underfloor wheel lathe and automated train washing.

In order to ensure no disruption to the CBD Metro train services, all track and tunnel maintenance activities will be confined to night-time periods when train operations have ceased. These activities will include routine track inspections, loading of equipment onto hi-rail vehicles, entering tunnels and operation of a diesel or battery powered maintenance locomotive for track inspections and maintenance. It is likely that the maintenance will be undertaken during the weekdays, except for the emergency works.

Airborne noise impacts can be a key issue for sensitive receivers near the proposed stabling depot. The potential noise sources include train movements within the depot, steady noise from train auxiliary systems during daytime and night-time periods and noise emissions from the train maintenance activities. The potential airborne noise emissions from operational train movements within the depot are assessed separately in **Section 14**.

15.2 Site Description and Noise Catchment Areas

15.2.1 Site Description

The proposed Rozelle stabling and maintenance depot is situated at the site of the former Rozelle Marshalling Yard, located between Lilyfield Road and the City-West Link Road. The depot is located in a 3 m to 7 m cutting that is situated between Lilyfield Road and the northwest end of depot.

The existing land uses on the northern and southern sides of the proposed depot are predominantly residential with a small number of commercial buildings. Lilyfield Road and the City-West Link Road separate these residencies from the depot. The noise emissions from these roads therefore contribute to increased ambient noise levels at the nearby residential receivers.

The nearest residences located on the northern side of the depot are situated along Lilyfield Road at an approximate distance of 30 m from the site boundary. The nearest residences on the southern side are on Brenan Street and Railway Parade, and are approximately 80 m to 100 m away.

A group of residential receivers located to the north of the facility, along Lilyfield Road, are on elevated ground with respect to the depot such that these residences overlook the depot.

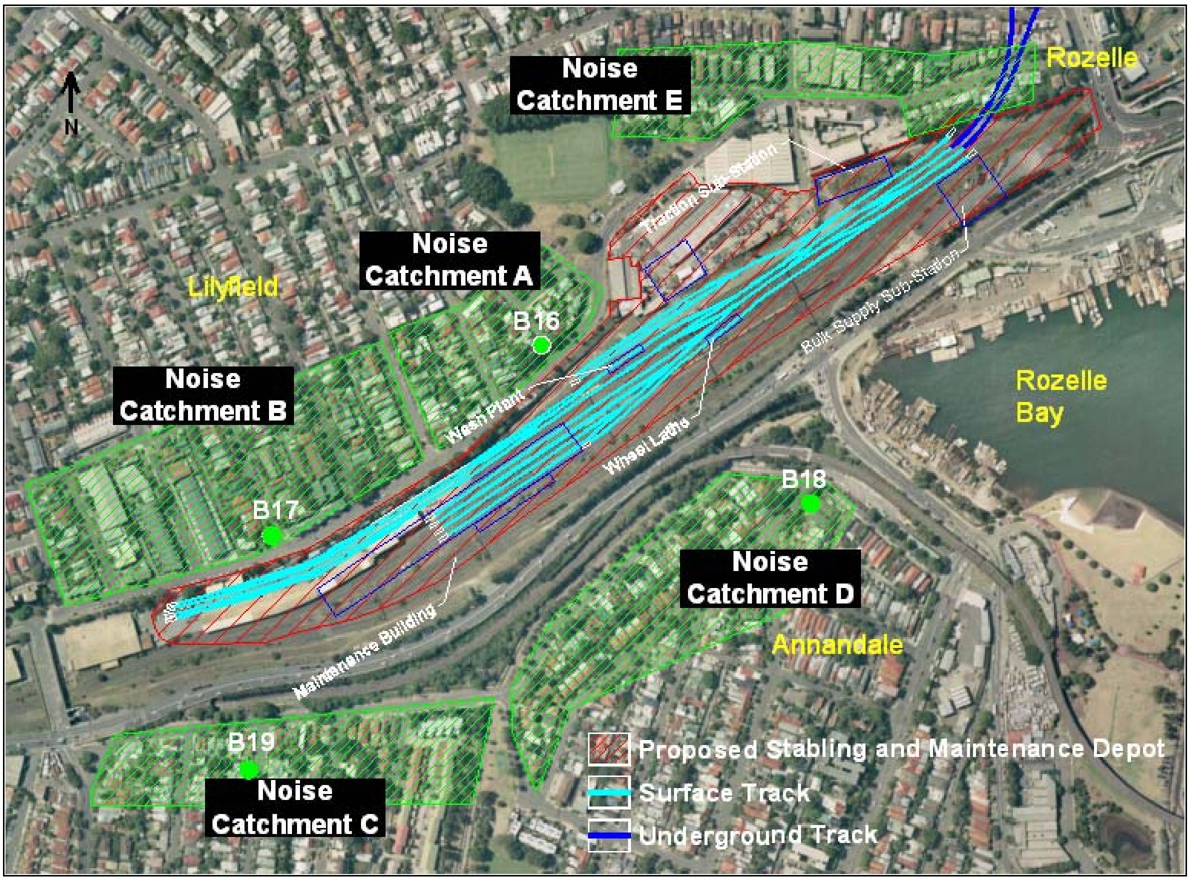
The Sydney Light Rail currently operates between Lilyfield and Central, running parallel to the City-West Link Road from Lilyfield station, located to the south-west of the depot. There is a noise barrier (approximately 1.5 m to 2.5 m high) situated between the Sydney Light Rail line and the City-West Link Road.

15.2.2 Noise Catchment Areas

For the purpose of this assessment, the residential areas surrounding the depot have been separated into following five noise catchment areas. These areas are illustrated in **Figure 38**.

- **Noise Catchment A**: North of depot (West of Cecily Street Lilyfield)
- **Noise Catchment B**: North of depot (East of Cecily Street Lilyfield)
- **Noise Catchment C**: South of depot (East of White Street Lilyfield)
- **Noise Catchment D**: South of depot (West of White Street Lilyfield)
- **Noise Catchment E**: North of depot (East of Easton Park)

Figure 38 Stabling and Maintenance Assessment - Noise Catchment Areas



15.2.3 Unattended Noise Measurements

Unattended ambient noise measurements were undertaken during March, April and May 2009 in the vicinity of the proposed Rozelle stabling and maintenance depot at the five locations illustrated in **Figure 38** (these locations have been previously described in detail in **Section 5.3**).

A summary of the ambient noise monitoring locations used as part of this assessment is presented in **Table 93**.

Table 93 Summary of Unattended Noise Logging Locations - Stabling and Maintenance Assessment

Noise Catchment Area	Unattended Ambient Noise Monitoring Location	Address
A	B16	2 Hutcheson Street, Rozelle
B	B17	101 Lamb Street, Lilyfield
C	B19	52 Starling Street, Lilyfield
D	B18	8 Pritchard Street, Annandale
E	B11	6 Burt Street, Rozelle

15.3 Train Stabling and Maintenance Noise Goals

The proposed stabling and maintenance depot is regarded as a fixed facility, hence all operational noise emissions are to be assessed in accordance with the DECCW's *"Industrial Noise Policy"* (INP).

15.3.1 Intrusiveness and Amenity Assessment

To assess noise of an industrial nature, the INP procedures make use of the Rating Background Level (RBL) and ambient L_{Aeq} noise levels during daytime, evening and night-time periods.

The RBL is the background noise level used for assessment purposes and represents the median of the daily background (L_{A90}) noise levels during each assessment period. The L_{Aeq} noise level represents the energy-averaged noise level during each assessment period.

The INP assessment procedure for industrial noise sources has two components:

- Controlling the intrusive noise impacts in the short-term for residents
- Maintaining noise level amenity for particular land uses for residences and other land uses

The **intrusive** $L_{Aeq(15minute)}$ noise goal for residential receivers limits noise emission levels to the RBL plus 5 dBA.

The **amenity** noise goal depends upon existing ambient L_{Aeq} noise levels within a locality and their relation to the acceptable noise levels specified in **Table 94**. For example, where existing L_{Aeq} noise levels exceed the acceptable noise levels given in **Table 94** by 2 dBA or more, the L_{Aeq} amenity noise goal would be set at 10 dBA below the existing L_{Aeq} levels in order to limit any further increase in ambient levels.

Both noise goals (intrusive and amenity) are applicable at residential and other sensitive receiver locations.

Table 94 NSW Industrial Noise Policy Amenity Goals

Type of Receiver	Indicative Noise Amenity Area	Time of Day[1]	Recommended L_{Aeq} Noise Level (dBA)	
			Acceptable	**Recommended Maximum**
Residence	Rural	Day	50	55
		Evening	45	50
		Night	40	45
	Suburban	Day	55	60
		Evening	45	50
		Night	40	45
	Urban	Day	60	65
		Evening	50	55
		Night	45	50
School Classroom (internal)	All	Noisiest 1 hour period when in use	35	40
Place of Worship (internal)	All	When in Use	40	45
Active Recreation Area	All	When in Use	55	60
Commercial Premises	All	When in Use	65	70

Note 1: DECCW Governing Periods - Day: 7.00 am to 6.00 pm, Evening: 6.00 pm to 10.00 pm, Night: 10.00 pm to 7.00 am.

15.3.2 Sleep Disturbance Assessment

When assessing the short term maximum noise levels from the proposed stabling and maintenance operations, the current sleep disturbance guideline used in NSW should be considered (refer **Section 7.5**).

If the $L_{A1(1minute)}$ noise levels exceed the L_{A90} noise level by more than 15 dBA, more detailed analysis using the DECCW's "*Environmental Criteria for Road Traffic Noise*" (ECRTN) and/or other guidance is required to determine the frequency and level of events, the time of day in which they occur and the prevailing background level at the time.

A review of research on sleep disturbance in the ECRTN indicates that in some circumstances, higher noise levels may occur without significant sleep disturbance. Based on studies into sleep disturbance, the ECRTN concludes that:

- Maximum internal noise levels below 50-55 dBA are unlikely to cause awakening reactions.
- One or two noise events per night, with maximum internal noise levels of 65-70 dBA, are not likely to affect health and wellbeing significantly.

It is generally accepted that internal noise levels in a dwelling, with the windows open, are 10 dBA lower than external noise levels. Based on a worst case minimum attenuation, with windows open, of 10 dBA, the first conclusion above suggests that short term external noises of 60-65 dBA are unlikely to cause awakening reactions.

15.3.3 Train Stabling and Maintenance Depot Noise Goals

The procedures contained within the INP have been followed in order to determine the RBL and ambient L_{Aeq} noise levels during daytime, evening and night-time periods.

Table 95 presents the RBL and ambient L_{Aeq} noise level for each of the monitoring locations during the daytime, evening and night-time periods, along with the resulting intrusive and amenity noise goals for residential receivers based on the "urban area" classification. The sleep disturbance screening criterion is also presented for the night-time periods at each location.

The INP states that in areas where road traffic noise is the dominant noise source such that the existing traffic noise levels exceed the acceptable noise levels given in **Table 94** by 10 dBA or more, the L_{Aeq} amenity noise goals should be set at 10 dBA below the existing traffic noise level.

At the B16 and B17 monitoring locations, the existing ambient noise levels exceed the acceptable amenity noise goal by more than 10 dBA during the evening and night-time periods, primarily due to the road traffic noise from Lilyfield Road and the City-West Link Road. Hence at these locations the amenity noise goals are set at 10 dBA below the ambient L_{Aeq} noise level for the corresponding period.

Table 95 Summary of Operational Noise Goals for Train Stabling Operations

Noise Catchment Area	Time of Day[1]	Existing Noise Levels (dBA)		Operational Noise Goals (dBA)		
		RBL Noise Levels	$L_{Aeq(Period)}$	$L_{Aeq(15 min)}$ Intrusive	$L_{Aeq(Period)}$ Amenity[2]	$L_{A1(1 min)}$ Sleep Disturbance
A (B16 - 2 Hutcheson Street)	Day	57	65	62	60	-
	Evening	57	64	62	54	-
	Night	49	60	54	50	64
B (B17 - 101 Lamb Street)	Day	56	66	61	60	-
	Evening	55	64	60	54	-
	Night	47	59	52	49	62
C (B19 - 52 Starling Street)	Day	49	58	54	60	-
	Evening	49	57	54	50	-
	Night	42	51	47	45	57
D (B18 - 8 Pritchard Street)	Day	53	59	58	60	-
	Evening	51	58	56	50	-
	Night	44	54	49	45	59
E (B11 - 6 Burt Street)	Day	45	60	50	60	-
	Evening	46	58	51	50	-
	Night	36	48	41	45	51

Note 1: DECCW Governing Periods are Day: 7.00 am to 6.00pm, Evening: 6.00pm to 10.00pm, Night: 10.00pm to 7.00 am.

Note 2: Noise goals are for residences in an Urban Area.

15.4 Train Stabling and Maintenance Modelling Methodology

A computer noise model was developed in SoundPLAN Version 6.5 using the CONCAWE noise prediction algorithms.

15.4.1 Source Noise Levels - Train Stabling

On the basis of measurements undertaken by Heggies on other projects, the source noise levels in **Table 96** and **Table 97** have been used in a computer noise model.

Table 96 Sound Power Levels for Stabling Noise

Noise Source	Sound Power Level (dBA re 10^{-12}W)	Location of Noise Source
Air Compressors	87 dBA - LAeq	Under floor - Two per Train
Inverter	83 dBA - LAeq	Top of Train - Two per Train
Air Conditioner	82 dBA - LAeq	Top of Train - One per Car
Air Dryer	105 dBA - LA1(1minute)	Under floor - Two per Train
Brake Release	105 dBA - LA1(1minute)	Under floor - Two per Train

Most of the source noise levels used in the stabling noise modelling are generally based on measurements taken of Singapore Metro trains. These noise levels are considered to be comparable to typical modern metro trains around the world in terms of the noise specifications for auxiliary systems.

The inverter noise level is based on previous Heggies measurements of the NSW CityRail Millennium trains due to the absence of alternative noise data for metro trains. These noise levels are deemed to be conservative, as noise emitted by the auxiliary systems of typical metro trains are known to be lower than the noise of heavy rail trains in Sydney.

The brake release source noise level is assumed to be consistent with the metro train air dryer noise due to their similar noise characteristic (ie a short duration of concentrated hissing noise while discharging compressed air).

15.4.2 Source Noise Levels - Train Maintenance

The source noise levels associated with proposed train maintenance and building facilities are presented in **Table 97**.

Table 97 Sound Power Levels for Maintenance Activity Noise

Noise Source	Sound Power Level (dBA re 10^{-12}W)	Location of Noise Source
General Workshop Noise	105 dBA - LAeq	Inside Maintenance Building
Hand tool (Welding/Grinding)	100 dBA - LAeq	Inside Maintenance Building
Diesel Loco Idling	101 dBA - LAeq	Inside Maintenance Building
Train Wash Facility	84 (75)[1] dBA - LAeq	Train Wash Facility Façade
Truck (2t)	99 dBA - LAeq	Site Internal Road adjacent to Maintenance Building
Building Air Conditioner / Ventilation	86 dBA - LAeq	Top of Site Building
Substation	74 dBA - LAeq	Substation Building Façade

Note 1: Sound Power Level inside the brackets represents the noise emission through the façade due to the noise sources inside the building. Sound Power Level of 84 dBA represents the noise emission through the opening.

Train Wash Facility

Noise emissions for the modelling process were based on measurements of the existing train wash facility at the Singapore Metro Maintenance Depot, as it is likely that the proposed CBD Metro train wash facility will have similar noise characteristics.

Noise from the train wash facility at the Singapore Metro Maintenance Depot is shielded by the buildings which enclose the washing equipment. The open ends through which trains enter and leave the buildings do not provide any shielding. When trains are being washed however, the open area at the ends of the building is substantially reduced (by the presence of entering or emerging vehicles) for a significant period of the train wash cycle, thereby reducing noise emitted from the ends of wash plant buildings.

It is likely that one out of three trains will be washed on returning to the depot from service. Assuming a five minute service interval within the facility, one train is expected to be washed during any 15 minute period when trains are returning from service.

Substations

Two substations (Traction and Bulk Supply) are proposed to be constructed in the vicinity of the tunnel portal which will feed the stations, depot supply systems and the 1500 V DC traction supply for the CBD Metro. Noise from these substations is included as part of this noise assessment.

Noise emission levels from an existing RailCorp substation were used as the reference noise source for the modelling. It is noted that the proposed substations outside the Rozelle stabling and maintenance depot area are assessed separately as part of the Ancillary Facilities Assessment in **Section 16**.

15.4.3 Other Noise Sources

Infrastructure Maintenance

Rail grinding and major track maintenance would occur during the night-time shutdown period, however these activities (other than routine inspection) are likely to be performed on an infrequent basis.

Wheel Lathe

Given that the correcting of train wheels would be performed on an infrequent basis and that the proposed underfloor wheel lathe is likely to be built in an acoustic enclosure, the contribution from this facility is regarded as being minimal.

Audible Alarm System for Infrastructure Maintenance Rail Vehicles

It is anticipated that some form of visible and audible warning system will be used at the depot for the purpose of alerting staff when trains are approaching and when vehicles are reversing. It is recommended that all audible alarm systems within the depot should be non-tonal and that the maintenance hard stand areas and turning spaces should be designed such that vehicles do not need to reverse unnecessarily. Considering that maintenance depot is located some distance away from the residences and separated by major roads, the noise impacts due to the audible alarm systems will be minimal.

Train Cleaning

Train cleaning will not involve external noise sources and will therefore not contribute significantly to noise emission from the depot.

Stabling Facility Staff Car Park and Vehicle Movements

Noise levels from staff arrivals and departures from the Gordon Street entrance have been calculated. This includes noise from doors closing, cars starting, idling and driving in the on-site car park. It is assumed that up to five vehicle movements may occur within a 15 minute period. Under such conditions, it is predicted that the $L_{Aeq(15minute)}$ noise level at the nearest residential receivers in Denison Street and Burt Street would be in the range 30 dBA to 36 dBA (depending on the noise levels of the individual vehicles).

Considering the proximity of Lilyfield Road to surrounding residences the road traffic noise would be likely to mask the noise emissions from the staff car park and the vehicle movements within the depot and impacts would be negligible.

PA System

A Public Address (PA) system is likely to be used at the facility for the staff working within the depot. In order to achieve voice clarity, PA systems are usually designed to provide sound levels at least 10 dBA above the ambient noise level at the listening position.

The PA system for the CBD Metro depot is likely to have a capability to be operated on a quiet mode when the background noise level is low. On the basis of this and considering its occasional and short duration use, the contribution of the PA System to the overall ambient L_{Aeq} noise level would be minimal.

15.4.4 Noise Modelling Assumptions

Due to the lack of information available regarding the proposed ground contours for the Rozelle stabling and maintenance depot at the time of performing this assessment, several assumptions have been made. These include modifying the existing ground contours to more adequately reflect the possible future ground terrain (inline with the depot layout described in the EA) and assuming a consistent ground level for the base of each depot building.

The noise modelling assumptions are based on the information provided during the consultations with Sydney Metro and the rolling stock engineers.

Train Stabling

Unlike at some other stabling facilities in Australia, the CBD Metro trains will have all auxiliary systems turned off after a shut-down procedure once a train is brought to a standstill in the sidings. Some of these auxiliary systems may however need to be temporarily left on for the train cleaning staff.

The following assumptions are adopted for the stabling noise modelling:

- Trains will be stabled in a dormant state with all train auxiliary systems switched off except when they are being cleaned
- A maximum of three trains will have auxiliary systems operational during any 15 minute period at the stabling area
- As the trains are driverless and staff access to the track is strictly limited, train horns will not be required within the stabling depot

Train Maintenance

The following assumptions are adopted for the maintenance noise modelling:

- Train routine inspection will be undertaken with the auxiliary systems turned off
- Intensive train maintenance work will be undertaken during the daytime period only
- No delivery heavy vehicle movements will occur within the facility during the night-time period
- Rail grinding will not be undertaken frequently (eg every week)
- All audible alarm systems will be non-tonal

15.4.5 Noise Modelling Scenarios

In order to assess the noise emissions from the stabling and maintenance operations, various L_{Aeq} noise levels have been predicted for the daytime, evening and night-time periods.

The incidence of air dryer operation and brake testing will be likely to peak in the early morning as trains stabled over-night prepare to leave the stabling facility. Despite their short duration, the high noise levels which are emitted by the air dryers and brake testing have the potential to cause sleep disturbance at the nearby residences. These noise emissions have therefore been assessed separately against $L_{A1(1minute)}$ sleep disturbance noise screening criterion.

The following noise modelling scenarios have been assessed:

Scenario 1 (Noise Contour Plots in **Appendix J**)

- $L_{Aeq(15minute)}$, $L_{Aeq(11hour)}$ Daytime and $L_{Aeq(4hour)}$ Evening Scenarios
  - Three trains with auxiliary systems operational within the stabling area in any 15 minute period
  - General maintenance works being carried out inside the maintenance facility building
  - One train with auxiliary systems operational inside the maintenance facility in any 15 minute period
  - Delivery/maintenance heavy vehicle movements within the maintenance depot area
  - All air conditioners/ventilation systems operational for each facility building
  - Operation of train wash facility
  - Operation of two substations near tunnel portal

Scenario 2 (Noise Contour Plots in **Appendix K**)

- $L_{Aeq(15minute)}$ and $L_{Aeq(9hour)}$ Night-time Scenarios
  - Three trains with auxiliary systems operational within the stabling area in any 15 minute period
  - One train with auxiliary systems operational inside the maintenance facility in any 15 minute period
  - A diesel locomotive idling near the maintenance facility
  - Operation of train wash facility
  - All air conditioners/ventilation systems operational for each facility building
  - Operation of two substations near tunnel portal

Scenario 3 (Noise Contour Plots in **Appendix L**)

- $L_{A1(1minute)}$ Air Dryer Scenario
  - Train air dryers operating within the stabling area and inside the maintenance facility while train auxiliary systems are operating

Scenario 4 (Noise Contour Plots in **Appendix M**)

- $L_{A1(1minute)}$ Brake Test Scenario
  - Train brake testing within the stabling area and inside the maintenance facility prior to departure from the depot

15.5 Predicted Train Stabling and Maintenance Noise Levels

15.5.1 Noise Modelling Results - Stabling and Maintenance Noise (Scenario 1 and Scenario 2)

The results of the computer noise modelling for Scenarios 1 and 2 are presented in the form of $L_{Aeq(15minute)}$ and $L_{Aeq(period)}$ noise contour plots in **Appendix J** and **K**, respectively. The noise contours are calculated at the heights of 2 m and 4.8 m above ground, indicative of first floor and second floor receivers.

A summary of the noise modelling results, representing typical noise levels at upper floor levels of nearest receivers is presented in **Table 98**. These noise levels are considered conservative for one storey houses as the noise levels are likely to be higher at an upper floor height.

Table 98 Summary Train Stabling and Maintenance Noise Levels

Noise Catchment Area	Time of Day	Operational Noise Goals (dBA)		Predicted Noise Levels (dBA)[1]	
		$L_{Aeq(15min)}$ Intrusive[2]	$L_{Aeq(Period)}$ Amenity	$L_{Aeq(15min)}$ Intrusive[2]	$L_{Aeq(Period)}$ Amenity
A	Day	62	60	54	53
	Evening	62	54	54	53
	Night	54	50	52	49
B	Day	61	60	51	50
	Evening	60	54	51	50
	Night	52	49	48	41
C	Day	54	60	43	42
	Evening	54	50	43	42
	Night	47	45	<39	<34
D	Day	58	60	51	50
	Evening	56	50	51	50
	Night	49	45	<44	<43
E	Day	50	60	<40	<39
	Evening	51	50	<40	<39
	Night	41	45	<38	<37

Note 1: Outdoor noise level predicted at the worst-affected residential receivers.
Note 2: Representing the noise level during the worst-case 15 minute period.

The predicted noise levels in **Table 98** illustrate that the $L_{Aeq(15minute)}$ noise levels are likely to comply with the intrusive noise goals at all residential receivers locations. The predicted L_{Aeq} noise levels during daytime, evening and night-time are also likely to comply with the amenity noise goals.

As discussed in **Section 14.4**, there may be a requirement to accommodate additional train sets in the stabling and maintenance depot as part of an extension of the CBD Metro. In this case, the potential noise levels may be marginally higher than indicated in **Table 98** at some locations. On the basis that the CBD Metro trains are proposed to be stabled at the northern extent of the stabling facilities (close to residential receivers at Lilyfield Road), any potential noise increase from additional trains (stabled further away) would be likely to be less than 2 dBA and therefore not noticeable at the nearest receivers.

15.5.2 Noise Modelling Results - Air dryer and Brake Release Noise (Scenario 3 and Scenario 4)

The results of the computer noise modelling for Scenarios 3 and 4 are presented in the form of $L_{A1(1minute)}$ noise contour plots in **Appendix L** and **M**, respectively. The noise contours are calculated at the heights of 2 m and 4.8 m above ground, indicative of first floor and second floor receivers.

A summary of the noise modelling results, representing typical $L_{A1(1minute)}$ noise levels at upper floor levels of nearest affected receivers is presented in **Table 99**. These noise levels are considered conservative for single storey houses as the noise levels are likely to be higher at the upper floor height as presented in the table.

Table 99 Summary of Air Dryer and Brake Release Noise Levels

Noise Catchment Area	Existing Average Ambient Noise Level $L_{A1(15\ minute)}$ (dBA)	Sleep Disturbance Screening Criterion $L_{A1(1\ minute)}$ (dBA)	Predicted $L_{A1(1\ minute)}$ Night-time Noise Levels (dBA)[1]	
			Air Dryer Noise	Brake Release Noise
A	65	64	59	58
B	67	62	61	61
C	55	57	<50	<50
D	59	59	<45	<45
E	52	51	<35	<35

Note 1: Outdoor noise level predicted at the worst-affected residential receivers.

The predicted noise levels in **Table 99** illustrate that the $L_{A1(1minute)}$ air dryer and brake release noise levels are likely to comply with the sleep disturbance noise goals at all residential receiver locations.

At some of the nearest residential receivers in Noise Catchment B only marginal compliance with the screening criterion is predicted, however the existing average ambient $L_{A1(15minute)}$ noise levels already exceed 65 dBA at Noise Catchment B (refer to **Appendix C** for 24 hour average ambient noise monitoring plots), primarily due to traffic noise. The noise emissions from the air dryer and the brake release activities are therefore predicted to be lower than the existing ambient $L_{A1(15minute)}$ noise levels, hence the potential noise impact of these activities is regarded to be minimal.

However, if future brake release noise levels should be significantly higher than that specified in **Table 96** there may be a requirement for some form of noise mitigation in order to minimise potential sleep disturbance at the nearest residences during the night-time period. In such a case, acoustic silencers (on the noise sources) would be the preferred option. Also given that the air dryer and brake release noise emissions would occur beneath the carriage, the operational noise mitigation could include an option of stabling the early-arrival trains on the outermost tracks so that they effectively form a noise barrier for other trains.

15.6 Conclusions

The potential noise impact due to the proposed Rozelle stabling and maintenance depot at the former Rozelle Marshalling Yard has been assessed in accordance with the DECCW's INP. Additionally, the risk of sleep disturbance at the nearby residences has also been assessed with reference to the DECCW's ENCM guideline.

Comprehensive noise modelling has been undertaken to predict the potential cumulative noise impact from the train stabling, maintenance and other associated operations performed at the depot. The modelling was based on the depot layout described in the EA, with the inclusion of the assumptions as described in **Section 15.4.4**. The modelling was carried out for a range of representative scenarios to predict noise emissions confidently during the daytime, evening and night-time periods.

The noise modelling indicates that noise levels will comply with the intrusive and amenity goals at all locations in the vicinity of the facility. This compliance is primarily due to the proposed depot being located in a deep cutting with respect to the surrounding residencies. The cutting forms an effective noise barrier, despite the relative proximity of residential areas to the proposed depot.

It is also unlikely that the short duration of high noise emissions from air dryer and brake testing, which will peak in the early hours of the morning as trains prepare for service, would cause sleep disturbance at any residences. Additional mitigation measures are available if required to manage this risk effectively.

The noise emissions from the proposed substations near the tunnel portal are likely to be negligible considering the masking effects of road traffic noise along the Lilyfield Road, which would be much higher than the noise from the substations. Likewise the potential noise impact due to the car park near the Gordon street entrance would be minimal.

15.7 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. **Table 100** details the draft SoC associated with the Train Stabling and Maintenance Assessment for the CBD Metro.

Table 100 Draft Statement of Commitments - Airborne Noise Assessment - Train Stabling and Maintenance

Report Section	Measure Type	Commitment	Desired Environmental Outcome
15.3.3	Manage	For residential receivers adopt the operational noise goals specified in the DECCW's "*Industrial Noise Policy*".	Minimise train stabling and maintenance airborne noise levels at nearby residential receivers.
15.4.1, 15.4.2	Mitigate	Source noise levels from auxiliary equipment on trains will be comparable with or lower than the values specified in Table 96 and Table 97, otherwise additional feasible and reasonable mitigation measures will need to be considered.	Minimise train stabling airborne noise levels at nearby residential receivers.
15.4.3	Avoid	All audible alarm systems within the depot will be non-tonal.	Minimise alarm system noise levels at nearby residential receivers.

16 AIRBORNE NOISE ASSESSMENT - ANCILLARY FACILITIES

At underground sections of track, airborne noise generated by trains is reduced to inaudible levels at above-ground receivers by the intervening rock and soil above the tunnels. The exception to this is at ventilation stacks and draught relief shafts. At these locations, airborne noise from trains may be audible even though there is little or no visible evidence of rail operations.

Other ancillary noise sources would typically include mechanical services plant to ventilate underground areas and surface buildings.

This section of the Environmental Assessment presents the acoustic assessment of the impact from noise emissions associated with the ancillary facilities of the CBD Metro Project.

At this stage the exact location and specification of the ancillary equipment which is likely to be used as part of the Reference Design has not yet been fixed and may be subject to change. This desktop assessment has therefore been limited to establishing noise goals and determining the maximum allowable noise emissions at each location where noise would be emitted to the external environment.

In general, these types of noise sources lend themselves readily to mitigation by appropriate equipment selection, design techniques and provision of engineering noise controls such as silencers, acoustic louvres, enclosures, etc.

16.1 Noise Goals

16.1.1 Unattended Noise Measurements

To determine the existing ambient noise climate within the CBD Metro Project area, unattended ambient noise measurements were undertaken during March, April and May 2009 (this process is described in detail in **Section 5.3**, with the monitoring locations being illustrated on the Site Plan in **Appendix B)**. Measurements were performed in the vicinity of all proposed CBD Metro Stations.

16.1.2 Mechanical Services Noise Goals

The noise goals for the external noise emissions associated with mechanical services are taken from the NSW Department of Environment, Climate Change and Water (DECCW) "*Industrial Noise Policy*" (INP). The assessment methodology embodied within the INP has been previously described in **Section 15.3.1**.

Noise emissions from the mechanical services in this assessment are normally of a continuous nature and do not change unless operational conditions vary. As a result of the general reduction in ambient existing noise levels during the latter periods of the day, the night-time INP noise goals are the most stringent and are therefore the limiting design goals at all locations for noise generated by ancillary equipment.

The locations of sensitive receivers and their corresponding industrial noise goals, determined through the procedures defined within the INP, are presented in **Table 101**.

"Commercial" and "recreation area" receivers are noted as having acceptable noise levels of 65 dBA and 55 dBA L_{Aeq} respectively (when in use).

The design goal applicable to "educational facilities" is an internal noise level of 35 dBA, specified as $L_{Aeq(1hour)}$ for the noisiest 1-hour period when the facilities are in use. As such, with windows open along the noise exposed facade to allow for natural ventilation, this would correspond to an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 45 dBA (when assuming a typical noise reduction of 10 dBA from outside to inside).

The design goal applicable to "places of worship" is an internal noise level of 40 dBA $L_{Aeq(period)}$. When considering places of worship, with windows open to provide for natural ventilation, a resulting external design goal of 50 dBA is apparent.

Table 101 Sensitive Receivers in the Vicinity of Ancillary Facilities

Location	Shaft	Receiver	Address	Distance	Logging Location[1]	External Noise Goal (dBA)
Central	Shaft 1 E	Residential	509 Pitt Street	25 m	B01	56
	Shaft 1 W	Residential	2 Lee Street	25 m	B01	56
	Shaft 3	Commercial	Central Station	50 m	-	65
		Residential	505 Pitt Street	100 m	B01	56
		Recreation Area	Belmore Park	<10 m	-	55
Town Hall Square	Shaft 1	Commercial	Pitt Street	10 m	-	65
	Shaft 2	Commercial	115 Bathurst Street	20 m	-	65
		Residential	300 Pitt Street	30 m	B02	58
Martin Place	Shaft 1	Commercial	Martin Place	10 m	-	65
	Shaft 2	Commercial	4 Castlereagh Street	10 m	-	65
Barangaroo-Wynyard	Shaft 1 E	Residential	44 Margaret Street	50 m	B04	53
	Shaft 1 W	Commercial	30 Clarence Street	10 m	-	65
	Shaft 2	Commercial	10 Shelley Street	30 m	-	65
		Commercial	56 Sussex Street	30 m	-	65
Pyrmont	Shaft 1	Residential	103 Pyrmont Street	< 10 m	B05	41
		Commercial	13 Union Street	20 m	-	65
	Shaft 2	Residential	104 Miller Street	20 m	B06	41
		Commercial	108 Miller Street	20 m	-	65
Lilyfield	Tunnel Portals	Residential	Lilyfield Rd	30-40 m	B09	49[3]
Rozelle	Shaft 1	Residential	91 Victoria Rd	< 10 m	B13	47
		Childcare Centre	668 Darling Street	15 m	-	45[2]
		Place of Worship	St. Thomas, 668 Darling Street	30 m	-	50[2]
	Shaft 2	Place of Worship	St. Pauls, 665A Darling Street	10 m	-	50[2]
		Educational	Rozelle Primary School	25 m	-	45[2]
		Residential	669 Darling Street	30 m	B14	49

Note 1: Noise goals for places of worship as well as commercial and educational premises are absolute levels, and are not relative to existing background noise levels.

Note 2: Assuming windows partially open and 10 dB noise reduction between outside and inside.

Note 3: All other industrial noise sources that form part of the CBD Metro proposal are predicted to have an insignificant contribution to the overall noise level at this location.

16.1.3 Train Passby Noise Goals

Train passby noise emitted from ventilation shafts or other openings has been considered with regard to the following $L_{Amax\ (fast)}$ noise goals:

Table 102 Train Passby Noise Goals

Usage	Existing Noise Level $L_{Aeq(period)}$[1] (dBA)	Noise Goal L_{Amax} (dBA)
Residential	≤ 50	55
	50-55	$L_{Aeq(period)}$ + 5 dBA
	> 55	60
Commercial	Not applicable	65

Note 1: Noise goals for residential receivers are based on the existing daytime, evening and night-time equivalent noise levels. However, the night-time noise goals are envisaged to be controlling.

The L_{Amax} noise level refers to the 95th percentile train passby event (ie 5% of train passbys are permitted to exceed these levels). The absolute maximum event is not used for design, as it cannot be precisely defined and would be a highly infrequent event.

These noise goals are comparable with the adopted design goals for the Epping to Chatswood Rail Line (ECRL) and Sydney Airport Rail Line and are also more stringent than the noise goals applied in the DECCW's "*Interim Guideline for the Assessment of Noise from Infrastructure Projects*" (IGANRIP), relating to airborne noise from the operation of trains on surface track.

16.2 Modelling Methodology

The airborne noise modelling results presented in this assessment is based on the preliminary shaft locations which are still potentially subject to change. Specific equipment is also not known at this stage and the expected noise levels can therefore not be predicted. As such, the maximum total allowable emitted sound power at each location has been calculated, specifying the acoustic emission limit for all equipment (combined operation) at each location.

The noise sources have been assumed not to require the application of modifying factors, as defined in the INP. Hence they have been assumed to not operate with a noticeable tonal, impulsive or intermittent nature, unless otherwise stated.

16.3 Noise Predictions

The maximum allowable sound power levels emitted by industrial-type noise sources have been predicted for each location in order to meet the noise goals at nearby sensitive receivers. The results are presented in **Table 103**.

Table 103 Ancillary Facilities - Maximum Acceptable Noise Emissions

Location	Shaft	Maximum Acceptable Sound Power Level (dBA)
Central	Shaft 1 E	89
	Shaft 1 W	89
	Shaft 3	74
Town Hall Square	Shaft 1	90
	Shaft 2	93
Martin Place	Shaft 1	90
	Shaft 2	90
Barangaroo-Wynyard	Shaft 1 E	92
	Shaft 1 W	90
	Shaft 2	100
Pyrmont	Shaft 1	60
	Shaft 2	72
Lilyfield	Tunnel Portals	77[1]
Rozelle	Shaft 1	66
	Shaft 2	78

Note 1: A 5 dBA noise penalty has been allowed due to the noise characteristics at this location having a high tonality and also being intermittent.

16.4 Train Noise Break-out

Although the proposed railway line would operate underground, noise generated during train passbys has the potential to escape from the tunnels via tunnel ventilation shafts and draught relief shafts.

The in-tunnel maximum reverberant noise levels used for predictions of the train noise break-out are presented in **Table 104**.

Table 104 In-tunnel Reverberant Noise Levels

	Maximum Noise Levels, $L_{max\ (fast)}$ [dB]									
Octave Band Centre Frequency [Hz]	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dBA**
In-tunnel noise levels	94	88	86	93	101	97	92	90	83	**102**

Discussions with PBACH indicate that each station would have two 20 m^2 draught relief shafts openings, lined with concrete. As concrete is a highly reflective material with practically no absorptive characteristics, the reduction losses as noise propagates to the surface through the shafts would be negligible.

Based on the above assumptions, maximum noise levels from a train passby would be expected to exceed the design goals where unmitigated draught relief shafts are located:

- Within 350 m of residential facades
- Within 125 m of commercial facades

Tunnel ventilation shafts are expected to have attenuators on both the ambient and tunnel sides of the fans in order to attenuate the fan noise. Typical acoustic performance of a 1.5 m long attenuator with a 40% open area is assumed for the tunnel side and a similar but 3 m long attenuator on the ambient side. The combined insertion loss provided by these attenuators will decrease the train noise to less than 50 dBA at 1 m from the surface discharge, providing a considerable margin to the noise goals at all sensitive receivers outlined in **Section 16.1**.

16.5 Mitigation/Conclusion

The maximum allowable mechanical services sound power levels emitted at each location for detailed design purposes have been calculated and range from 60 dBA to 100 dBA.

Mitigation measures are likely to be required for some station and tunnel ventilation equipment/locations in order to comply with the INP noise goals. Mitigation measures that may need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train noise break-out through the tunnel ventilation shafts from trains operating within the tunnel is not expected to exceed the noise design goals. However, all draught relief shafts will require mitigation measures (typically in-duct noise attenuation) in order to comply with the noise goals at the nearby sensitive receivers. Applying the nominal insertion loss values of a 3 m long attenuator would allow for compliance at residential receivers approximately 10 m from the shaft opening.

16.6 Draft Statement of Commitments

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments. **Table 105** details the draft SoC associated with the Ancillary Facilities Assessment for the CBD Metro.

Table 105 Draft Statement of Commitments - Airborne Noise Assessment - Ancillary Facilities

Report Section	Measure Type	Commitment	Desired Environmental Outcome
16.1.2	Manage	For steady noise emissions from tunnel ventilation equipment and other ancillary equipment, adopt the operational noise goals specified in the DECCW's "*Industrial Noise Policy*".	Minimise airborne noise levels at sensitive receivers.
16.1.3	Mitigate	For noise breakout from the ventilation shafts during train passbys, adopt airborne noise goals (external) of $L_{Amax(fast)}$ 55 dBA at residential facades and $L_{Amax(fast)}$ 65 dBA at commercial facades.	Minimise airborne noise levels at sensitive receivers.

17 OPERATIONAL NOISE AND VIBRATION MANAGEMENT PLAN

Prior to operations, the operator will be required to prepare an operational noise and vibration management plan (ONVMP). This plan will include the following:

- A summary of the operational noise and vibration design goals and project commitments
- Predicted operational noise and vibration impacts (as documented in the detailed design)
- Monitoring procedures and locations for regular ground-borne noise, airborne noise and ground-borne vibration measurements
- A description of the proposed management procedures for dealing with and resolving complaints relating to noise and vibration issues
- Procedure for ongoing reporting of measurement results and changes to the ONVMP

The ONVMP is to address noise and vibration from all aspects of the CBD Metro operations, not limited to ground-borne noise and vibration from train passbys, airborne noise from train operations between the stabling facility and tunnels, airborne noise from the train stabling and maintenance facilities, car park noise and airborne noise from other ancillary facilities including stations and tunnel ventilation shafts.

18 DRAFT STATEMENT OF COMMITMENTS

The Director-General's Requirements (DGRs) for the Environmental Assessment (**Section 3**) require a draft Statement of Commitments (SoC) to be prepared which summarises the proposed measures to avoid, minimise, manage, mitigate, offset and/or monitor impacts identified in the noise and vibration assessments.

For construction noise and vibration, a summary of the SoC's is provided in the main body of the Environmental Assessment. For operational and maintenance noise and vibration, a summary of the SoC's are provided in each relevant section of the report and summarised below:

Table 106 Draft Statement of Commitments

Report Section	Measure Type	Commitment	Desired Environmental Outcome
Ground-borne Vibration Assessment - Train Operations			
12.2	Manage	A ground-borne vibration level of 106 dB_V (0.2 mm/s rms) has been adopted as a design goal. This goal is based on residential receivers with higher levels being applicable for commercial and industrial buildings.	Ensure that vibration levels during train passbys do not cause disturbance to building occupants
Ground-borne Noise Assessment - Train Operations			
13.2	Manage	For residential receivers, schools, educational institutions and places of worship, adopt the "noise trigger" levels in the DECCW's *"Interim Guideline for the Assessment of Noise from rail Infrastructure Projects"* as design goals.	Minimise ground-borne noise levels at nearby sensitive receivers
13.2	Manage	For other sensitive receivers, adopt the ground-borne noise design goals in Table 87.	Minimise ground-borne noise levels at nearby sensitive receivers
13.5	Mitigate	The track design will incorporate moderately resilient and/or highly resilient rail support systems to achieve compliance with the ground-borne noise design goals.	Minimise ground-borne noise levels at nearby sensitive receivers
12.3.3	Manage	Wheel and track maintenance procedures will be adopted to ensure that source vibration levels are within the specified limits. Monitoring systems will be implemented to measure the condition of the wheels and track. A wheel lathe and track grinding machine will be used to restore the track condition to specified limits when required. If wheel flats or other wheel defects do occur, these would be identified by a permanent monitoring station and rectified using a wheel lathe or other measures to return the wheel condition to an acceptable degree of smoothness.	Ensure that the ground-borne noise goals remain within the design goals on a long-term basis.

Report Section	**Measure Type**	**Commitment**	**Desired Environmental Outcome**
13.9	Manage	Compliance monitoring will be undertaken at the commencement of train operations at selected receiver locations.	Assess compliance with the ground-borne noise design goals and determine if any additional feasible and reasonable mitigation measures are required.
Airborne Noise Assessment - Train Operations			
14.2	Manage	For residential receivers, schools, educational institutions and places of worship, adopt the "noise trigger" levels in the DECCW's "*Interim Guideline for the Assessment of Noise from rail Infrastructure Projects"* as design goals.	Minimise airborne noise levels at nearby sensitive receivers
14.3.4	Mitigate	For the tunnel portals, noise barriers and/or portal extensions may be required if the detailed assessment indicates a curving noise is likely.	Minimise general train noise and any curve squeal noise which may be generated from the curved underground sections.
14.5	Mitigate	During the detailed design stage, careful attention will need to be taken to ensure that the risk of curve flanging and curve squeal do not occur at locations where the curve radius is less than approximately 300 m. It is anticipated that gauge face lubrication and top of rail friction modification may be required near the tunnel portals to minimise the risk of curving noise.	Minimise general train noise and any curve squeal noise which may be generated from the curved underground sections.
Airborne Noise Assessment - Train Stabling and Maintenance			
15.3.3	Manage	For residential receivers adopt the operational noise goals specified in the DECCW's "*Industrial Noise Policy"*.	Minimise train stabling and maintenance airborne noise levels at nearby residential receivers.
15.4.1, 15.4.2	Mitigate	Source noise levels from auxiliary equipment on trains will be comparable with or lower than the values specified in Table 96 and Table 97, otherwise additional feasible and reasonable mitigation measures will need to be considered.	Minimise train stabling airborne noise levels at nearby residential receivers.
15.4.3	Avoid	All audible alarm systems within the depot will be non-tonal.	Minimise alarm system noise levels at nearby residential receivers.
Airborne Noise Assessment - Ancillary Facilities			
16.1.2	Manage	For steady noise emissions from tunnel ventilation equipment and other ancillary equipment, adopt the operational noise goals specified in the DECCW's "*Industrial Noise Policy"*.	Minimise airborne noise levels at sensitive receivers.
16.1.3	Mitigate	For noise breakout from the ventilation shafts during train passbys, adopt airborne noise goals (external) of $L_{Amax(fast)}$ 55 dBA at residential facades and $L_{Amax(fast)}$ 65 dBA at commercial facades.	Minimise airborne noise levels at sensitive receivers.

19 CONCLUSIONS

For new underground railway projects, consideration of the potential noise and vibration impacts during the design stage is critical in order to achieve a cost-effective and acceptable environmental outcome for the surrounding community. The application of add-on mitigation measures after construction is completed is usually very expensive, and in many cases is not feasible after train operations commence.

The proposed CBD Metro represents a unique opportunity to influence the design, maintenance and operation of a low noise and vibration railway system. Sydney Metro's Acoustical Technical Advisor (Heggies) has been a key member of the design team from the outset of the project, providing input to the route options studies, track design, rolling stock specifications and maintenance practices.

Construction Noise and Vibration

Because of the temporary nature of construction works, the potential noise and vibration impacts during the construction phase of a project are often less significant than the long-term operational impacts.

Notwithstanding the above, the noise and vibration emissions are typically higher during the construction phase of projects than during operations. Construction often requires the use of heavy machinery which can generate significant noise and vibration emissions at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts need to be effectively managed and minimised.

At any particular location, the potential noise and vibration impacts can vary greatly depending on factors such as the relative proximity of noise-sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration emissions, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

At this early stage in the planning process, detailed information in relation to the proposed construction works, equipment, timeframes and the location of sensitive receivers in relation to the construction sites is not available. The construction noise and vibration assessment has therefore been based on preliminary information, and should be reviewed in more detail as the project progresses and the future land-uses in the vicinity of the proposed construction sites are better understood.

Notwithstanding the above, it is anticipated that at White Bay compliance with the daytime and night-time Noise Management Levels (NMLs) is predicted, noting the White Bay site is well placed for construction works, with sensitive receivers distant and in many instances shielded by topography and commercial buildings. At the Rozelle stabling and maintenance depot site activities are expected to occur during the daytime and for general earthworks minor exceedances are predicted, and compliance for construction of the building facilities. During portal and dive structure construction and excavation a significant exceedance of up to 11 dBA occurs primarily as a result of the high noise levels from the excavation equipment, and the relative close proximity of Lilyfield receivers.

At the station construction sites, predicted levels for excavation and construction at all the sites indicate significant exceedances of the NMLs for daytime operations at most receivers. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Higher exceedances are predicted during the evening and night-time periods as a result of the lower NMLs. Careful management will be required at the nearest receivers to all the station sites.

To mitigate impacts, feasible mitigation measures may include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites, noting noise walls are effective for receivers at or near ground level (eg outdoor eating areas) and not effective for receivers overlooking the sites. Full enclosures would only be considered at locations where night-time construction activities are proposed to be undertaken for extended periods of time. The indicative enclosure construction would consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where increased noise insulation is required this can be achieved by upgrading the enclosure elements by using, for example, a double skin or masonry construction. The reasonableness of the identified feasible mitigation measures would be undertaken during the construction planning and site establishment phases of the project.

Excavation activities are unlikely to be permitted to occur during the evening and night-time periods at the station sites, without significant noise mitigation and careful management of all noise-producing equipment and activities. These mitigation measures could also include alternative excavation methods such as penetrating cone fracture techniques.

Having considered all reasonable and feasible noise mitigation, the CBD Metro *"Construction Noise and Vibration Strategy"* would be implemented to manage the potential noise impacts.

Buildings that are potentially at risk of threshold or cosmetic vibration damage will be identified by the contractor prior to the commencement of construction works. At these locations, impacts will be managed in accordance with the procedures outlined in Sydney Metro's *"Construction Noise and Vibration Strategy"* which may require building condition surveys to be conducted before the commencement of construction activities and after construction are completed.

Where exceedances of the human comfort or sensitive equipment vibration goals are predicted, these will also need to be managed or mitigated in accordance with the procedures outlined in Sydney Metro's *"Construction Noise and Vibration Strategy"*.

Potential ground-borne noise impacts are likely to be highest at sensitive receiver locations close to the station caverns or main tunnel alignments. At station cavern sites, roadheaders are anticipated to operate during the daytime and night-time. Ground-borne noise levels may exceed the design goals when the roadheader is located close to sensitive receivers. At these locations, the ground-borne noise levels are likely to reduce over time as the roadheader moves away from the receiver and the depth of the station cavern increases.

The railway tunnels are proposed to be excavated using tunnel boring machines between White Bay and Central Station and using roadheaders between White Bay and Rozelle/Lilyfield. Tunneling activities are anticipated to occur on 24 hour per day basis. At any particular receiver location, the potential ground-borne noise impact from tunneling operations is anticipated to occur only for short periods of time when each roadheader or tunnel boring machine passes by.

Operational Noise and Vibration

Ground-borne noise and vibration modeling was undertaken for the Reference Design track alignment.

On the basis of the proposed alignment, operating speeds and design/maintenance assumptions, the predicted ground-borne vibration levels with the proposed standard trackform design are more than 10 dB below the design goals at the nearest sensitive receiver locations.

For the proposed CBD Metro, two trackforms have been proposed as part of the Reference Design to achieve the ground-borne noise objectives. These comprise a "standard attenuation" trackform, with moderately resilient rail fasteners, and a "high attenuation" trackform, incorporating highly resilient rail fasteners.

The ground-borne noise modelling indicates that the “standard attenuation” trackform will not achieve compliance with the ground-borne noise goals at all locations. At critical locations (which include residential receivers in Pyrmont and Rozelle), a “high attenuation” trackform will be required to achieve the ground-borne noise design goals. With the proposed combination of “standard attenuation” and “high attenuation” trackforms, compliance with the ground-borne noise design goals is predicted at all sensitive receiver locations.

Airborne noise assessments were also undertaken for the operation of the proposed Rozelle stabling and maintenance depot, train stations, sub-stations and ventilation shafts.

The noise modelling indicates that noise levels are anticipated to comply with the appropriate goals at all locations in the vicinity of the stabling and maintenance. This compliance is primarily due to the proposed depot being located in a deep cutting with respect to the surrounding residencies. The cutting therefore forms an effective noise barrier, despite the relative proximity of residential areas to the proposed depot.

At the proposed train stations, appropriate noise mitigation measures are likely to be required for some station and tunnel ventilation equipment/locations in order to comply with the INP noise goals. Mitigation measures that may need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train noise break-out through the tunnel ventilation shafts from trains operating within the tunnel is not expected to exceed the noise design goals. However, all draught relief shafts will require mitigation measures (typically in-duct noise attenuation) in order to comply with the noise goals at the nearby sensitive receivers.

Through the completion of the above assessments it is believed that this report fully addresses the Director-Generals Requirements relating to potential noise and vibration impacts resulting from the CBD Metro Project.

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