HEGGIES

REPORT 10-4805-R3

Final

Kingsgrove to Revesby Quadruplication
Assessment of Noise and Vibration Emissions
Construction and Operations

PREPARED FOR

Transport Infrastructure Development Corporation
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EXECUTIVE SUMMARY

The purpose of this report is to assess the potential noise and vibration emissions during construction and operation of the Kingsgrove to Revesby Quadruplication Project (proposal). Based on the proposed rail alignment, this report identifies the principle areas where noise or vibration mitigation is considered likely to be required. Detailed barrier optimisation has been undertaken to determine feasible and reasonable mitigation for the proposed operation.

The proposed quadruplication will involve the construction of an additional Down Main Line and Up Main Line between Kingsgrove and Revesby, several new underbridges, modification of several overbridges to accommodate the additional lines, and additional turnouts. The quadruplication will allow separation of Rail Clearways 3 and 4 and allow local trains to be terminated at Revesby rather than continuing through to East Hills.

Operational Noise

In order to assess the operational noise impacts, two noise modelling scenarios have been considered. These being: the existing rail operations (Year 2006), and the future long-term rail operations approximately ten years after opening (Year 2021). The operational noise emissions have been assessed in accordance with the guidelines in the *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* (IGANRIP) (NSW Government - April 2007).

For a rail upgrade project, the IGANRIP provides trigger levels relating to the overall noise levels (L_{Amax} and L_{Aeq}), as well as the increase in noise levels as a result of the project. In order to initiate an assessment of rail noise impacts and investigate mitigation measures, both the increase in rail noise levels as a result of the project **AND** the overall level of rail noise must exceed the trigger levels. No further assessment is required at locations where both trigger levels are not exceeded.

Compared with the existing situation, the number of residential locations exceeding the overall noise trigger levels in Year 2021 is predicted to increase from 46 to 161 on the Down (southern) Side of the railway corridor and from 46 to 156 on the Up (northern) Side of the railway corridor as a result of the project.

On the basis of the calculated future noise levels, the predicted increase in L_{Aeq} noise levels at the nearest receivers (without mitigation) would typically be approximately 5 dBA in every hour. Similarly, at most locations, the predicted increase in L_{Amax} noise levels as a result of the project would be approximately 4 dBA. The significant increase in L_{Aeq} and L_{Amax} noise levels results from the proposed increase in train speeds on the new lines and the reduced offset distance between the new tracks and receiver locations.

As well as the increase in noise levels, the overall level of railway noise also has an influence on the potential noise impact at sensitive receiver locations. On the basis of the predicted future noise levels, the total number of receivers likely to be "annoyed" would increase from approximately 160 to 320, and the total number of receivers likely to be "highly annoyed" would increase from approximately 60 to 120 as a result of the proposal.

On this basis, it is concluded that without mitigation, the percentage of the population "annoyed" or "highly annoyed" by railway noise would be doubled as a result of the project and the consideration of noise mitigation measures to maximise the protection of the environment is warranted.

On the basis of the operational noise modelling, residential and other noise sensitive receivers predicted to exceed the trigger levels have been identified. At these locations, detailed noise barrier analysis has been undertaken to determine whether noise barriers are feasible and reasonable. Noise barriers are proposed at 30 locations, with a total barrier length of 6.850 m.

At locations where noise barriers are considered to be feasible and reasonable, compliance with the overall noise trigger levels is achieved at the majority of residential receiver locations. At locations where noise barriers are not cost effective or where the proposed barriers are not high enough to achieve significant noise reductions at the upper levels of residential buildings, building treatments may need to be considered.

Overall, the number of noise sensitive receiver locations exceeding the overall noise trigger levels of L_{Amax} 85 dBA and daytime $L_{Aeq(15hour)}$ 65 dBA in Year 2021 is predicted to be reduced from 161 to 33 on the Down Side of the track and from 156 to 36 on the Up Side of the track as a result of the proposed noise barriers, compared to Year 2021 without any mitigation. It should be noted that this is a slight decrease in trigger level exceedances compared to the existing Year 2006 scenario.

Of the 69 residual trigger level exceedances, on the basis of site observations 13 of these receivers are located within recently constructed developments and a further 5 of these receiver locations are school or community centre buildings. On that basis building treatments may need to be considered at the remaining 51 residual receiver locations.

At this early stage in the assessment process, other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal have not been assessed to the same level of detail. The proposed mitigation measures are indicative only and may change as more detailed project information becomes available and consultation with affected stakeholders occurs.

Operational Vibration

The reduction in distance to receivers is likely to increase the vibration levels at residential buildings on both the Down side and Up side of the railway corridor. On the basis of measurements undertaken as part of the proposal and proposed alignment of the new track, future vibration levels at two locations are predicted to exceed the vibration dose-based vibration trigger levels. Resilient ballast mat is proposed on the near track at each location in order to mitigate future vibration levels.

Construction Noise and Vibration

Construction noise modelling has been undertaken for nineteen different scenarios across a total of twelve major work areas covering activities that are planned to occur during the nominated two and a half year construction programme.

At the majority of locations, the predicted L_{A10} construction noise levels will at times exceed the noise goals when plant and equipment is located in close proximity to residential and commercial receiver locations. This results from the small offset distances, rather than particularly noisy construction plant.

The highest impacts are predicted to occur adjacent to residential locations where rockbreakers are required. It is anticipated that the rockbreakers would be used for relatively short periods of time, therefore resulting in significantly lower construction noise levels for the majority of the works.

Mitigation measures such as providing site hoardings where feasible and reasonable, sourcing of quiet equipment, delivering equipment during daytime hours and other measures described in **Section 6.8** will be undertaken to minimise potential construction noise impacts particularly during the night-time period.

In order to minimise disruptions to the local community and prevent damage to nearby buildings during vibration-generating construction activities (such as rockbreaking and vibratory rolling), buffer distances between plant items and adjacent structures are proposed. Vibration monitoring will be undertaken if any work is required within the proposed buffer zones.

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1 INTRODUCTION

1.1 Scope

Heggies Pty Ltd (Heggies) has been engaged by the Transport Infrastructure Development Corporation (TIDC) to undertake a noise and vibration study for the proposed Kingsgrove to Revesby Quadruplication project (proposal).

This proposed upgrade forms part of the NSW Government's Rail Clearways Program to develop five independent rail clearways across the CityRail network by 2010.

The existing East Hills Line is a double-track line running through the study area between Kingsgrove and Revesby. The proposed quadruplication would provide a total of four tracks between Kingsgrove and Revesby. The new tracks would be located on the outside of the existing tracks and would become the Up Main and Down Main tracks. The existing tracks would become dedicated Up Local and Down Local tracks.

The capacity of the line would be increased by providing additional track and turnouts. Ten bridges would need to be modified as part of the proposal.

The purpose of this report is to assess the potential noise and vibration emissions during construction and operation and provide locations where mitigation measures are predicted to be required.

Heggies Report 10-4805-R1 collates the background information required to undertake the assessment including building occupancy surveys, ambient noise investigations and attended noise and vibration measurements for the existing operations.

1.1 Terminology

Specific acoustic terminology is used within this report. An explanation of common terms is included as **Appendix A**.

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

2 PROPOSAL DESCRIPTION

The Rail Clearways Program has been developed to untangle the current complex Sydney rail network and provide a more frequent and reliable train service. The main objective of the program is to split the network into five distinct lines or clearways, preventing a delay or incident on one clearway from affecting rail operations on the other four clearways.

The Proposal is a component of Clearways 3 and 4. The Revesby Turnback currently under construction will replace the existing turnback facility at East Hills and will be the first step in the creation of Clearway 4. The Kingsgrove to Revesby Quadruplication is due for completion in 2010 to complete the separation of Clearway 3 from Clearway 4.

The existing East Hills Line between Kingsgrove and Revesby comprises a single track in each direction. At Revesby Station, there is an existing single island platform where approximately 60% of trains stop and 40% do not stop.

The Revesby Turnback project is currently under construction. After completion in 2008 it will allow some trains to be terminated at Revesby rather than continuing through to East Hills. A new track will be constructed on the Down (southern) side of the existing railway corridor from Wyreema Avenue to Tarro Avenue (a distance of approximately 960 m). The existing Down track will terminate at Revesby Station and become a new bi-directional turnback road. The new Down track will run over a new underbridge at The River Road and through a new platform at Revesby Station. Two new crossovers will be constructed, with one located immediately to the east of The River Road underbridge and the second located approximately 150 m west of Wyreema Avenue.

The proposal comprises the following additional components:

- Construction of new underbridges at the following locations:
  - Beverly Hills storm water canals
  - Broad Arrow Road, Narwee
  - Bonds Road, Riverwood
  - Webb Street, Riverwood
  - Salt Pan Creek
- Modification of overbridges at the following locations:
  - King Georges Road, Beverly Hills
  - Belmore Road, Riverwood
  - Davies Road, Padstow
  - Memorial Drive, Padstow
  - Doyle Road, Padstow
- Construction of a new track on the Down (southern) side of the existing railway corridor between Westbrook Street, Beverly Hills and Tarro Avenue, Revesby. The new Down Main track will connect into the existing Down Main approximately 150 m east of Westbrook Street and connect with the new Down Local track approximately 170 m west of Tarro Avenue.
- Construction of a new track on the Up (northern) side of the existing railway corridor between Bundara Street, Beverly Hills and The River Road, Revesby. The new Up Main track will connect into the existing Up Main approximately 250 m east of Bundara Street and connect with the existing Up Main track approximately 100 m east of The River Road.
- New turnouts will be required approximately 50 m east of Westbrook Street, Beverly Hills to connect the new Down Main and Up Main to the existing Down Local and Up Local respectively.

- Several new crossovers will be required between Wilberforce Road and The River Road, Revesby to allow Up and Down direction trains to switch from Local to Main tracks and vice versa.
- A crossover installed for the Revesby Turnback project in the same area will be removed as part of the proposal.

3 EXISTING ACOUSTIC ENVIRONMENT AND SENSITIVE RECEIVER LOCATIONS

3.1 Existing Acoustic Environment

The existing acoustic environment in the proposal area can be generally summarised as suburban.

Adjacent to the railway corridor, residential and other sensitive receiver locations are currently exposed to noise emissions from the existing rail operations. At many locations (discussed in **Section 4.8**), the existing noise levels exceed the proposed operational noise goals, resulting from the small offset distances between the existing railway line and the adjacent receivers.

There are also a number of roads running parallel to and/or intersecting with the railway corridor. The noise emissions from these roads contribute to increased ambient noise levels at nearby residential and other sensitive receiver locations.

3.2 Sensitive Receiver Locations

The distribution of sensitive receivers along the East Hills Line between Kingsgrove and Revesby is summarised below in order of increasing chainage. A site plan is provided in **Appendix B**, showing the location of the relevant streets.

Table 1 Sensitive Receivers - Down Side

Location	Description
Westbrook Street to King Georges Road	Morgan Street is adjacent to the corridor with receivers comprising single-level residential buildings facing the railway. There are commercial receivers fronting King Georges Road.
King Georges Road to Broad Arrow Road	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings fronting King Georges Road. Adjacent to the railway corridor, there are multi storey residential buildings on Melvin Street South and along Bryant Street.
Broad Arrow Road to Bonds Road	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings in the vicinity of Narwee Station. Immediately to the west of Narwee Station, Narwee Primary School is located adjacent to the railway corridor.
Bonds Road to Belmore Road	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings fronting Thurlow Road near Riverwood Station. Adjacent to the railway corridor, there are multi storey residential buildings on Romilly Street and Thurlow Street. St Josephs Primary School is also located on Thurlow Street.
Belmore Road to Salt Pan Creek	The majority of nearby receivers comprise single-level residential buildings located along Webb Street, with multi-storey residential buildings on Webb St near Riverwood Station. Commercial buildings are located along Belmore Road near Riverwood Station.
Salt Pan Creek to Memorial Drive	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings fronting Howard Road near Padstow Station. Adjacent to the railway corridor, there are new two storey residential buildings east of Davies Road and there is a multi storey residential building under construction on Howard Road adjacent to the multi level car park near Padstow Station.
Memorial Drive to Wyreema Avenue	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings including Padstow RSL fronting Howard Road near Padstow Station.

Location	Description
Wyreema Avenue to The River Road	The majority of nearby receivers comprise single-level residential buildings. A new residential development comprising five two-level villas is currently proposed at 23-25 Montgomery Avenue. Three of the proposed villas will be located adjacent to the railway boundary.
The River Road to Tarro Avenue	The majority of nearby receivers are commercial. The nearest residential receivers are located at the Revesby Pacific Hotel at 176 The River Road. It is understood that the accommodation is on the upper floor of the hotel, opposite Blamey Street.
Tarro Avenue to Carson Street	The majority of nearby receivers comprise single-level residential buildings. In this area, there will be a small amount of additional track and a turnout joining the Down Main and Down Local approximately 250 m west of Tarro Avenue.

Table 2 Sensitive Receivers - Up Side

Location	Description
Bundara Street to King Georges Road	Tooronga Terrace is adjacent to the corridor with receivers comprising single-level residential buildings facing the railway. There is a multi storey residential building on Tooronga Terrace near Beverly Hills Station and there are commercial receivers fronting King Georges Road.
King Georges Road to Broad Arrow Road	The majority of nearby receivers comprise single-level residential buildings, along with several two storey residences and a group of multi storey residential buildings near the corner of Broad Arrow Road and Wiruna Crescent. Beverly Hills Girls High School and the Intensive English Centre are located to the west of King Georges Road.
Broad Arrow Road to Bonds Road	The majority of nearby receivers comprise single-level residential buildings, with multi storey residential buildings located on Hannans Road in the vicinity of Narwee Station, near the corner of Hannans Road and Nanowie Street, and also on Bonds Road.
Bonds Road to Belmore Road	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings on Belmore Road near Riverwood Station. Adjacent to the railway corridor, there are multi storey residential buildings on Phillip Street and Coleridge Street.
Belmore Road to Salt Pan Creek	The majority of nearby receivers comprise single-level residential buildings, with multi storey residential buildings on William Road near Riverwood Station and along Lillian Road. Montessori School is located within the railway corridor on the southern side of Lillian Road.
Salt Pan Creek to Memorial Drive	The majority of nearby receivers comprise single-level residential buildings, with commercial buildings on Bridge Street. Adjacent to the railway corridor, there is a large multi storey residential building complex on Davies Road.
Memorial Drive to Wilberforce Road	The majority of nearby receivers comprise single-level residential buildings. Adjacent to the railway corridor, there are multi storey residential buildings on Alice Street, Cory Avenue and Arab Road.
Wilberforce Road to The River Road	The majority of nearby receivers comprise single-level residential buildings. Adjacent to the railway corridor, a new two-level residential development is currently under construction at 117 Sphinx Avenue. Revesby pre-school is located at 123 Sphinx Avenue and a commercial building is located on the corner of Sphinx Avenue and The River Road.
The River Road to Polo Street	The majority of nearby receivers are commercial. The nearest residential buildings are the Revesby Abbey Buildings in Marco Avenue. This is a four-level development with residential receivers on the upper three levels. The mixed use development comprises four blocks. The nearest to the railway corridor has no openable windows facing the railway corridor. Approximately 27 apartments in the remaining blocks are potentially exposed to rail noise emissions.
Polo Street to Carson Street	The nearby receivers comprise single-level residential buildings and commercial buildings along Marco Avenue. In this area there will be a turnout joining the Up Main and Up Local approximately 280 m west of Polo Street.

4 OPERATIONAL NOISE

4.1 Assessment Process

Guidance in relation to the operational assessment process for the proposal is provided in the *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* (IGANRIP) (NSW Government – April 2007). The main purpose of the guideline is to assist the ongoing expansion of rail transport by ensuring that potential noise impacts associated with rail developments are assessed in a consistent and transparent manner.

For new and upgraded railway lines, the assessment process is illustrated in **Figure 1**.

Figure 1 Assessment Process (based on Figure 2 in IGANRIP)

Pre Environmental Assessment Stage (Completed)

Consult with the community and relevant agencies to determine the environmental noise and vibration values to be protected.

↓

Environmental Assessment Stage (This Report)

1. Determine the noise and vibration trigger levels (refer **Sections 4.3** and **5.4**

2. Undertake a noise and vibration assessment to determine locations where the noise and vibration trigger levels are likely to be exceeded as a result of the proposal (refer **Sections 4.3** to **4.8** and **Sections 5.5** to **5.6**).

3. At locations exceeding the noise and vibration trigger levels, undertake a cost-benefit analysis of feasible and reasonable mitigation measures and prioritise these to maximise the protection of the environment. This includes noise, vibration, community views and aesthetic impacts (refer **Sections 4.9** to **4.11** and **Section 5.6**

4. Incorporate the proposed mitigation measures and identify the noise and vibration levels achievable for the proposal (refer **Sections 4.12** and **4.13** and **Section 5.6**

↓

Public Exhibition and Submissions Report Stage

1. Consult with the affected community to review the noise and vibration levels achievable for the proposal (exhibition stage of the Environmental Assessment).

2. Review the proposed mitigation measures following community consultation and produce a report (eg submissions report) documenting the proposed mitigation measures and achievable noise and vibration levels for the proposal.

↓

Planning Approval Stage

Achievable noise and vibration levels and/or mitigation measures for the proposal are included in the approval conditions.

Pre Environmental Assessment Stage

The pre environmental assessment stage included the preparation of a *Part 3A Project Application Report* (Connell Wagner, 15 January 2007), which outlined the statutory planing and approval requirements, the need and justification for the proposal, a description of the proposal and the potential environmental impacts (including noise and vibration).

Public information sessions we undertaken on Thursday 31 May 2007 (at Beverly Hills Uniting Church) and Saturday 2 June 2007 (at Revesby Community Centre). These were undertaken in order to inform the community and obtain feedback about the proposal.

In relation to noise and vibration, the main community concerns were:

- General noise and vibration emissions from the proposal resulting from the proposed additional tracks and more frequent train movements.
- Noise and vibration from existing freight train movements during the night-time and weekend periods and concern that the additional tracks (located closer to residents) could be used for more frequent freight train movements.
- Adequate implementation of noise mitigation measures, particularly noise walls.

On the basis of the above, and the large number of noise sensitive receivers adjacent to the proposal area, the Environmental Assessment is required to include an assessment of the potential noise and vibration impacts and potential mitigation measures.

Environmental Assessment Stage

This report forms part of the Environmental Assessment and describes in detail, the noise and vibration assessment process. This includes:

- Determining the noise and vibration “trigger levels” at sensitive receiver locations in accordance with the relevant guidelines.
- Identifying sensitive receiver locations where the project-related noise and vibration “trigger levels” are likely to be exceeded.
- At these locations, the guideline requires further assessment to be undertaken to identify the feasible and reasonable mitigation measures and achievable noise and vibration levels for the proposal,

  Section 3.1 of IGANRIP provides the following guidance in relation to determining feasible and reasonable mitigation measures:

  - *Feasibility* relates to engineering considerations and what can practically be built or modified, given the opportunities and constraints of a particular site.
  - *Reasonableness* relates to a judgement which takes into account the following factors:

    * Noise mitigation benefits - noise reduction provided, number of people protected

    * Cost of mitigation - total cost and cost variation with level of benefit provided

    * Community views

    * Aesthetic impacts

    * Track maintenance and access requirements

    * Noise levels for affected land uses - existing and future levels, expected changes in noise levels

    * Benefits arising from the development or its modification

In this report, the reasonableness assessment is limited to addressing the first two points (ie, the noise mitigation benefits and cost of mitigation). At this early stage in the assessment process, other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal have not been assessed to the same level of detail.

On this basis, the proposed mitigation measures in this report are indicative only and demonstrate the future noise and vibration levels that can be achieved (excluding other factors). The height and extent of the proposed noise barriers, the extent of ballast mat and potential property treatments may change as more detailed project information becomes available and consultation with affected stakeholders occurs.

Public Exhibition and Submissions Report Stage

During the public exhibition stage, the community and other stakeholders are invited to provide formal feedback on the Environmental Assessment (via written submissions), including the indicative noise and vibration mitigation measures,

Once all of the submissions are reviewed, the proponent is required to produce a Submissions Report responding to all of the queries and suggestions made during the public exhibition period. This report will provide a summary of any changes to the proposed mitigation measures and the achievable noise and vibration levels (after considering the input from the community, other stakeholders, and feasible/reasonable measures).

Planning Approval Stage

During the planning approval stage, the achievable noise and vibration levels and/or the proposed mitigation measures (as documented in the Submissions Report) are included in the approval of the proposal.

4.2 Operational Noise Metrics

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

L_{Amax} the "Maximum Noise Level" occurring during a train passby noise event.

$L_{Aeq(24 hour)}$ the "Equivalent Continuous Noise Level", sometimes also described as the "energy-averaged noise level". The $L_{Aeq(24hour)}$ may be likened to a "noise dose", representing the cumulative effects of all the train noise events occurring in one day.

$L_{Aeq(15 hour)}$ the Daytime "Equivalent Continuous Noise Level". The $L_{Aeq(15hour)}$ represents the cumulative effects of all the train noise events occurring in the daytime period from 7.00 am to 10.00 pm.

$L_{Aeq(9 hour)}$ the Night-time "Equivalent Continuous Noise Level". The $L_{Aeq(9hour)}$ represents the cumulative effects of all the train noise events occurring in the night-time period from 10.00 pm to 7.00 am.

$L_{Aeq(1 hour)}$ the busiest 1-hour "Equivalent Continuous Noise Level". The $L_{Aeq(1hour)}$ represents the typical L_{Aeq} noise level from all the train noise events during the busiest 1-hour of the assessment period.

L_{AE} 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 $L_{Aeq(24hour)}$ values from individual noise events.

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

4.3 Operational Noise Trigger Levels

For airborne noise created by the operation of surface track, noise trigger levels are provided for rail infrastructure projects including a “new railway line” or “redevelopment on an existing railway line”. The trigger levels for residential and other noise sensitive receiver locations are provided in **Table 3** and Table 4.

In assessing noise levels at residential receiver locations, the noise level is to be assessed at 1 m in front of the most affected building façade. Internal noise level refer to the noise level at the centre of the habitable room that is most exposed to the noise source and are to apply with windows open sufficiently to provide adequate ventilation.

For new and redeveloped rail projects, the noise trigger levels apply both immediately after operations commence and for projected traffic volumes at an indicative period into the future to represent the expected typical level of rail traffic usage (eg, ten years or similar period into the future).

The “redevelopment of an existing rail line” trigger levels are applicable where residential or other sensitive receivers are subject to existing rail noise at or above the noise trigger levels in **Table 3** for a “new rail line” development.

Table 3 Airborne Noise Trigger Levels for Surface Track - Residential

Type of Development	**Residential noise trigger levels (dBA)**		
	Day (7 am to 10 pm)	**Night (10 pm to 7 am)**	**Commentary**
New rail line development	Development increases existing rail noise levels AND Resulting rail noise levels exceed:		These numbers represent levels of noise that trigger the need for a rail infrastructure project to conduct an assessment of potential noise impacts. An increase in existing rail noise levels is taken to be an increase of 2.0 dB or more in LAeq in any hour or an increase of 3.0 dB or more in LAmax.
	60 LAeq(15hour) 80 LAmax	55 LAeq(9hour) 80 LAmax	
Redevelopment of existing rail line	Development increases existing rail noise levels AND Resulting rail noise levels exceed:		
	65 LAeq(15hour) 85 LAmax	60 LAeq(9hour) 85 LAmax	

Table 4 Airborne Noise Trigger Levels for Surface Track - Other Sensitive Land Uses

Sensitive Land Use	**Noise trigger levels (dBA)**	
	New rail line development	**Redevelopment of existing rail line**
	Development increases existing rail noise levels by 2.0 dBA or more in LAeq in any hour AND Resulting rail noise levels exceed:	
Schools, educational institutions - internal	40 LAeq(1hour)	45 LAeq(1hour)
Places of worship - internal	40 LAeq(1hour)	45 LAeq(1hour)
Hospitals - internal	35 LAeq(1hour)	35 LAeq(1hour)
Hospitals - external	60 LAeq(1hour)	60 LAeq(1hour)
Passive recreation	LAeq as per residential noise level values in **Table 3** (does not include maximum noise level component)	
Active recreation (eg, golf course)	65 LAeq(24hour)	65 LAeq(24hour)

4.4 Operational Noise Sources

Noise emissions from suburban electric passenger trains are predominantly caused by the rolling contact of steel wheels on steel rails. Even under ideal conditions, noise would occur as a result of the rolling contact and the finite roughness of typical wheel and rail running surfaces. Other noise sources on electric passenger trains, (such as air-conditioning plant and air compressors) are generally insignificant when compared with the wheel-rail interaction, unless the train is travelling at very low speed or is stationary.

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. Some types of rail bridges may also increase the level of noise emission.

In areas where there are tight radius curves, flanging noise or curve squeal may also increase the level of noise emission.

The SoundPLAN input data used in the modelling for this proposal were adapted to ensure that the calculated noise levels accurately reflect local conditions (ie CityRail trains, etc). The reference noise levels used for the noise modelling (**Table 5**) were based on the attended noise measurements undertaken adjacent to the railway corridor between Kingsgrove and Revesby (see **Table 6**) and were consistent with other measurements undertaken by Heggies on recent projects.

Table 5 Reference Noise Levels used for Modelling

Train Types	Reference Conditions	LAmax	LAE
Millennium/Tangara	15 m, 80 km/h	85 dBA	88 dBA
Double Deck Suburban	15 m, 80 km/h	87 dBA	91 dBA

The modelling includes allowances for local increases in noise emission as follows:

- 6 dBA at turnouts.
- 4 dBA for the existing ballasted steel girder bridge at The River Road.
- 8 dBA for the existing steel framed bridges with side screens at Broad Arrow Road and Bonds Road for Year 2006.
- 4 dBA for the replacement ballasted steel girder bridges at Broad Arrow Road and Bonds Road for Year 2021 (Up and Down Local tracks only).
- 10 dBA for the existing steel girder bridge at Salt Pan Creek.

The new underbridges are proposed to be ballasted concrete bridges and hence no increase in the source noise levels has been assumed in the noise model.

A more detailed description of the various noise sources, typical noise levels and how these have been represented within the SoundPLAN computer noise modelling is provided in **Appendix C**.

4.5 Noise Modelling Inputs

Ground Terrain

The ground terrain data for the current modelling was provided by TIDC's Technical Advisor (TA) for the Clearways projects. The ground terrain data (X,Y,Z coordinates) were provided in the form of 2 m contours in DXF format.

Track Alignment Strings and Ground Terrain within Railway Corridor

The track alignment strings and ground terrain data within the railway corridor was provided by TIDC's TA for the Clearways Projects. This information was provided in the form of 3-dimensional AutoCAD drawings of the existing and future alignment options.

Rail Traffic Data

The existing traffic data for the Year 2006 noise model was based on the current CityRail timetable (dated May 2006). The train speeds and track features (eg turnouts) were derived from site observations, the posted line speeds, information provided by TIDC's TA and aerial photography.

For the future noise modelling scenario (Year 2021), estimates of the future train numbers were derived as part of the Revesby Turnback project, based on 8 trains per hour in each direction for each of the four tracks and up to 16 trains per hour in the peak direction on the Main Lines during the AM and PM peak.

For the current timetable (Year 2006), there is a total of 254 train movements per day, compared with 596 per day for the future modelling scenario (Year 2021). This represents an approximate doubling in the number of train services as a result of the proposed upgrade and future traffic growth.

Buildings and Receiver Locations

All buildings adjacent to the East Hills Line within the proposal area were surveyed to determine the occupancy type, number of levels, number of receivers per level, address and height above ground for the first residential level. This information has been included in the computer noise modelling.

Some additional buildings were observed to be under construction during the survey period. These have been included in the noise modelling.

The location of buildings and their representation within the noise model was derived from aerial photography, provided by TIDC's TA.

4.6 Validation of the Computer Model

Noise measurements have been undertaken as part of this current study at 34 locations adjacent to the East Hills Line.

A summary of the noise measurement locations along with the modelling results is provided in **Table 6**. The full measurement results are presented in Heggies Report 10-4805-R1.

Table 6 Attended Noise Measurement Locations and Results

Measurement Location	Number of Train Events	Measured Noise Levels (dBA)			Modelled[1] Noise Levels (dBA) [4]	
		Highest LAmax	95th Percentile LAmax	Calculated LAeq(24hour)[2]	LAmax[3]	LAeq(24hour)
N1 - 80 Tooronga Terrace, Beverly Hills	20	82	81	57	79 (-2)	57 (0)
N2 - 109A Morgan St, Beverly Hills	21	79	79	58	81 (+2)	58 (0)
N3 - Beverly Hills Girls High School, Beverly Hills	20	77	77	52	76 (-1)	54 (+2)
N4 - 2 Gregory Cr, Beverly Hills	21	83	81	57	83 (+2)	60 (+3)
N5 - 6 Wiruna Cr, Beverly Hills	22	83	80	57	81 (+1)	58 (+1)
N6 - 19 Bryant St, Narwee	21	84	81	57	83 (+2)	61 (+4)
N7 - 13 Narwee Ave, Narwee	21	83	83	60	84 (+1)	62 (+2)
N8 - 4 Ventura Ave, Narwee	20	88	83	60	83 (0)	60 (0)
N9 - 12 Yardley Ave, Narwee	22	82	82	56	79 (-3)	56 (0)
N10 - 2 Karne St, Narwee	20	84	80	56	77 (-3)	55 (-1)
N11 - 68 Josephine St, Riverwood	24	88	86	62	85 (-1)	62 (0)
N12 - 216A Bonds Rd, Riverwood	20	97	95	68	93 (-2)	69 (+1)
N13 - 25 Romilly St, Riverwood	20	80	78	55	78 (0)	55 (0)
N14 - 1A Coleridge St, Riverwood	20	76	75	52	75 (0)	53 (+1)
N15 - Webb St car park, Riverwood	22	88	85	57	87 (+2)	64 (+7)
N16 - 3 Bennett Rd, Riverwood	20	83	81	57	83 (+2)	60 (+3)
N17 - 49 Webb St, Riverwood	21	80	79	54	81 (+2)	59 (+5)
N18 - William St car park, Riverwood	20	83	79	56	86 (+7)	62 (+6)
N19 - 95 Webb St, Riverwood	22	82	80	58	85 (+5)	62 (+4)

Measurement Location	Number of Train Events	Measured Noise Levels (dBA)			Modelled[1] Noise Levels (dBA) [4]	
		Highest LAmax	95th Percentile LAmax	Calculated LAeq(24hour)[2]	LAmax[3]	LAeq(24hour)
N20 - 89 Davies Rd, Padstow	20	87	86	62	87 (+1)	64 (+2)
N21 - 4 Bridge St, Padstow	21	86	85	59	85 (0)	62 (+3)
N22 - 68 Davies Rd, Padstow	21	82	82	56	81 (-1)	58 (+2)
N23 - Banks St car park, Padstow	22	86	82	60	86 (+4)	61 (+1)
N24 - 32 Alice St, Padstow	20	79	78	54	83 (+5)	60 (+6)
N25 - 2 Crusade Ave, Padstow	20	84	82	60	87 (+5)	63 (+3)
N26 - 15 Cory Ave, Padstow	21	84	81	57	83 (+2)	60 (+3)
N27 - 2 McGirr St, Padstow	20	77	74	52	76 (+2)	54 (+2)
N28 - 55 Sphinx Ave, Revesby	20	89	86	64	84 (-2)	60 (-4)
N29 - 24 Hendy Ave, Panania	27	77	76	53	79 (+3)	56 (+3)
N30 - Tooronga Terrace car park, Beverly Hills	20	79	77	53	82 (+5)	59 (+6)
RN1 - Reserve at Rear Murphy St	24	80	78	53	78 (0)	56 (+3)
RN2 - Wyreema Ave Gate	21	83	83	59	85 (+2)	62 (+3)
RN3 - Tarro Street Gate	21	87	82	60	81 (-1)	59 (-1)
RN4 - 21 Montgomery Ave	26	79	78	55	79 (+1)	57 (+2)

Note 1 Modelled noise levels based on reference levels presented in **Table 5**.

Note 2 The calculated LAeq(24hour) noise levels are based on the measured LAE noise levels and 254 train passby events in a 24 hour period (based on the current CityRail timetable - dated May 2006).

Note 3 Representing the notional 95th percentile of LAmax train noise levels.

Note 4 The numbers in brackets represent the difference between the modelled noise levels and the measured noise levels. A positive number indicates that the modelled noise levels are higher than the measured noise levels. For the LAmax noise levels, the modelled noise levels are compared with the 95th percentile levels.

The results in **Table 6** indicate that for more than 80% of the 34 measurement locations, the predicted LAeq(24hour) noise levels are within -2 dBA to + 2 dBA of the attended measurement results and the LAmax noise levels are within -1 dBA to + 3 dBA of the attended measurement results. These results are within the normal tolerances for railway noise predictions and are generally on the conservative side (i.e. the predicted noise levels are, on average, 1 dBA to 2 dBA higher than the measured levels).

For the remaining measurement locations, representing only a small percentage (less than 20%), the variation in the measured and predicted noise levels are greater. At some locations, this is a result of the small number of train measurements and observed speed range, whilst at other locations, the difference resulted from local conditions such as noise shielding effects. The differences at specific locations are discussed below:

- At measurement locations N9 and N10, the predicted L_{Amax} noise levels are 3 dBA lower than the measured 95th percentile L_{Amax} noise level. At these localities, the computer noise model does not accurately take into account the shielding provided by the railway cutting.
- At measurement locations N15 and N18, the typical speed of the trains was 30 km/h to 50 km/h compared with a modelled train speed of 90 km/h at this location (based on speed boards and free flowing traffic). This results in predicted L_{Amax} noise levels approximately 6 dBA higher than the measured levels and $L_{Aeq(24hour)}$ noise levels approximately 4 dBA higher than the measured levels.
- At measurement location N24, the predicted L_{Amax} and $L_{Aeq(24hour)}$ noise levels are 5 dBA and 6 dBA higher than the measurement results respectively. At this locality, the computer noise model does not include the shielding provided by the boundary fence.
- At measurement location N28 the predicted L_{Amax} and $L_{Aeq(24hour)}$ noise levels are 2 dBA and 4 dBA lower than the measurement results respectively. At this locality, the computer noise model does not accurately take into account the shielding provided by the railway cutting.
- At measurement location N29, the predicted L_{Amax} and $L_{Aeq(24hour)}$ noise levels are both 3 dBA higher than the measurement results. At this locality, the computer noise model does not include the shielding provided by the boundary fence.
- At measurement location N30, the predicted L_{Amax} and $L_{Aeq(24hour)}$ noise levels are 5 dBA and 6 dBA higher than the measurement results respectively. At this locality, the computer noise model does not accurately take into account the shielding provided by the local topography in the surrounding car park.

On the basis of the attended measurement results, it is concluded that the noise model is providing satisfactory predictions of both the L_{Amax} and $L_{Aeq(24hour)}$ noise levels.

4.7 Noise Modelling Scenarios

In order to assess the operational noise emissions for the proposal, three noise modelling scenarios have been considered:

- **Scenario 1** - Existing Situation (Year 2006). This model incorporates the existing ground terrain, rail traffic and tracks. The Year 2006 model also includes the existing 2.5 m noise barriers located at the eastern end of the proposal area at the following locations:
  - Down side barrier up to chainage 14.18.
  - Up side barrier up to chainage 14.10.
- **Scenario 2** – Year 2021 Without Mitigation (approximately 10 years after opening). This model incorporates the new Up and Down Main tracks, additional turnouts, new underbridges and rail traffic increase due to the proposed Clearways Timetable. The clearways timetable is proposed to be implemented in 2010 and the train numbers for this scenario are considered to be representative of the maximum throughput approximately 10 years after opening. The train numbers are provided for Year 2021 as this was the closest year to 2020 for which train timetable information was available. The model also includes the Down Main noise barrier being constructed as part of the Year 2008 Revesby Turnback project between chainage 20.25 km and 20.76 km.
- **Scenario 3** – Year 2021 with Proposed Barriers. This model incorporates the indicative noise barriers alongside the new Up and Down Main tracks in areas where these are considered to be feasible and reasonable.

Noise Trigger Levels and Assessment Parameters

In order to undertake an assessment of the future rail operations, **Table 3** provides noise trigger levels for both the daytime and night-time assessment periods. In terms of the L_{Amax} assessment parameter, the noise trigger levels at residential receiver locations are the same during the daytime and night-time periods, however the L_{Aeq} noise trigger levels during the night-time period are 5 dBA lower (ie more stringent) than the daytime period.

Table 7 provides a summary of the total passenger train numbers adopted for the existing and future noise modelling scenarios.

Table 7 Summary of Passenger Train Movements for Modelling Scenarios

Year	Passenger Trains per 24-hour Period			
	Down Direction		Up Direction	
	Tangara/Millennium	Double Deck Suburban	Tangara/Millennium	Double Deck Suburban
2006 - Current[1]	74	55	71	54
2021 - Future East of Revesby	223	75	223	75
2021 - Future West of Revesby[2]	114	38	114	38

Note 1 For the current situation, no trains turn back at Revesby Station and the number of trains east and west of Revesby Station is the same.

Note 2 For the Year 2021 scenario, it is assumed that all Local trains turn back at Revesby.

For the existing and future scenarios, **Table 8** provides a summary of the estimated train numbers east of Revesby station in each 1-hour period. The future train numbers are preliminary and should not be relied upon for determining the future timetable with the proposed upgrade.

Table 8 Summary of Hourly Train Movements for Modelling Scenarios

Time Period	Number of passenger train movements east of Revesby Station	
	Existing (Y2006)	**Proposed (Y2021)**
00:00 - 01:00	0	0
01:00 - 02:00	0	0
02:00 - 03:00	0	0
03:00 - 04:00	0	0
04:00 - 05:00	3	0
05:00 - 06:00	14	32
06:00 - 07:00	14	32
07:00 - 08:00	14	32
08:00 - 09:00	14	44
09:00 - 10:00	14	32
10:00 - 11:00	14	32
11:00 - 12:00	14	32
12:00 - 13:00	14	32
13:00 - 14:00	14	32
14:00 - 15:00	14	32
15:00 - 16:00	14	32
16:00 - 17:00	14	32
17:00 - 18:00	14	40
18:00 - 19:00	14	32
19:00 - 20:00	14	32
20:00 - 21:00	14	32
21:00 - 22:00	13	32
22:00 - 23:00	10	32
23:00 - 00:00	4	0
Totals	254	596

On the basis of the hourly train numbers in **Table 8**, there are 209 and 45 train movements during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods respectively for the existing situation. For the future situation, there are approximately 500 and 96 train movements during the daytime and night-time periods respectively.

If it is assumed that average number of rail cars is similar during the daytime and night-time periods, and all other operating patterns are similar (eg, train speeds, percentage of non-stopping trains, etc), then the $L_{Aeq(15hour)}$ noise levels would be approximately 5 dBA higher than the $L_{Aeq(9hour)}$ noise levels for both the existing and future train operations. In reality, it is anticipated that the average number of rail cars and non-stopping trains would be less during the night-time period and hence the daytime L_{Aeq} noise levels would be approximately 6 dBA higher than the night-time L_{Aeq} levels.

On this basis, and since the L_{Aeq} noise trigger levels are 5 dBA less stringent during the daytime period, the $L_{Aeq(15hour)}$ daytime noise trigger levels are more stringent than the night-time noise trigger levels (ie, the daytime L_{Aeq} noise trigger levels are more difficult to achieve than the night-time noise trigger levels).

The noise modelling scenarios evaluated in this assessment are therefore based on the daytime scenario, noting that the night-time L_{Aeq} noise levels would be approximately 6 dBA less than the daytime noise levels. The L_{Amax} noise levels would be the same during the daytime and night-time periods.

Noise Trigger Levels for Educational Receivers

It should be noted that the trigger levels for non-residential receivers included in **Table 4** refer to the $L_{Aeq(1hour)}$ internal noise level.

Within the project area, the relevant non-residential receivers include several educational institutions located adjacent to the railway corridor. The approximate chainage of the educational receivers considered in this assessment are summarised in **Table 9**.

Table 9 Location of Educational Receivers

Side of Corridor	Chainage	Name
Down	15.89	Narwee Primary School
Down	16.99	Kindergarten
Down	17.27	St Josephs Primary School
Up	14.85	Beverly Hills Girls High School
Up	18.25	Montessori Primary School
Up	20.67	Revesby Pre-School

The future train movements indicate that during the morning and afternoon peak, the total number of hourly train movements for the relevant Main track is expected to be 16 compared to 8 daytime hourly movements outside peak hour. This represents an increase of 3 dBA over the $L_{Aeq(15hour)}$ daytime noise level. In other words, the $L_{Aeq(1hour)}$ noise levels during the busiest 1-hour daytime period would be approximately 3 dBA higher than the $L_{Aeq(15hour)}$ daytime noise level.

The trigger levels in **Table 4** refer to an internal $L_{Aeq(1hour)}$ noise level of 45 dBA for schools. 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 façade of approximately 55 dBA. Since the busiest 1-hour L_{Aeq} noise level will be approximately 3 dBA higher than the $L_{Aeq(15hour)}$ daytime level, the external trigger level for schools can be expressed as $L_{Aeq(15hour)}$ 52 dBA. The noise trigger level may be considered somewhat conservative, since the morning and afternoon peak will typically occur outside normal teaching hours.

External playground areas for educational receivers should be considered to have the same trigger levels as residential receivers, i.e. $L_{Aeq(15hour)}$ 65 dBA. The trigger levels are summarised in **Table 10**.

Table 10 Rail Noise Trigger Levels for Educational Receivers

Educational Receiver	Noise Trigger Levels (dBA)	
	$L_{Aeq(1hour)}$	$L_{Aeq(15hour)}$
Schools, educational institutions - internal	45	42
Schools, educational institutions - external	55	52
School playground	N/A	65

4.8 Noise Modelling Results

4.8.1 Noise Contour Plots

The results of the computer noise modelling for the Year 2006 existing scenario (Scenario 1) have been presented in the form of L_{Amax} and $L_{Aeq(15hour)}$ daytime noise contour plots, representing receiver positions 2.0 m above ground level in **Appendix E**.

The results of the computer noise modelling without the proposed noise barriers (Scenario 2) are presented in **Appendix F**.

The results of the computer noise modelling with the proposed noise barriers (Scenario 3) are presented in **Appendix G**.

As discussed in **Section 4.1**, the extent and height of the proposed noise barriers in Scenario 3 are indicative only and do not take into account other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal.

4.8.2 Noise Modelling Results - Individual Receivers

The noise model has also been used to carry out "point receiver" calculations. This point receiver modelling allows the height above ground level to be entered individually for each dwelling. By comparison, the noise contours are normally calculated at a fixed height above ground, indicative of ground floor receivers.

Site observations have been made to confirm the number of storeys of each residential building and whether it is elevated with respect to the adjacent ground. The point receiver modelling has enabled the number of affected dwellings and the extent of noise goal exceedance to be evaluated in detail.

Scenario 1 - Existing Situation (Year 2006)

A scatter graph representation of the calculated point receiver noise levels for the Down and Up sides of the railway corridor is presented in **Figure 2** and **Figure 3**, respectively. Each "+" and "x" represent the calculated noise levels at a single residence. For multi-level buildings, the noise levels are calculated for each residence facing the railway corridor and for each level of the building.

Figure 2 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Down Side of track (Year 2006)

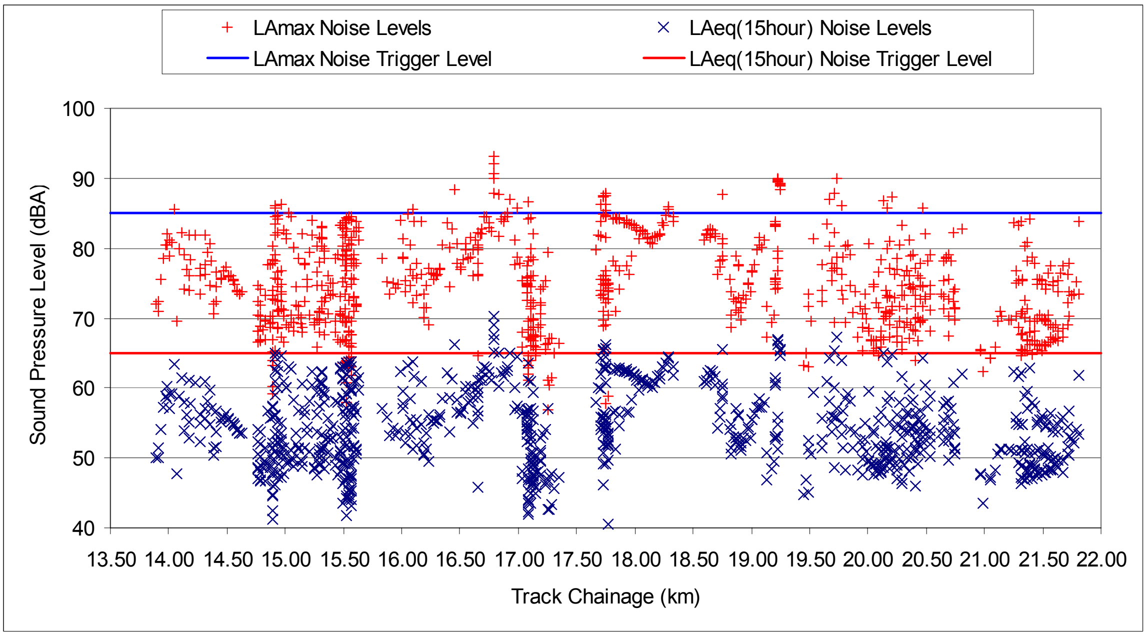
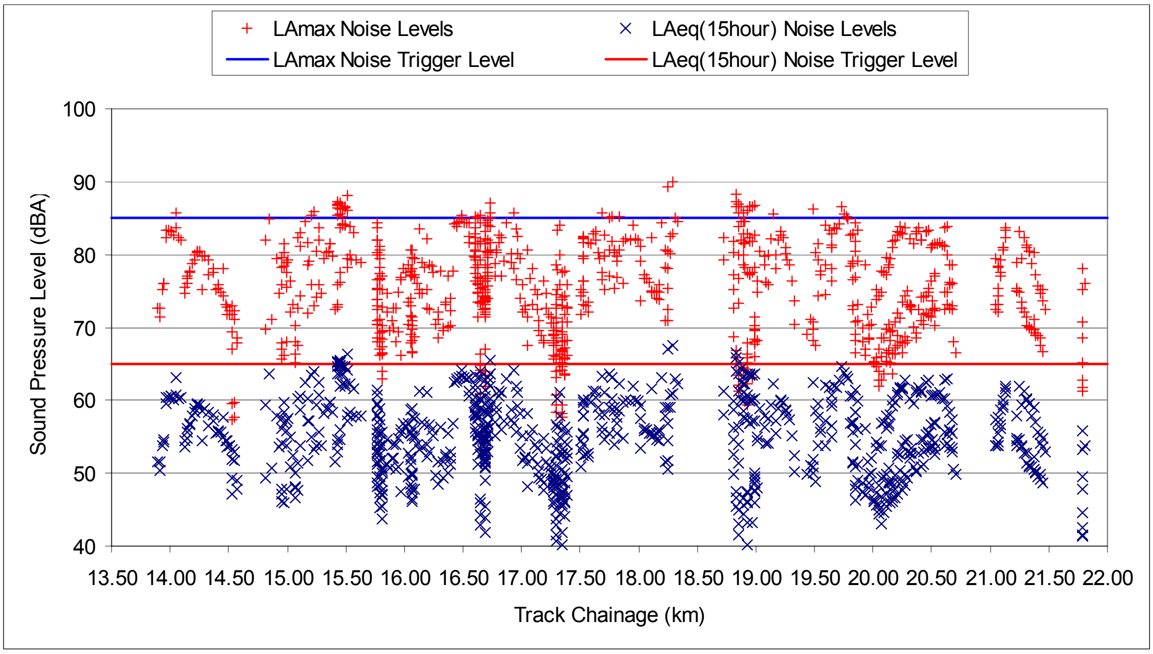


Figure 3 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Up Side of track (Year 2006)



On the basis of the calculated noise levels presented in **Figure 2** and **Figure 3**, the following observations are made:

- On the Down side of the railway corridor, the existing noise levels exceed the LAmax 85 dBA and/or LAeq(15hour) 65 dBA trigger levels at 46 locations.

- On the Up Side of the railway corridor, the existing noise levels exceed the LAmax 85 dBA and/or LAeq(15hour) 65 dBA trigger levels at 46 locations.
- In total, the calculated noise levels for the existing operations exceed the overall noise trigger levels of LAmax 85 dBA and/or LAeq(15hour) 65 dBA at 92 residential locations.

Scenario 2 - Future Situation (Year 2021) without Noise Barriers

A scatter graph representation of the calculated point receiver noise levels for the Down and Up sides of the railway corridor is presented in **Figure 4** and **Figure 5** respectively.

Figure 4 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Down Side of track (Year 2021) - Without Mitigation

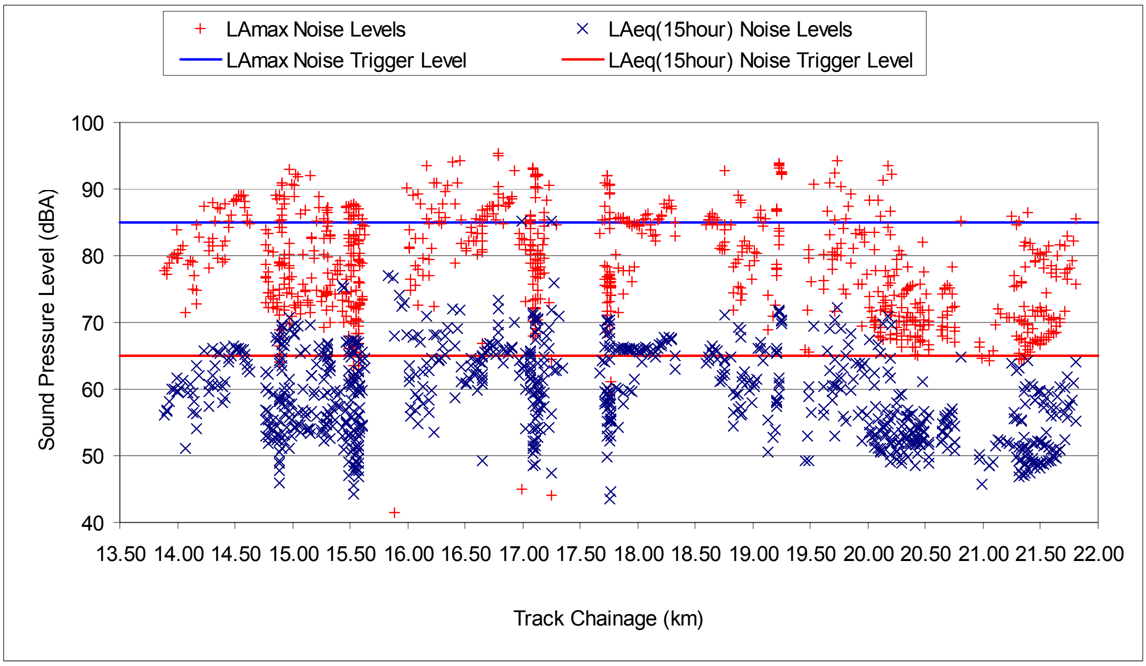
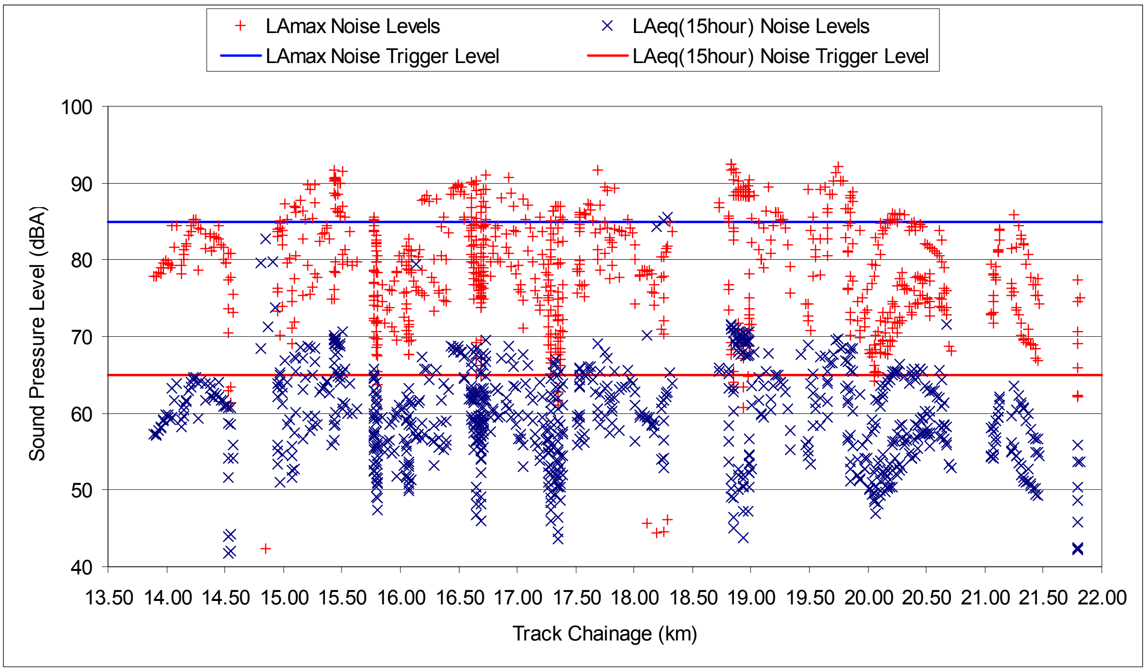


Figure 5 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Up Side of track (Year 2021) - Without Mitigation



On the basis of the calculated future noise levels without noise barriers (presented in **Figure 4** and **Figure 5**), the following observations are made:

- On the Down side of the railway corridor, the predicted noise levels exceed the LAmax 85 dBA and/or LAeq(15hour) 65 dBA trigger levels at 161 locations.
- On the Up Side of the railway corridor, the predicted noise levels exceed LAmax 85 dBA and/or LAeq(15hour) 65 dBA trigger levels at 156 locations.
- In total, the calculated noise levels for the future operations (without mitigation) exceed the overall noise trigger levels of LAmax 85 dBA and/or LAeq(15hour) 65 dBA at 317 residential locations.
- Compared with the existing situation, the number of locations exceeding the LAmax 85 dBA and/or LAeq(15hour) 65 dBA noise trigger levels is predicted to increase from 46 to 161 on the Down Side of the track and from 46 to 156 on the Up Side of the track.
- The predicted increase in LAeq noise levels at the nearest receivers as a result of the proposal (without mitigation) would typically be approximately 5 dBA in every hour. Similarly, at most locations, the predicted increase in LAmax noise levels as a result of the proposal would be approximately 4 dBA. The increase in LAeq and LAmax noise levels results from the proposed increase in train speeds on the new lines (compared with the existing lines) and the reduced offset distance between the new tracks and receiver locations.

Discussion of Future Noise Levels without Mitigation

As discussed in **Section 4.1**, the IGANRIP assessment guideline requires a further assessment of the potential noise impacts to be undertaken at locations exceeding the noise trigger levels.

The noise trigger levels in the IGANRIP address the increase in noise levels due to a rail infrastructure project as well as the overall future noise levels. Further assessment of rail noise impacts is only required at locations that exceed both trigger levels.

The subjective response of humans to changes in sound pressure level has been investigated by Bies and Hansen (1998[1]). A summary of the noise perception relating to changes in sound pressure level is provided in **Table 11**.

Table 11 Subjective Effect of Changes in Sound Pressure Level (Bies and Hansen[1])

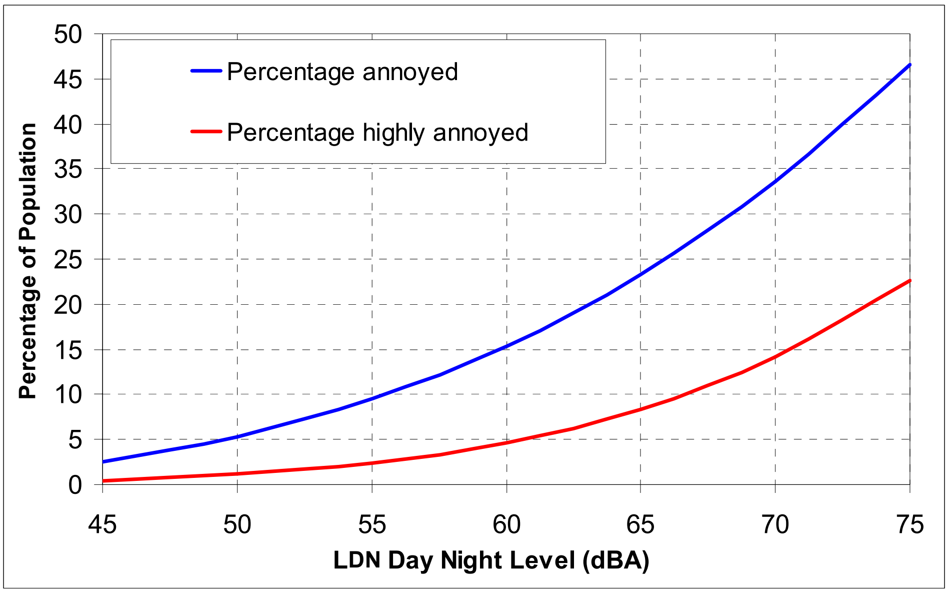
Change in Sound Pressure Level (dB)	Change in Apparent Loudness
3	Just Perceptible
5	Clearly Noticeable
10	Half or twice as loud
20	Much quieter or louder

On the basis of the information in **Table 11**, it is apparent that the IGANRIP noise increase trigger levels of 2 dBA in L_{Aeq} and 3 dBA in L_{Amax} are approximately equal to a "just perceptible" change in apparent loudness. Given, that the predicted increase in noise levels are approximately 5 dBA in L_{Aeq} and 4 dBA in L_{Amax} as a result of the project, it follows that these increases would approximately represent a "clearly noticeable" change in apparent loudness at the nearest receiver locations without mitigation.

As well as the change in apparent loudness, the overall level of railway noise also has an influence on the potential noise impact at sensitive receiver locations. On the basis of the predicted future noise levels in **Figure 4** and **Figure 5** (without mitigation), there are a large number of residential receiver locations where the predicted $L_{Aeq(15hour)}$ noise levels are between 65 dBA and 70 dBA.

The subjective response of humans to noise from transportation noise has been investigated by Miedema and Oudshoorn[2]. For railway noise, **Figure 6** provides a summary of the percentage of the population "annoyed" and "highly annoyed" by differing levels of railway noise.

Figure 6 Percentage of Population Annoyed by Railway Noise (Miedema and Oudshoorn[2])



[1] Engineering Noise Control - Theory and Practice 2nd Edition, *David A. Bies and Colin H. Hansen - Pg 53*
[2] Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals, *Henk M.E. Miedema and Catharina G.M. Oudshoorn*, Environmental Health Perspectives Vol 109, April 2001

In **Figure 6**, the railway noise levels are presented in terms of the day night level (L_{DN}), which is based on the $L_{Aeq(15hour)}$ daytime and $L_{Aeq(9hour)}$ night-time noise levels with a 10 dBA penalty applied at night. For this proposal, in which the $L_{Aeq(9hour)}$ night-time noise levels are predicted to be 6 dBA lower than the $L_{Aeq(15hour)}$ daytime noise levels, the L_{DN} noise level would be approximately 2 dBA higher than the $L_{Aeq(15hour)}$ noise level.

By extrapolation from **Figure 6**, based on the predicted noise levels for the existing Year 2006 situation (Scenario 1) and the future Year 2021 situation without mitigation (Scenario 2), the total number of receivers "annoyed" would increase from approximately 160 to 320, and the total number of receivers "highly annoyed" would increase from approximately 60 to 120 as a result of the proposal.

The Miedema and Oudshoorn paper notes that the percentage annoyance curves may not be representative of all populations or individuals. Nevertheless, the curves are a useful measure for determining the effect of a general increase in noise level in a given population. On this basis, it is concluded that without mitigation, the percentage of the population "annoyed" or "highly annoyed" by railway noise would increase by approximately 100% as a result of the project.

On the basis that the increase in L_{Aeq} noise levels as a result of the project would be "clearly noticeable" and the percentage of the population "annoyed" or "highly annoyed" by future noise levels would increase by approximately 100%, the consideration of noise mitigation measures to maximise the protection of the environment is warranted. The process for determining the proposed mitigation measures is described in **Sections 4.9** and **4.10**.

Scenario 3 - Future Situation (2021) with Noise Barriers

Scenario 3 includes the proposed noise barriers discussed in Section 4.12. These notional noise barriers are based on the assessment and optimisation methodology outlined in **Section 4.10**.

A scatter graph representation of the calculated point receiver noise levels (with the proposed noise barriers) for the Down and Up sides of the railway corridor is presented in **Figure 7** and **Figure 8** respectively.

As discussed in **Section 4.1**, the extent and height of the proposed noise barriers are indicative only and do not take into account other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal.

Figure 7 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Down Side of track (Year 2021) - With Mitigation

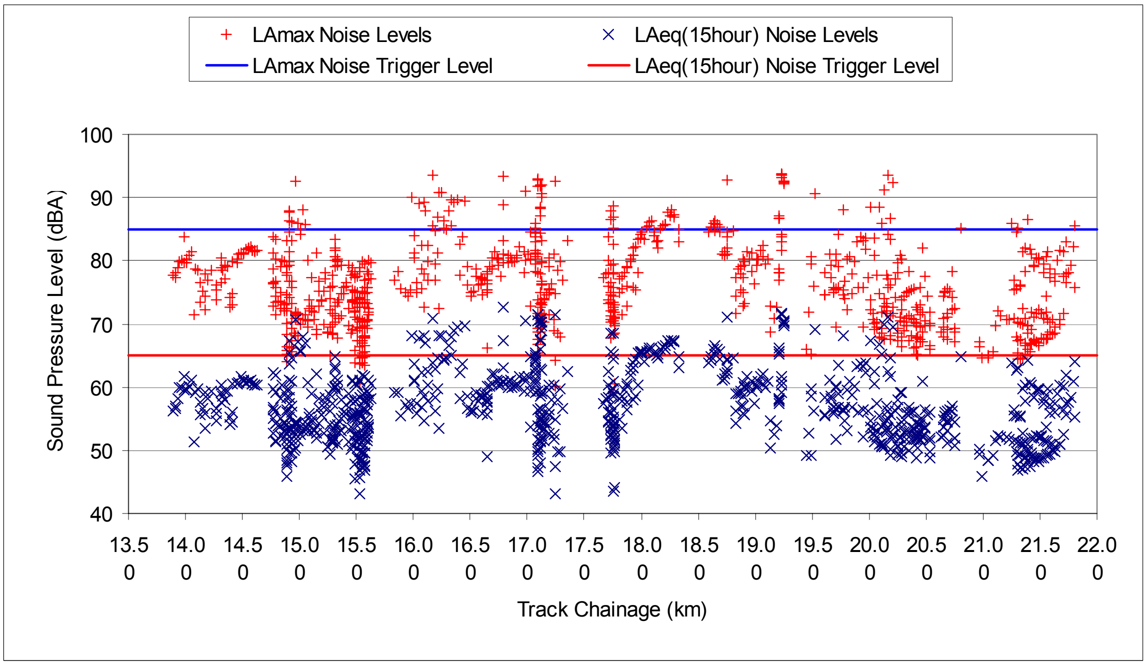
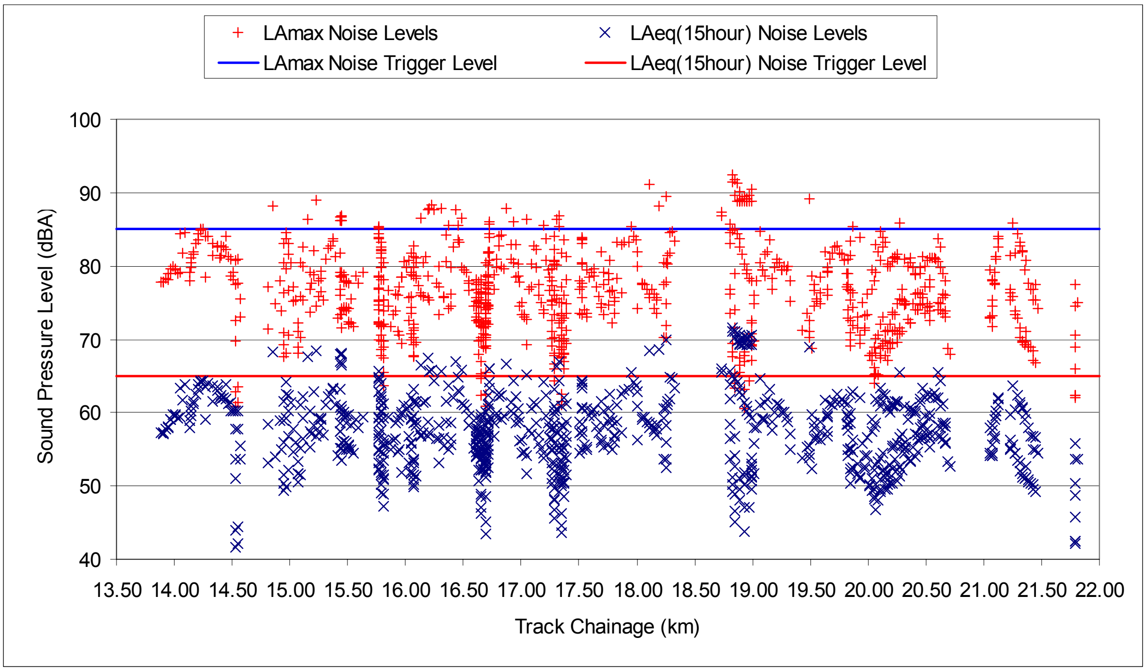


Figure 8 Scatter Graph Representation of LAmax and LAeq(15hour) Daytime Noise Levels on Up Side of track (Year 2021) - With Mitigation



On the basis of the calculated future noise levels with the proposed barriers presented in **Figure 7** and **Figure 8**, the following observations are made:

- On the Down side of the railway corridor, the predicted noise levels exceed the LAmax 85 dBA and/or LAeq(15hour) 65 dBA trigger levels at 33 locations.

- On the Up Side of the railway corridor, the predicted noise levels exceed L_{Amax} 85 dBA and/or $L_{Aeq(15hour)}$ 65 dBA trigger levels at 36 locations.
- In total, the calculated noise levels for the future operations (without mitigation) exceed the overall noise trigger levels of L_{Amax} 85 dBA and/or $L_{Aeq(15hour)}$ 65 dBA at 69 locations.
- Compared with the existing situation, the number of locations exceeding the overall noise trigger levels is predicted to decrease from 46 to 33 on the Down Side of the track and from 46 to 36 on the Up Side of the track.
- Compared with the Year 2021 situation without noise barriers, the number of locations exceeding the overall noise trigger levels is predicted to be reduced from 161 to 33 on the Down Side of the track and from 156 to 36 on the Up Side of the track.

4.8.3 Other Sensitive Receiver Locations

The predicted noise levels in the above sections relate to the noise levels at residential and educational receiver locations adjacent to the East Hills Line between Kingsgrove and Revesby. There are no other sensitive receiver types in the vicinity of the railway corridor within the proposal area.

4.9 Operational Noise Mitigation

The noise modelling results discussed in **Section 4.8** identified a number of locations where the future noise levels and increase in noise levels as a result of the proposal have triggered the need to undertake a further assessment of feasible and reasonable mitigation measures.

The potential mitigation options include:

- Modifying existing rolling stock to have lower noise emissions.
- Designing new bridges to incorporate noise mitigation measures.
- Consideration of at-source mitigation.
- Lowering operating speeds.
- Providing acoustic shielding (through the use of noise barriers/mounds and cuttings).
- Working with local government to set acoustic standards in the consent conditions for new residential buildings.
- Dwelling treatments.

The hierarchy of noise control is to give first preference to source control measures, then to physical mitigation measures between the source/receiver and as a final measure, receiver controls. These are described briefly below.

Source Control Measures

Source control measures include route selection to maximise the offset distance between the railway line and residential areas, regular track maintenance (to remove track defects), improved wheel condition, speed restrictions and the introduction of quieter rollingstock. At specific locations, source noise levels can be reduced by installing “quiet” bridges (such as ballasted concrete spans with side screens) and applying lubrication or top-of-rail friction modifiers to mitigate noise on tight-radius curves.

For the proposed quadruplication, it is understood that the existing RailCorp fleet would be utilising the new infrastructure, rather than providing a dedicated fleet. On this basis, there is little opportunity to reduce the source noise levels of the rollingstock significantly. The noise modelling does assume, however, that 75% of the electric passenger fleet would be Tangara or Millennium, which are approximately 2 dBA to 3 dBA quieter on average compared with the noisier double deck suburban trains. On this basis, it is considered reasonable to assume that the frequency of noisier train events would reduce over time as older rollingstock is retired.

RailCorp's DEC licence also requires the preparation of a "Whole of Network Strategy", aimed at reducing train noise on the Metropolitan Rail network over time. It is reasonable to expect that this strategy would benefit residents adjacent to the East Hills Line.

Lowering the train speeds is not desirable from an operational perspective as this would provide an adverse long-term constraint on the rail line.

Source/Receiver Measures

This includes the construction of noise barriers, enclosures or other structures (which shield some of the direct airborne noise that propagates between the source and receiver locations), and land use planning measures (which increase the distance between the source and sensitive receivers).

Noise barriers can provide significant noise reductions in areas where source control measures are not adequate to mitigate noise levels completely. Noise levels on the ground floor (including back yards and living areas) can usually be significantly reduced through the use of noise barriers. Noise barriers are not as effective, however, for upper floor receivers and are usually ineffective above the second level.

In terms of noise reduction, noise barriers (walls) and earth mounds can be regarded as providing similar acoustic performance if the top of the barrier and mound are at the same height and distance from the track. In practice, earth mounds may be preferred because they can be visually less intrusive and are less likely to be vandalised. The disadvantage, however, is that they require a larger land area (due to the batter) and this may result in the top of an earth mound being located further from the track than an equivalent noise barrier. Earth mounds are generally not suitable for use where track is on embankment, as the resultant widening of the embankment can require substantial amounts of fill. In the proposal area, noise barriers are likely to be the only feasible option for this type of mitigation due to the restricted land area. However, the final outcome may change as more detailed project information becomes available and consultation with affected stakeholders occurs.

The use of planned setbacks can reduce or remove the need for noise barriers (which can have detrimental visual, cost and social impacts). Large setback distances are often required, however, in order to achieve noise levels below the trigger levels. For this proposal, however, the land use adjacent to the railway corridor has already been developed at most locations and hence this option would not be feasible.

Receiver Controls

This generally involves the inclusion of specific acoustical measures as part of the design of individual dwellings in order to reduce noise levels inside buildings.

Treatments to buildings usually involve higher performance windows, doors and seals to keep noise out. Building treatments effectively require occupants to keep their windows and doors closed and hence alternative ventilation is usually required to maintain adequate air flow. An obvious disadvantage is that building treatments would not have any effect on the noise levels outside the dwelling in their front or back yards. Building treatments are normally more costly than source control and source/receiver control measures. Building treatments are generally not favoured until after all other options have been explored.

As previously discussed, whilst the provision of noise barriers can significantly reduce noise levels at ground floor and first floor receiver locations, noise barriers are usually ineffective at upper floor receiver locations. For upper floor receiver locations, it is anticipated that a combination of source/receiver measures (eg noise barriers or earth mounds) would be required in conjunction with receiver controls as the most cost effective mitigation option in situations where noise mitigation is required.

Noise from Underbridges

When trains operate on elevated structures, including bridges, vibration of the rails is also transmitted into the supporting structure, resulting in noise radiation from the bridge. Depending on the design of the structure, wayside noise levels may exceed the typical noise levels adjacent to at-grade track by as much as 10 dBA.

Noise emissions from elevated structures are dependent on the mass and damping properties and resonant behaviour of the structural elements. Unballasted steel bridges typically generate the highest noise emissions, whereas noise emissions from concrete bridges with ballasted or resiliently fixed track may be almost as low as at-grade noise emission levels. Some bridge designs incorporating parapets may actually reduce noise emissions to below at-grade levels by virtue of the noise barrier effect provided by the parapets.

The design of bridges on the existing East Hills Line predominantly consists of unballasted track supported by a steel transom. Noise levels would be expected to be louder than at-grade track by up to 10 dBA. Several of the noise measurement locations adopted for the noise assessment were adjacent to bridges and the results were found to be consistent with these typical characteristics.

An initiative of RailCorp's Line Based Noise Pollution Reduction Program was to prepare a guideline or policy in relation to the design of future bridges. It is understood that this nominates a clear preference for ballasted concrete bridges at all locations where such bridges are feasible.

If a ballasted concrete bridge is not feasible at a specific location, consideration would need to be given to other forms, such as a ballasted composite bridge. Mitigation of the structure-borne noise could comprise resilient ballast mat, selected to minimise any enhancement of low frequency emissions.

Based on information provided by TIDC's TA, the computer noise modelling in the preceding sections assumed that ballasted concrete bridges would be constructed at all new underbridge locations. All new bridges should be designed to incorporate reasonable measures to mitigate noise.

4.10 Principles of Feasible and Reasonable Noise Mitigation

As discussed in **Section 4.1**, the determination of feasible and reasonable mitigation measures is based on a number of factors including engineering considerations, noise mitigation benefits, cost, community views, track maintenance and access requirements, aesthetic impacts, the change in noise levels and the wider community benefits of the proposal.

The noise barrier optimisation process and potential building treatment locations discussed in this and the following sections is limited to the potential noise mitigation benefits and cost of mitigation only.

At this early stage in the assessment process, other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal have not been assessed to the same level of detail. Whilst some of these other factors are discussed below, the proposed mitigation measures are indicative only and may change as more detailed project information becomes available and consultation with affected stakeholders occurs.

Reasonableness Assumptions

For upgraded railway lines including the Kingsgrove to Revesby Quadruplication, relevant noise trigger levels for various noise-sensitive receiver types are discussed in **Section 4.3**.

In order to initiate an assessment of rail noise impacts and investigate mitigation measures, both the increase in rail noise levels as a result of the project **AND** the overall level of rail noise must exceed the trigger levels. No further assessment is required at locations where both trigger levels are not exceeded.

As indicated in **Table 3**, an increase in existing rail noise levels is taken to be an increase of 2.0 dBA or more in L_{Aeq} in any hour or an increase of 3.0 dBA or more in L_{Amax}. An increase in noise level of up to 2 dBA in the L_{Aeq} or 3 dBA in the L_{Amax} are normally considered to be acceptable for an upgrade project on the basis that changes of this magnitude would not have a “noticeable” effect on acoustic amenity.

Where exceedances of the overall trigger levels are indicated, and there is a noticeable increase in noise levels associated with the project, consideration has been given to reasonable and feasible mitigation measures such as noise barriers and building treatments to reduce noise levels.

At locations where the future noise levels do not exceed the trigger levels, residential and other sensitive receiver locations will benefit from other long-term source mitigation measures such as the retiring of older, noisier rollingstock and improved maintenance of track and rollingstock.

In situations where it is not feasible or reasonable to mitigate noise emissions via source control measures or noise barriers, architectural building treatments may be considered after all other options have been explored.

Thus, for the proposal, noise barriers will only be considered at locations where:

- Source noise mitigation measures are not available, are not feasible or not effective.
- The future noise levels exceed the overall trigger levels, namely L_{Amax} 85 dBA or $L_{Aeq(15hour)}$ daytime 65 dBA **and** the predicted noise level increase as a result of the proposed upgrade is 2.0 dBA or more in L_{Aeq} in any hour or an increase of 3.0 dBA or more in L_{Amax}.

At locations meeting the above criteria, the design of noise barriers will be considered, subject to the additional feasibility and reasonableness assumptions discussed in the following section.

Noise Barrier Location Guidelines

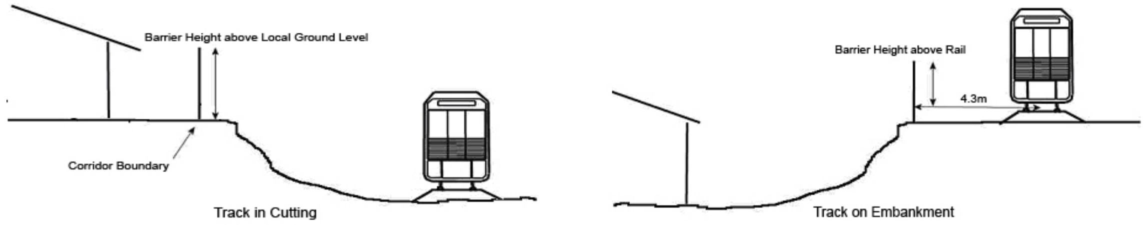
The following procedure was used to determine the appropriate location of a potential noise barrier, depending on the topography in the vicinity of the proposed barrier.

- Where the rail line was considered to be at grade or in cutting relative to the noise sensitive receivers, the barrier was located at the railway corridor boundary at local ground level (refer left sketch in **Figure 9**). <u>The height of the barrier in this situation is quoted relative to the local ground level.</u>

- Where the rail line was considered to be on embankment relative to the noise sensitive receivers, the barrier was located at a distance of 4.3 m from the centre line of the nearest track at top of rail level (refer right sketch in **Figure 9**). The height of the barrier in this situation is quoted relative to top of rail level.

The location of the proposed barriers at the above locations maximises the potential noise benefits, whist at the same time, does not preclude access to the track for maintenance purposes (where required).

Figure 9 Noise Barrier Location Sketches



Further Considerations

The definitions of "feasible and reasonable" are not fixed, and it is therefore necessary for the project proponents and designers to propose measures that would be regarded as feasible and reasonable in conjunction with the project objectives. In due course, the community would also need to be consulted, which may have some influence on what is considered "reasonable".

In addition to the above noise related assumptions, the following additional principles have been applied to determine whether the proposed noise barriers are feasible and/or reasonable.

- **Noise Barriers will only be considered if they can provide a reduction in L_{Aeq} and/or L_{Amax} noise levels at dwellings of at least 5 dBA**. The 5 dBA reduction must be achieved for at least one sensitive receiver location in the sub-catchment where the predicted noise levels exceed the trigger levels. This test was applied to avoid constructions with significant visual impact that are later criticised by the community as providing little or no acoustic benefit. It is also consistent with the minimum degree of attenuation normally expected for a noise barrier that breaks the line of sight between the source and receiver in a simple acoustic environment (i.e. free from excessive reflections). For this reason, it is often impractical to achieve a 5 dBA reduction in noise levels at the upper floors of multi-level buildings.
- **Noise Barrier Effectiveness Threshold**. When the future noise levels are mitigated to a level 5 dBA lower than the trigger levels, any additional noise benefit resulting from an increase in the barrier height is not considered to be equitable and is therefore not considered in the noise benefit calculations.
- **The height of the noise barriers will be optimised to provide the most efficient barrier design**. A discussion of the barrier optimisation methodology is provided in the following section.
- **The height of the noise barriers will be limited to 4.0 m above the Top of Rail**. At embankment locations, this limit would result in an overall barrier height of approximately 5.0 m, assuming that the top of the retaining wall is located 1.0 m below the top of rail. At cutting and at-grade sections, the barrier height would be limited to 4.0 m above the local ground level at the base of the barrier (refer **Figure 9**).
- **For reasons of cost-effectiveness, noise barriers will only be considered at locations where three or more receivers qualify for noise barrier consideration.**

Feasibility Issues

Issues of engineering feasibility must also be taken into account in the design of noise barriers. If barriers cannot be physically constructed within the available space or present an operational impediment or hazard, then this must be taken into account at whatever point in the design process it becomes apparent. Such issue may include (but are not limited to):

- Civil/structural limitations (such as the size of footings required to withstand wind loads).
- Safe access requirements for inspection staff and, where required, train drivers.
- Safe access requirements for future railway maintenance (including access for large machines).
- Signal sighting (which may be compromised by barriers on track curves).
- Safe access for future barrier maintenance (including for graffiti removal).

To address the feasibility issues, it may be necessary to redesign the barrier with a change in location, height or structure or, if an engineering solution cannot be found, to delete the barrier.

Cost Considerations

Cost is always an important item when considering how reasonable noise barriers are. The costs of the construction and long term maintenance of the barriers will be addressed by TIDC as part of the design process.

Community Considerations

In all cases where noise barriers are proposed, the community should be consulted to address issues such as overshadowing, loss of outlook, damage to existing vegetation, vandalism concerns, etc. Where there is a clear community preference for no barriers, or for a particular style or scale of noise barrier, this should be given due consideration in the final assessment of what constitutes “reasonable”.

Reflected Noise from Barriers

Noise barriers are normally constructed from hard materials that reflect, rather than absorb incident sound waves. The noise is thus reflected away from the barrier in the opposite direction.

In the case of a noise barrier located adjacent to a railway line, it is therefore possible in some instances for noise emissions to be reflected over the top of the train towards receivers on the opposite side of the track. This will generally only occur at locations where the top of the noise barrier is higher than the top of the train.

Acoustic Treatment of Individual Dwellings

At some locations where the noise trigger levels are exceeded as a result of the proposal, the feasibility and reasonableness considerations discussed above may indicate that the construction of a noise barrier is not feasible, reasonable or cost effective. At such locations, noise mitigation in the form of acoustic treatment to individual dwellings may be required to achieve a reduction in the internal noise environment.

The acoustic treatment of individual dwellings is generally not favoured for reasons including:

- It may not be cost effective if required on a widespread basis.
- It may not be effective for lightweight buildings.
- It provides no protection to outdoor areas.

- Mechanical ventilation and/or air-conditioning is required, resulting in higher energy consumption.

The acoustic treatment of individual dwellings will only be considered at noise-sensitive receiver locations where the future noise levels (with the proposed noise barriers) exceed the noise trigger levels. Consideration should generally not be given to building treatments at locations where there is no noticeable noise increase as a direct result of the project or where the future noise levels are below the overall noise trigger levels of L_{Amax} 85 dBA or $L_{Aeq(15hour)}$ 65 dBA.

Consideration of the Development Approval conditions for existing and planned developments will be taken into account when determining any additional acoustic treatments to be provided. Building treatments will not generally be provided to buildings where a Development Approval required that rail noise be addressed.

Where acoustic treatments are provided, these should aim to achieve **internal** noise levels in habitable rooms 20 dBA below the external trigger levels of L_{Amax} 85 dBA and $L_{Aeq(15hour)}$ 65 dBA. This results in **internal** noise levels of L_{Amax} 65 dBA and $L_{Aeq(15hour)}$ 45 dBA.

For light-framed and masonry buildings, **Table 12** provides a summary of the typical noise reductions from passenger train sources achieved with open, single and double-glazed windows. Whilst the indicative building noise reductions in **Table 12** are based on road traffic, similar reductions would be expected for typical passenger train sources.

Table 12 Indicative Building Noise Reduction (from RTA's ENMM 2001)

Building type	Windows	Internal Noise Reduction
All	Open	10 dBA
Light Frame	Single glazed (closed)	20 dBA
Masonry	Single glazed (closed)	25 dBA
Masonry	Double glazed (closed)#	30 dBA

Note that heavy single glazing is often used in lieu of double glazing.

At locations where acoustic treatments are provided, consideration will also need to be given to providing alternative ventilation in accordance with BCA requirements so that building occupants have the option to keep their windows closed, if desired, in order to maintain an appropriate **internal** noise environment.

For a typical masonry dwelling, internal noise levels of L_{Amax} 65 dBA and $L_{Aeq(15hour)}$ 45 dBA can be achieved with standard single glazing (closed) for external noise levels less than or equal to L_{Amax} 90 dBA and $L_{Aeq(15hour)}$ 70 dBA. For external noise levels above L_{Amax} 90 dBA and $L_{Aeq(15hour)}$ 70 dBA, additional building façade treatments such as upgraded windows and glazing, solid core doors, upgrading window and door seals and the sealing of wall vents would need to be considered.

Building element treatments such as upgraded windows are more effective when they are applied to masonry structures than light-framed/clad buildings. For feasibility reasons, upgraded building elements will not be considered for light-framed/clad buildings. Notwithstanding the above, the provision of alternative ventilation could provide a reduction in internal noise levels and would be considered for both masonry and light-framed/clad buildings.

Consistent with the RTA's ENMM, funding for building treatments would be subject to the execution of a Deed of Release. While due care must be taken in the design and selection of acoustic treatments for which funding is required, TIDC makes no representations that any particular internal noise level will be achieved. There is therefore no need to verify that a particular internal noise level has been achieved, and post-treatment noise monitoring is not required.

Noise Barrier Optimisation

Subject to the feasibility and reasonableness considerations in the preceding section, the following methodology has been used to determine the optimal noise barrier height within a given area:

a. Identify all noise sensitive receivers in the catchment area (i.e. where the predicted future noise levels without noise mitigation exceed the overall trigger levels of L_{Amax} 85 dBA or $L_{Aeq(15hour)}$ 65 dBA).

b. Break-up the large catchment area into smaller, manageable sub-catchments. The sub-catchments are typically 200 m to 400 m long sections encompassing sensitive receiver locations having a similar geographic environment and exposure to railway noise emissions. This allows the barrier height in each sub-catchment to be optimised separately. For this proposal, a total of 44 sub-catchments have been defined on each side of the railway corridor, labelled Dn-A to Dn-V for the Down side of the railway corridor and Up-A to Up-V for the Up side of the railway corridor. Sub-catchments Dn-B, Dn-H and Dn-N have been further subdivided into two smaller sub-catchments to enable more effective barrier optimisation. The extent of each sub-catchment is provided in **Table 13**.

c. For each sub-catchment, determine the number of noise sensitive receiver locations that exceed the overall noise trigger levels and noise barrier design goals. Determine from the reasonableness assumptions whether detailed noise barrier analysis is required.

d. For each sub-catchment, determine the noise barrier height that would be required to comply with external noise levels of L_{Amax} 80 dBA and $L_{Aeq(15hour)}$ 60 dBA at all noise sensitive receiver locations. This barrier is referred to as the "target" barrier. Note however, that a maximum barrier height of 5.0 m has been assessed in this analysis in order to evaluate the cost effectiveness 1.0 m beyond the maximum barrier height of 4.0 m (above top of rail).

e. Determine whether the target noise barrier provides an insertion loss of at least 5 dBA (L_{Aeq} or L_{Amax}) at any of the noise affected receiver locations. This test is applied to avoid constructions with significant visual impact that are later criticised by the community as providing little or no acoustic benefit. It is also consistent with the minimum degree of attenuation normally expected for a noise barrier that breaks the line of sight between the source and receiver in a simple acoustic environment (i.e. free from excessive reflections). The construction of a noise barrier will not be considered if this minimum performance standard is not achieved.

f. For each sub-catchment, calculate the overall noise levels and reductions for noise barriers of varying height in 0.5 m or 1.0 m increments (0.5 m increments were used in the current study).

g. For each sub-catchment, calculate and plot the **Total Noise Benefit (TNB)**. The TNB is the sum of the dBA reductions (L_{Amax} plus $L_{Aeq(15hour)}$) achieved at all noise-sensitive receptors within each sub-catchment for the barrier height. Note however, that the dBA reductions are only summed if the predicted noise levels exceed noise levels of L_{Amax} 80 dBA and $L_{Aeq(15hour)}$ 60 dBA (i.e., additional benefit to the community is not included in the justification for noise barriers once the predicted noise levels are 5 dBA below the overall trigger levels).

h. For each sub-catchment, calculate the **Marginal Benefit Value per Unit Area (MBVA)** and **Total Noise Benefit per Unit Area (TNBA)**. The MBVA represents the increase in TNB per unit increase in barrier area. (The methodology assumes barrier costs are proportional to barrier areas and are hence proportional to barrier heights, even though other factors such as barrier material will also have an influence on costs.) The TNBA represents the TNB per unit area of the barrier in the sub-catchment being examined.

i. Following calculation of the above parameters (TNB, MBVA and TNBA), these are plotted on charts to determine peaks in cost effectiveness. The number of exceedances is also plotted on the charts. Peaks in the MBVA curve correspond to barrier options with the greatest *marginal* cost effectiveness. Peaks in the TNBA curve correspond to the barrier options with the greatest *overall* cost effectiveness, compared with the other barrier height options being considered. In conjunction with the predicted noise level reductions, the cost effectiveness curves are reviewed to determine the "assessed" barrier. In order for a noise barrier to be considered cost-effective, both the MBVA and TBNA values must exceed 0.2 dBA per square metre of noise barrier. This level of 0.2 dBA per square metre was determined on the basis of previous experience on other projects and is considered to represent a cost effectiveness threshold which ensures that noise barrier heights and extents are assessed in an equitable manner across all Rail Clearways projects.

j. For each sub-catchment, determine whether the assessed barrier provides the required insertion loss of 5 dBA (L_{Aeq} or L_{Amax}) at any of the noise affected receiver locations.

k. Review other project related feasibility and reasonableness considerations to determine whether the "assessed" or "target" noise barrier should be constructed. To further reduce the total number of residual receivers the following additional feasibility and reasonableness considerations were implemented:

- Where the MBVA exceeds 0.2 dBA per square metre and the TNBA has a value between 0.15 and 0.2 dBA per square metre, the noise barrier may be considered "marginally cost effective" and the "assessed" barrier is to be determined.
- Consideration may be given to an incremental increase in barrier height (to a maximum of 4.0 m above top of rail or local ground height) for sub-catchments where such a height increase would result in compliance for at least two additional residual receivers within that sub-catchment.

Other Sensitive Receiver Locations

The noise barrier optimisation methodology discussed above is applicable to residential receiver locations only. For other sensitive receiver locations (eg schools), calculation of the TNB, MBVA and TNBA are based on the noise reductions at all receiver locations within the catchment area. Since a school building or other sensitive receiver location only represents a single calculation point within the noise model, the residential noise barrier optimisation methodology does not work for such receivers.

In order to optimise noise barriers at other sensitive receiver locations, the determination of the proposed feasible and reasonable barrier heights has been determined by following items a to f, and j to k, substituting the appropriate noise barrier design levels and trigger levels as required.

l. As a final additional step (for other sensitive receiver locations), the predicted noise barrier reduction for each incremental barrier height is investigated in order to estimate its cost effectiveness. If the incremental noise reduction (for each 0.5 m increase in barrier height) falls at or below 1 dBA, the additional increase in barrier height is not considered to be cost effective.

4.11 Screening Test for Noise Barrier Assessment

The first step in determining the reasonableness of providing a noise barrier is to assess the predicted future noise levels and the increase in noise levels resulting from the proposed upgrade (see **Section 4.3**).

Table 13 provides a summary of the initial screening test for the 44 sub-catchments adjacent to the railway corridor. The final column in **Table 13** indicates whether further detailed noise barrier analysis is required. Detailed barrier analysis is only required at locations where the answer to both questions in **Table 13** are "Yes" and where there are three or more receivers where the predicted future noise levels are above the trigger levels.

Table 13 Noise Barrier Screening Test

Sub-Catchment Chainage (km)	Name of Sub-Catchment	Do the predicted future noise levels exceed the overall trigger levels of L_{Amax} 85 dBA or $L_{Aeq(15hour)}$ 65 dBA?	At locations where the overall trigger levels are exceeded, are the predicted future noise levels also 2.0 dBA or more in L_{Aeq} in any hour or 3.0 dB or more in L_{Amax} above the existing noise levels?	Is detailed noise barrier analysis required?
14.18 - 14.68	Dn - A	Yes (3 locations)	Yes (3 locations)	**Yes**
	Up - A	No	N/A	No
14.68 - 14.90	Dn - B1	No	N/A	No
14.90 - 14.97	Dn - B2	Yes (7 locations)	Yes (7 locations)	**Yes**
14.90 - 14.97	Up - B	Yes (6 locations)	Yes (6 locations)	**Yes** [2]
14.97 - 15.36	Dn - C	Yes (14 locations)	Yes (14 locations)	**Yes**
	Up - C	Yes (11 locations)	Yes (11 locations)	**Yes**
15.36 - 15.65	Dn - D	Yes (16 locations)	Yes (16 locations)	**Yes**
	Up - D	Yes (18 locations)	Yes (18 locations)	**Yes**
15.65 - 15.97	Dn - E	Yes (5 locations)	Yes (5 locations)	**Yes** [2]
	Up - E	Yes (2 locations)	Yes (2 locations)	No [1]
15.97 - 16.33	Dn - F	Yes (5 locations)	Yes (5 locations)	**Yes**
	Up - F	Yes (6 locations)	Yes (6 locations)	**Yes**
16.33 - 16.80	Dn - G	Yes (17 locations)	Yes (17 locations)	**Yes**
	Up - G	Yes (26 locations)	Yes (26 locations)	**Yes**
16.80 - 17.05	Dn - H1	Yes (7 locations)	Yes (7 locations)	**Yes**
17.05 - 17.14	Dn - H2	Yes (11 locations)	Yes (11 locations)	**Yes**
16.80 - 17.14	Up - H	Yes (5 locations)	Yes (5 locations)	**Yes**
17.14 - 17.40	Dn - I	Yes (3 locations)	Yes (3 locations)	**Yes** [2]
	Up - I	Yes (6 locations)	Yes (6 locations)	**Yes**
17.40 - 17.65	Dn - J	No	N/A	No
	Up - J	Yes (8 locations)	Yes (8 locations)	**Yes**
17.65 - 18.02	Dn - K	Yes (27 locations)	Yes (27 locations)	**Yes**
	Up - K	Yes (5 locations)	Yes (5 locations)	**Yes**
18.02 - 18.40	Dn - L	Yes (10 locations)	Yes (10 locations)	**Yes**
	Up - L	Yes (5 locations)	Yes (5 locations)	**Yes** [2]
18.40 - 18.79	Dn - M	Yes (9 locations)	Yes (9 locations)	**Yes**
	Up - M	Yes (1 location)	Yes (1 location)	No [1]
18.79 - 18.96	Dn - N1	Yes (3 locations)	Yes (3 locations)	**Yes**
18.96 - 19.17	Dn - N2	Yes (2 locations)	Yes (2 locations)	**Yes**
18.79 - 19.09	Up - N	Yes (29 locations)	Yes (29 locations)	**Yes**
19.17 - 19.46	Dn - O	Yes (12 locations)	Yes (12 locations)	**Yes**

Sub-Catchment Chainage (km)	Name of Sub-Catchment	Do the predicted future noise levels exceed the overall trigger levels of L_{Amax} 85 dBA or $L_{Aeq(15hour)}$ 65 dBA?	At locations where the overall trigger levels are exceeded, are the predicted future noise levels also 2.0 dBA or more in L_{Aeq} in any hour or 3.0 dB or more in L_{Amax} above the existing noise levels?	Is detailed noise barrier analysis required?
19.09 - 19.46	Up - O	Yes (4 locations)	Yes (4 locations)	**Yes**
19.46 - 19.88	Dn - P	Yes (6 locations)	Yes (6 locations)	**Yes**
	Up - P	Yes (18 locations)	Yes (18 locations)	**Yes**
19.88 - 20.25	Dn - Q	Yes (4 locations)	Yes (4 locations)	**Yes**
	Up - Q	No	N/A	No
20.25 - 20.52	Dn - R	No	N/A	No
	Up - R	Yes (5 locations)	Yes (5 locations)	**Yes**
20.52 - 20.77	Dn - S	No	N/A	No
	Up - S	Yes (1 location)	Yes (1 location)	No [1]
20.77 - 21.22	Dn - T	No	N/A	No
	Up - T	No	N/A	No
21.22 - 21.52	Dn - U	No	N/A	No
	Up - U	No	N/A	No
21.52. - 21.82	Dn - V	No	N/A	No
	Up - V	No	N/A	No
Totals	**Down**	**161**	**161**	-
	Up	**156**	**156**	-

Note 1: Detailed barrier design will not be undertaken at these localities on the basis that there are fewer than three locations qualifying for noise barrier consideration.

Note 2: Detailed barrier design will be undertaken at these localities regardless of the number of receivers exceeding the trigger levels, on the basis that some or all of the exceedances are school buildings.

In **Table 13**, a number of sub-catchment areas are identified where the predicted future noise levels exceed the trigger levels at fewer than three locations. On the basis of the reasonableness considerations described above, no detailed design of barriers at these locations has been undertaken. The feasibility of building treatments at these locations is discussed in **Section 4.13**.

4.12 Detailed Noise Barrier Analysis and Preliminary Recommendations

At the 32 sub-catchment localities identified in **Table 13** where further detailed noise barrier analysis is required, the procedure in **Section 4.10** has been followed to determine the target and assessed barrier heights.

The cost-effectiveness curves for each sub-catchment are provided in **Appendix H**. A number of sub-catchments were further optimised during the project specific feasibility and reasonableness considerations described in step “k” of the noise barrier optimisation methodology and these are summarised in **Table 14**. The “First Pass Barrier Height” was determined from step “a” to “j” of the noise barrier optimisation methodology, and then the “Assessed Barrier Height” was subsequently determined from step “k” and incorporated into the future (Year 2021) situation (with mitigation).

Table 14 Further Project Specific Optimisation of Noise Barriers

Sub-Catchment	Assessed Barrier Height (m)	First Pass Barrier Height (m)	Assessed Barrier Residual Exceedances	First Pass Barrier Residual Exceedances
Dn - C	3	2	1	6
Dn - F [1]	2	N/A	0	5
Dn - G	3	1.5	1	2
Dn - K	2.5	2	0	4
Dn - Q [1]	3.5	N/A	0	4
Up - D	3.5	2.5	2	6
Up - F [1]	3	N/A	0	6
Up - G	3	2	0	5

Note 1: In these sub-catchments the detailed noise barrier analysis concluded that the construction of noise barriers is marginally cost-effective.

Table 15 provides a summary of the proposed barrier heights and locations for each sub-catchment where a detailed assessment of barriers has been undertaken (including the assessed barrier heights indicated in **Table 14**). **Table 15** also provides a summary of the number of exceedances for the existing (Year 2006) and future (Year 2021) situations with and without noise barriers for the target and assessed barriers.

As discussed in **Section 4.1**, the proposed noise barriers in **Table 15** have been determined on the basis of the noise mitigation benefits and cost of mitigation only. At this stage in the assessment process, the proposed barrier extents and heights do not take into account other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal. These other factors will be determined during the community consultation and detailed design stage of the proposal.

The locations of the proposed noise barriers are illustrated in the site plan in **Appendix B**.

Noise barriers for the following 2 sub-catchments were found to be either not cost effective or provided insufficient noise reduction as discussed below.

Sub-catchment Dn-M

In Sub-catchment Dn-M the detailed noise barrier analysis concluded that the construction of noise barriers is not recommended as a barrier would not provide the required 5 dBA noise reduction at any receiver locations within the sub-catchment (for noise barrier heights up to the maximum of 4.0 m).

Sub-catchment Dn-O

In Sub-catchment Dn-O the detailed noise barrier analysis concluded that the construction of noise barriers is not cost-effective. Within this sub-catchment there are a large number of receivers in a new multi-level building overlooking the noise barrier.

Additional discussion in relation to potential building treatments is provided in **Section 4.13**.

At the remaining 30 sub-catchment areas, where noise barriers are considered to be cost-effective, noise barriers ranging from 1.0 m to 4.0 m above top of rail have been proposed on the basis of acoustic requirements.

Table 15 Summary of Proposed Noise Barrier Heights and Locations (subject to further consultation and feasible considerations)

Name of Sub-Catchment	Assessed Barrier Chainage (km)	Assessed Barrier Length (m)	Target Barrier Height (m) [1]	Assessed Barrier Height (m) [1]	Number of Trigger Level Exceedances			
					Y2006 Without Mitigation	Y2021 Without Mitigation	Y2021 With Target Barrier	Y2021 With Assessed Barrier
Dn - A	14.18 to 14.38	200	4.0	**1.0**	0	**3**	0	**0**
Dn - B2	14.9 to 14.97	70	>5.0	**4.0**	2	**7**	1	**1**
Dn - C	14.97 to 15.34	370	5.0	**3.0**	1	**14**	0	**1**
Dn - D	15.41 to 15.65	240	>5.0	**1.5**	0	**16**	0	**0**
Dn - E	15.78 to 15.97	190	>5.0	**3.5**	5	**5**	0	**0**
Dn - F	15.97 to 16.18	210	4.5	**2.0**	1	**5**	0	**0**
Dn - G	16.33 to 16.8	470	>5.0	**3.0**	6	**17**	0	**0**
Dn - H1	16.8 to 17.01	210	>5.0	**1.5**	3	**7**	0	**0**
Dn - H2	17.08 to 17.14	60	>5.0	**4.0**	1	**11**	3	**6**
Dn - I	17.14 to 17.31	170	>5.0	**3.0**	3	**3**	1	**1**
Dn - K	17.65 to 18	350	5.0	**2.5**	6	**27**	0	**0**
Dn - L	18.17 to 18.35	180	>5.0	**1.0**	2	**10**	0	**1**
Dn - M	18.6 to 18.78	180	>5.0	**N/A** [2]	1	**9**	1	**9**
Dn - N1	18.85 to 18.91	60	>5.0	**2.5**	0	**3**	0	**0**
Dn - N2	19.03 to 19.12	90	3.0	**2.5**	0	**2**	0	**0**
Dn - O	19.17 to 19.26	90	>5.0	**N/A** [3]	8	**12**	8	**12**
Dn - P	19.63 to 19.81	180	>5.0	**3.0**	4	**6**	1	**2**
Dn - Q	19.99 to 20.25	260	>5.0	**3.5**	3	**4**	0	**0**
Up - B	14.73 to 14.97	240	>5.0	**3.5**	4	**6**	3	**3**
Up - C	14.97 to 15.29	320	>5.0	**2.5**	1	**11**	0	**1**
Up - D	15.38 to 15.58	200	>5.0	**3.5**	16	**18**	2	**2**
Up - F	16.13 to 16.33	200	>5.0	**3.0**	0	**6**	0	**0**
Up - G	16.33 to 16.75	420	>5.0	**3.0**	2	**26**	0	**0**
Up - H	16.93 to 17.11	180	>5.0	**3.5**	1	**5**	0	**1**
Up - I	17.29 to 17.4	110	>5.0	**4.0**	0	**6**	1	**1**

Name of Sub-Catchment	Assessed Barrier Chainage (km)	Assessed Barrier Length (m)	Target Barrier Height (m) [1]	Assessed Barrier Height (m) [1]	Number of Trigger Level Exceedances			
					Y2006 Without Mitigation	**Y2021 Without Mitigation**	**Y2021 With Target Barrier**	**Y2021 With Assessed Barrier**
Up - J	17.5 to 17.65	150	5.0	**2.0**	0	**8**	0	**0**
Up - K	17.65 to 17.85	200	>5.0	**1.0**	1	**5**	0	**0**
Up - L	18.07 to 18.35	280	>5.0	**2.5**	2	**5**	0	**0**
Up - N	18.79 to 19	210	>5.0	**4.0**	12	**29**	22	**22**
Up - O	19.12 to 19.25	130	>5.0	**2.5**	1	**4**	1	**1**
Up - P	19.46 to 19.88	420	5.0	**3.0**	3	**18**	0	**1**
Up - R	20.26 to 20.47	210	>5.0	**1.5**	0	**5**	0	**0**
Totals	**-**	**6,850**	**-**	**-**	**89**	**313**	**44**	**65 [4]**

Note 1 At rail embankment locations, the barrier height is the height of the barrier above the Top Of Rail. At locations where the track is at grade or in cutting, the barrier height is the height of the barrier above the local ground height.

Note 2 Noise barriers at these locations are not recommended as the required 5 dBA noise reduction is not achieved at any receiver locations within the sub-catchment.

Note 3 Noise barriers are not cost effective in these areas as the TNBA and MBVA values within these sub-catchment areas are less than 0.2 dBA/m^2.

Note 4 The total number of residual receivers (with assessed barriers) in the proposal area also includes the residual receivers in sub-catchments identified in **Table 13** as containing less than three residuals i.e. sub-catchments Up-E (2 locations), Up-M (1 location) and Up-S (1 location). This gives a total of 69 residual receivers for Year 2021 with the assessed barriers.

4.13 Residual Exceedances and Potential Building Treatments

It is evident from the results in **Table 13** and **Table 15** that some residential and educational receivers are predicted to experience noise levels above the trigger levels, even with the proposed noise barriers.

As discussed in **Sections 4.3** and **4.9**, consideration of specific acoustic treatment to dwellings is recommended if the future noise levels exceed the trigger levels and there is a noticeable increase in noise levels resulting from the proposal. If the increase in noise levels due to the project is less than the trigger levels, consideration of specific acoustic treatment to dwellings is not required.

Appendix I contains a summary of residential and educational receiver locations with residual exceedances of the trigger levels, along with a brief description of each location. In total, there are 69 noise sensitive receiver locations where the predicted noise levels in Year 2021 exceed the overall trigger levels of L_{Amax} 85 dBA and $L_{Aeq(15hour)}$ 65 dBA and the increase in noise level resulting from the proposal is 2 dBA or more in the L_{Aeq} or 3 dBA or more in the L_{Amax}.

On the basis of site observations, 13 of these receivers are located within recently constructed developments, and consequently, it is likely that the Development Approval would have required noise emissions from the adjacent railway line to be taken into account in the building design.

A further 5 of these noise sensitive receiver locations are school or community centre buildings which are predicted to exceed internal noise levels of $L_{Aeq(1hour)}$ 45 dBA, on the basis of naturally ventilated conditions (windows open).

At the remaining 51 locations, building treatments in the form of alternative ventilation should be considered to allow residents to close their windows if desired in order to maintain a satisfactory internal noise environment.

Details of specific Development Approval requirements will be investigated by TIDC as part of the detailed design and hence the number of locations requiring building treatments cannot be finalised until this additional information is obtained. Noise measurements may also be undertaken at specific receivers prior to confirming offers of building treatments.

The number of building treatment locations in the above discussion is indicative only and is dependent on the extent and height of the proposed noise barriers. As discussed in **Section 4.1**, the proposed noise barriers described in this report do not take into account other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal.

5 OPERATIONAL VIBRATION

5.1 Introduction

Railway vibration is generated by dynamic forces at the wheel-rail interface and will occur to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness of the surfaces and elastic deformation). Significantly higher vibration levels can occur due to rail and wheel surface irregularities, including some irregularities that do not cause significant levels of airborne noise.

This vibration propagates via the sleepers or rail mounts into the ground or track support structure. It then propagates through the ground or structure, and may sometimes be felt as tactile vibration by the occupants of buildings.

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, those where the building contents may be affected and those in which the integrity of the building or the structure itself may be prejudiced.

Human Perception of Vibration

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. Industrial environments are clearly less sensitive than say, commercial buildings, where the usual expectation is that there should be little perceptible vibration.

Although people are able to perceive relatively low vibration levels, it is not appropriate to set vibration design goals requiring “no vibration”, since there will always be some vibration in any environment. It is necessary therefore to set realistic design goals which minimise disturbance and adverse impacts on amenity. The recommended assessment approach is discussed in **Section 7.4**

Effects 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 will be the human comfort design goals, and it is therefore not necessary to set separate design goals for this proposal in relation to the effect of railway vibration on most building contents.

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 consider the vibration acceptable. Hence, the controlling design goals will still be the human comfort design goals, and it is therefore not necessary to set separate design goals for this proposal in relation to building damage from railway vibration.

5.2 Ground-Borne Noise from Rail Operations

Ground-borne noise in buildings adjacent to railway lines is most common in railway tunnel situations where there is an absence of airborne noise to mask the ground-borne noise emissions. Ground-borne noise results from the transmission of ground-borne vibration rather than the direct transmission of noise through the air. The vibration is generated by wheel/rail interaction and is transmitted from the trackbed, via the ground and into the building structure.

The vibration entering the building then causes the walls and floors to faintly vibrate and hence to radiate noise (commonly termed “ground–borne noise” or “regenerated 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.

For surface rail projects, the effect of ground-borne noise tends to be less of an issue than for underground rail projects. This is because the airborne noise emissions in most circumstances are much higher than the ground-borne noise levels. In some situations, however, the ground-borne noise emissions may be audible (for example, at locations where airborne noise emissions are attenuated by a noise barrier, the track is located within a deep cutting or where there are no windows facing the railway corridor).

5.3 Vibration Propagation

The propagation of vibration through the ground is a complex phenomenon. Even for a simple source, the received vibration at any point may include the arrival of several different wave types, plus other effects such as damping, reflection, and impedance mismatch caused by changes in ground conditions along the propagation path.

It is useful to note that predictions of vibration normally involve a combination of empirical and analytical methods as the various characteristics are normally not sufficiently defined to enable full analytical modelling.

5.4 Vibration Trigger Levels

As discussed in **Section 5.1** the human comfort design goals for vibration tend to be more stringent than other possible design goals relating to the disturbance of building contents or building damage.

For new or upgraded railway lines, the IGANRIP specifies that a separate guideline, *“Assessing Vibration: a technical guideline”* (DEC 2006) is to be applied. The DEC guideline is based on British Standard BS 6472-1992 and provides vibration trigger levels to minimise the disturbance to building occupants from continuous, impulsive and transient vibration. For train passbys, the DEC guideline classifies vibration levels as being intermittent.

For **intermittent** vibration at residential receiver locations, vibration trigger levels are expressed in terms of the Vibration Dose Value (VDV) during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods. The VDV is a measure that takes into account the overall magnitude of the vibration levels during a train passby, as well as the total number of train passbys during the daytime and night-time periods.

For residential receiver locations, the guideline nominates “preferred” vibration dose values of 0.2 $m/s^{1.75}$ (daytime) and 0.13 $m/s^{1.75}$ (night-time) and “maximum” vibration dose values of 0.4 $m/s^{1.75}$ (daytime) and 0.26 $m/s^{1.75}$ (night-time). For this proposal, the more stringent “preferred” vibration dose values have been applied.

For offices, schools, educational institutions and places of worship, the guideline nominates VDVs twice the residential daytime levels (ie, 0.4 $m/s^{1.75}$ during the daytime and night-time periods).

The proposed vibration trigger levels are summarised in **Table 16**.

Table 16 Trigger Levels for Intermittent Vibration

Location	VDV ($m/s^{1.75}$)[1]	
	Day[2]	Night[2]
Residential Properties	0.2	0.13
Offices, Schools, Educational Institutions and Places of Worship	0.4	0.4

Note 1 Vibration Dose Values (VDVs) are based on the "preferred" values in the DEC guideline *Assessing vibration: a technical guideline (2006)*

Note 2 Daytime is 7.00 am to 10.00 pm and Night-time is 10.00 pm to 7.00 am

5.5 Source Vibration Levels

The US Federal Transit Administration's (FTA's) *"Transit Noise and Vibration Impact Assessment"* report provides indicative vibration levels versus distance for a variety of transport systems, including rapid transit rail systems. The base curve, shown in **Figure 10** shows the typical ground-surface vibration levels assuming rollingstock and rail in good condition and a train speed of 80 km/h. At other speeds, the change in vibration level is approximately proportional to 20 x log(speed/80 km/h), however the manual notes that sometimes the speed relationship has been observed to be as low as 10 to 15 x log(speed/80 km/h).

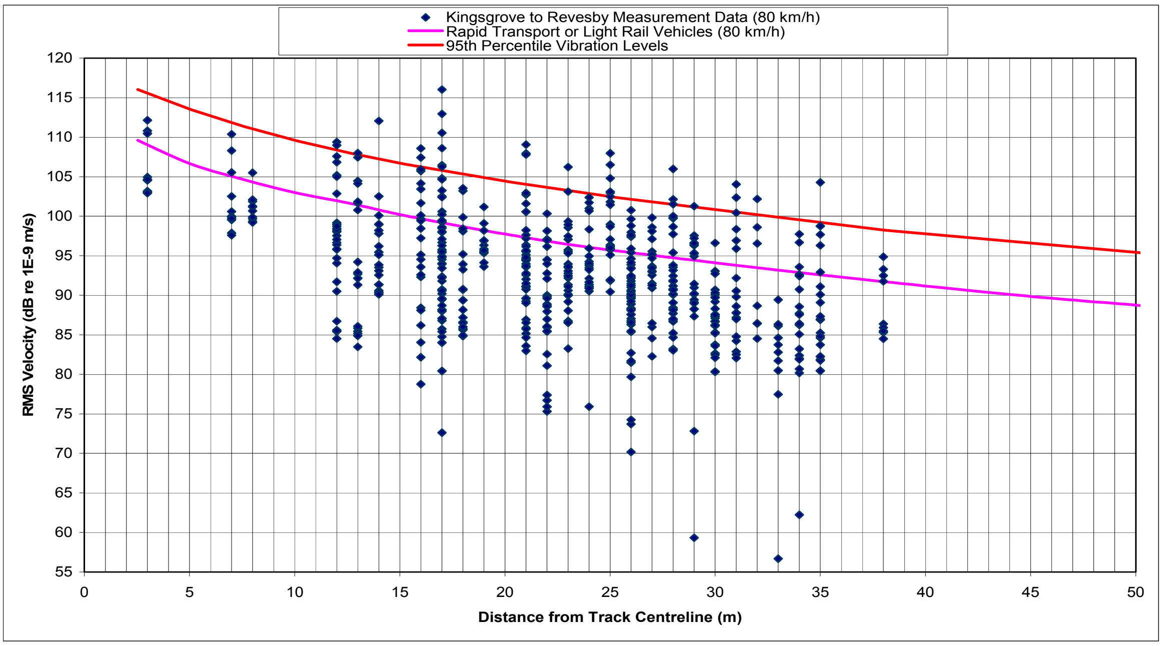
The vibration measurements undertaken for the current study are also presented in **Figure 10** for comparison (adjusted for speed to represent the 80 km/h reference). The full results are presented in Heggies Report 10-4805-R1. In **Figure 10**, the vibration levels are expressed in terms of the rms vibration velocity level in dB (re 10^{-9} m/s). The measurement data obtained as part of the current study represent the maximum vibration levels observed during each train passby.

From the measurement results at fifteen locations (V1 to V15) adjacent to the East Hills Line (2 measurement distances per location), it is evident that approximately 50% of the measurement results are above the reference line (for rapid transport or light rail vehicles) and 50% are below the reference line. The measurement results therefore appear to correlate well with the FTA reference levels for typical trains.

The upper line in **Figure 10**, labelled "95th Percentile Vibration Levels", represents the typical maximum vibration level and is 7 dB higher than the reference curve. On the basis of the measurement results and similar vibration measurements undertaken on other projects, the difference between the 95^{th} percentile (highest 1 in 20 trains) event and the median event is approximately 7 dB.

The 95^{th} percentile vibration curve, in conjunction with the typical 20 x log(speed/80 km/h) relationship has been used to predict the future vibration levels and the typical change in vibration levels as a result of the proposed upgrade. The 95^{th} percentile vibration curve and the number of train passbys during the daytime and night-time periods have also been used to predict the VDVs at individual receiver locations adjacent to the proposal.

Figure 10 Ground Surface Vibration Levels Versus Distance (adapted from Figure 10-1 in FTA' s Transit Noise and Vibration Impact Assessment Report)



5.6 Assessment of Ground-Surface Vibration Levels

Section B2.3 of the DEC vibration guideline provides a calculation procedure for determining the Vibration Dose Values (VDV) on the basis of the measured (or predicted) rms vibration velocity levels.

For an individual train passby, the estimated Vibration Dose Value (eVDV) is based on the following formula:

> eVDV = 0.07 x V_{rms} x $t^{0.25}$ ($m/s^{1.75}$), where t represents the time period for the train passby and V_{rms} is the vibration level of the passby expressed in mm/s.

For the daytime and night-time periods, the eVDV(overall) is based on the following formula:

> eVDV(overall) = 0.07 x V_{rms} x $(t \times N)^{0.25}$ ($m/s^{1.75}$) where t represents the time period for a representative train passby. V_{rms} is the vibration level for a representative train passby and N represents the number of trains within the assessment period (daytime or night-time).

On the basis of the proposed track alignments, the number of passbys and the maximum train speeds on each line, it is possible to calculate the allowable maximum V_{rms} vibration level (on the near track) corresponding to the vibration trigger levels.

The vibration trigger levels of 0.2 $m/s^{1.75}$ daytime and 0.13 $m/s^{1.75}$ night-time would permit vibration levels of up to 112 dB during the day or night at residential properties. For offices, schools, educational institutions and places of worship, the vibration trigger levels would permit V_{rms} vibration levels 6 dB higher than residential properties.

The 95th percentile vibration curve in **Figure 10** has conservatively been used, together with the proposed track alignment and train speeds on the nearest line to calculate the V_{rms} vibration levels at each sensitive receiver location adjacent to the proposal.

The V_{rms} vibration levels are predicted to exceed the 112 dB vibration trigger level (corresponding to a VDV of 0.2 $m/s^{1.75}$) at the following residential locations:

- 48 Vanessa Street, Beverly Hills - At this location, the predicted V_{rms} vibration level is 115 dB and exceeds the vibration trigger level by a margin of 3 dB. Compared with the existing situation, the future vibration levels are predicted to increase by 3 dB as a result of the proposal.
- 2 Gregory Crescent, Beverly Hills - At this location, the predicted V_{rms} vibration level is 113 dB and exceeds the vibration trigger level by a margin of 1 dB. Compared with the existing situation, the future vibration levels are predicted to increase by 7 dB as a result of the proposal.

At the above locations, the feasibility of installing ballast mat on the near track should be investigated as part of the detailed design process for the purpose of mitigating the future vibration levels.

Ballast mats comprise of a soft resilient layer, usually made from rubber or other synthetic compounds (typically 40 mm thick), and are placed beneath the ballast to reduce the vibration transmitted into the surrounding ground. It is anticipated that ballast mat would mitigate vibration levels by up to 5 dB and would provide a corresponding reduction in ground-borne noise levels of 5 dBA to 10 dBA. The ballast mat is typically required to be extended approximately 15 m to 20 m either side of the receiver location to provide the required attenuation.

At offices, schools, educational institutions and places of worship, the V_{rms} vibration levels are predicted to comply with the 118 dB vibration trigger level (corresponding to a VDV of 0.4 $m/s^{1.75}$) at all locations.

The DEC vibration guideline indicates that the threshold of perception for most people is approximately 103 dB. On the basis of the proposed train speeds and the 95th percentile vibration curve in **Figure 10**, it is anticipated that for some train passbys, vibration levels would be perceptible at buildings located within approximately 23 m from the nearest track (for train speeds of 80 km/h) or at building located within approximately 33 m from the nearest track (for train speeds of 115 km/h).

Because of the intermittent nature of the vibration generated by train passbys, the vibration trigger levels in the DEC guideline are set to be above the threshold of perception levels. The DEC guideline notes however that for intermittent vibration, there is a low probability of adverse comment or disturbance to building occupants at vibration levels below the trigger levels that have been adopted for this assessment

6 CONSTRUCTION NOISE MODELLING

6.1 Construction Noise Metrics

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

$L_{A1(60second)}$	the "Typical Maximum Noise Level" for an event, used in the assessment of potential sleep disturbance during night-time periods.
$L_{A10(15\ minute)}$	the "Average Maximum Noise Level" during construction activities. This parameter is used to assess the 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 (i.e. A-weighted).

6.2 Construction Noise Goals

The DEC's "*Environmental Noise Control Manual"* provides guidelines for assessing the noise impact from construction sites. The DEC's general approach to the control of noise from construction sites involves the following:

- **Limiting hours of operation for "noisy" construction work** - The DEC normally limits construction works to the following time periods: 7.00 am to 6.00 pm from Monday to Friday, 8.00 am to 1.00 pm on Saturdays and no work on Sundays and Public Holidays.
- **Use of silenced equipment** - All practical measures should be used to silence equipment, particularly in instances where extended hours of operation are required.
- **Compliance with noise emission objectives**:
  - For a construction period of up to 4 weeks duration, the L_{A10} noise level when measured over a period of not less than 15 minutes should not exceed the L_{A90} background noise level by more than 20 dBA.
  - For a construction period of between 4 and 26 weeks, the L_{A10} noise level should not exceed the L_{A90} background noise level by more than 10 dBA.
  - For a construction period of greater than 26 weeks, the L_{A10} noise level should not exceed the L_{A90} background noise level by more than 5 dBA.

As the overall duration of the proposed construction program is greater than 26 weeks, the L_{A90} background + 5 dBA noise goal is applicable to residential and other noise sensitive receiver locations (eg, schools, hospitals, nursing homes, etc.). The $L_{A10(15\ minute)}$ construction noise goal is based on the local L_{A90} background noise level during the relevant time period (day, evening or night).

For retail and commercial buildings, it is generally accepted that receivers are 5 dBA to 10 dBA less sensitive to noise emissions than residential receivers. For these receivers, an L_{A10} noise objective of L_{A90} background + 10 dBA has been conservatively applied. These criteria are only relevant in areas without nearby residential dwellings, otherwise the more stringent residential criteria will apply.

Some work is proposed to be carried out on weekends outside of the regular construction work hours during scheduled track possessions, night-time works and engineering hours.

Engineering hours refer to an overnight period when trains are not running (typically midnight to 5 am). Construction noise during these periods is discussed in **Section 6.3** and **Section 6.7.6**.

Unattended background noise monitoring was undertaken during July and August 2006 at fifteen locations in the vicinity of the proposed construction works between Beverly Hills and Panania. The full results of the unattended noise monitoring were presented in Heggies report 10-4805-R1. The locations of the noise loggers (BG1 to BG15) are illustrated in **Appendix B**.

As discussed in **Section 3.3** of report 10-4805-R1, the background noise data has been segregated into the relevant times of day to assist in setting noise criteria for construction noise emissions. The L_{A90} noise levels are the rating background noise levels (RBL), determined using the procedures set out in the DEC's Industrial Noise Policy.

The noise logging results have been used to estimate the L_{A90} background noise levels at locations throughout the proposed construction works for the purpose of determining the relevant L_{A10} construction noise objectives. **Table 17** presents the relevant L_{A10} construction noise objectives for nearby receiver groups, based on the L_{A90} background noise levels at the nearest equivalent unattended noise monitoring location. The receiver groups correspond to the proposed work areas defined in Section 3 of the *Preliminary Concept Design Report (Volume 1 - Rail Clearways Program, Kingsgrove to Revesby Quadruplication, September 2006)*, the *Draft 'Preliminary Assessment of Constructability, Cost, D&C Program and Program Risk Report' and* Chapter 7 of the *Environmental Assessment*.

Table 17 Summary of L_{A10} Noise Objectives for Nearby Receiver Groups

Work Area & Scenario	Location of Work Area	Description of Nearest Receiver Locations to the Proposed Construction Works	L_{A10} Construction Noise Objective (dBA)[1] RBL+5 dBA		
			Day	Evening	Night
1.1	Beverly Hills Station (City Side)	49 Cahill Street, Beverly Hills	58	56	49
		64 Cahill Street, Beverly Hills			
		78 Tooronga Terrace, Beverly Hills			
2.1	King Georges Road Overbridge, Beverly Hills	141 Morgan Street, Beverly Hills	58	56	49
		4-6 Edgbaston Road, Beverly Hills			
		Beverly Hills Girls High School (IEC)			
2.2	King Georges Road Overbridge, Beverly Hills	141 Morgan Street, Beverly Hills	58	56	49
		4-6 Edgbaston Road, Beverly Hills			
		Beverly Hills Girls High School (IEC)			
3.1	Broad Arrow Road, Narwee (Road)	20 Kardella Crescent, Narwee	63	57	45
		23 Bryant Street, Narwee			
		39 Broad Arrow Road, Narwee			
4.1	Broad Arrow Road, Narwee (Pedestrian)	140 Hannans Road, Narwee	63	57	45
		39 Kardella Crescent, Narwee			
		42 Broad Arrow Road, Narwee			
5.1[2]	Karne Street, Narwee	1 Karne Street, Narwee	44	48	39
		12 Huntingdale Avenue			
		2 Ventura Ave, Narwee			
6.1	Bonds Road, Riverwood	216A Bonds Road, Riverwood	56	52	44
		2A Bonds Road, Riverwood			
		68 Josephine Street, Riverwood			

Work Area & Scenario	Location of Work Area	Description of Nearest Receiver Locations to the Proposed Construction Works	LA10 Construction Noise Objective (dBA)[1] RBL+5 dBA		
			Day	Evening	Night
7.1	Belmore Road, Riverwood	1 Morotai Avenue, Riverwood	44	43	40
		3 Phillip Street, Riverwood			
		54 Thurlow Street, Riverwood			
7.2	Belmore Road, Riverwood	1 Morotai Avenue, Riverwood	44	43	40
		3 Phillip Street, Riverwood			
		54 Thurlow Street, Riverwood			
8.1	Webb Street, Riverwood (Road)	40 Lillian Road, Riverwood	45	47	43
		91 Webb Street, Riverwood			
		95 Webb Street, Riverwood			
8.2	Webb Street, Riverwood (Creek)	2 Meager Avenue, Padstow	45	47	43
		40 Lillian Road, Riverwood			
		95 Webb Street, Riverwood			
8.3	Webb Street, Riverwood	2 Meager Avenue, Padstow	45	47	43
		40 Lillian Road, Riverwood			
		95 Webb Street, Riverwood			
9.1	Davies Road, Padstow	68 Davies Road, Padstow	50	51	43
		70 Davies Road, Padstow			
		89 Davies Road, Padstow			
9.2	Davies Road, Padstow	68 Davies Road, Padstow	50	51	43
		70 Davies Road, Padstow			
		89 Davies Road, Padstow			
10.1	Padstow Station	32 Alice Street, Padstow	50	47	38
		49 Cahors Road, Padstow			
		59 Howard Road, Padstow			
10.2	Padstow Station	32 Alice Street, Padstow	50	47	38
		49 Cahors Road, Padstow			
		59 Howard Road, Padstow			
11.1	Doyle Road, Padstow	1 Bradley Street, Padstow	49	47	36
		153A Arab Road, Padstow			
		93 Doyle Road, Revesby			
11.2	Doyle Road, Padstow	1 Bradley Street, Padstow	49	47	36
		153A Arab Road, Padstow			
		93 Doyle Road, Revesby			
12.1	Revesby Station	143 The River Road, Revesby	46	46	40
		48 Simmons Street, Revesby			
		7 Macarthur Avenue, Revesby			

Note 1: The LA10 construction noise goals are applicable at the nearest and/or most affected residential receiver or other noise sensitive receiver location.

Note 2 Work Area 5.1 corresponds to a group of receivers located away from a major area of work ie Narwee Station and Bonds Road underbridge. However receivers such as these will be exposed to noise as a result of retaining wall and drainage works as well as noise associated with general track construction. This assessment location is representative of such receivers.

6.3 Construction Planning

Overall Planning

The construction scenarios presented in this report are based on the concept construction strategies discussed in the *Preliminary Concept Design Report (Volume 1 - Rail Clearways Program, Kingsgrove to Revesby Quadruplication, September 2006)*, the *Draft Preliminary Assessment of Constructability, Cost, D&C Program and Program Risk Report* and Chapter 7 of the *Environmental Assessment (Volume 1)*.

The overall construction program is anticipated to commence mid 2008 and is expected to be up to 32 months in duration. The project is due for completion late 2010 to early 2011.

Working Hours

The majority of the works can be carried out during standard construction hours:

- Monday to Friday between 7 am and 6 pm.
- Saturday between 8 am and 1 pm.
- No works on Sundays or public holidays.

However exemptions would be necessary under circumstances as outlined in Chapter 7.5 of the Environmental Assessment (Volume 1).

Track Possessions

There are currently 12 scheduled weekend track possessions planned during the construction period. A track possession is a planned shutdown of a section of the network generally taking place on a weekend between midnight on Friday and 4 am on Monday. Possessions are required where works cannot be safely undertaken due to their proximity to the existing rail lines or where there would be a risk that the works may adversely affect the existing operating lines.

Construction activities requiring track possessions may include:

- erection of safety barriers and fences to isolate the working areas from the live track:
- relocation, extension or reinforcement of in-corridor utilities in the Revesby station area;
- survey, marking and protection of the high pressure ethane gas pipeline;
- vegetation clearance;
- removal of advertising hoardings at various locations along the project alignment;
- installation of bridge decks for four bridges over stormwater canals east of King Georges Road;
- central pier strengthening works and demolition of existing abutments, demolition of bridge deck and installation of new deck on King Georges Road bridge, southbound;
- underpinning works and construction of blade walls on King Georges Road bridge northbound including blade wall construction;
- erection of new superstructure at Broad Arrow Road bridge;
- Installation of new structures at Narwee station underpass (both sides) including demolition of existing commercial building;
- erection of new structures at Bonds Road bridge;
- demolition, strengthening and construction of new bridges (both sides) at Belmore Road;

- installation of new superstructure at Webb Street underpass;
- construction and installation of new bridge decks at Salt Plan Creek;
- demolition of existing bridges and construction of new bridges at Davies Road, Memorial Drive, and Doyle Road;
- installation and then removal of pedestrian bridges at King Georges Road Beverly Hills, Belmore Road Riverwood and at Revesby Station (removal not required at Revesby);
- construction of footings in close proximity to the existing rail lines for the new overhead wiring structure;
- removal of existing overhead power lines and installation of new overhead wiring structures;
- construction, testing and commissioning of the new sub-station and upgrading of other sub-stations;
- temporary installation of signalling cables and installation of new signalling;
- conversion of existing turnouts, installation of new turnouts, adjustments to overhead wiring and installation of new overhead wiring at Revesby and Kingsgrove;
- installation of new high voltage cables at various locations along the alignment where the new cables are close to the existing rail line;
- removal of safety barriers and fencing; and
- testing and commissioning of the new system.

The current schedule of planned possessions is provided in Table 7.1 of the Environmental Assessment (Volume 1). It is noted that additional weekend possessions may be sought by RailCorp during the construction period.

Out of Hours Works

In addition to the planned track possessions, other construction works will be required outside of normal construction hours. These works may be undertaken during the evening (6 pm to 10 pm) and night-time (10 pm to 7 am) or during engineering hours. Engineering hours refer to an overnight period when trains are not running (typically midnight to 5 am).

Typical activities that would require out of hours works would include:

- Road works associated with bridge construction and modification.
- Bridge demolition and reconstruction of piers. These works would include activities such as abutment piling works, the cutting up of bridge decks and abutment walls.
- Under track drainage works.
- Pre-possession works that are to occur during engineering hours may include activities such as the installation of temporary rail infrastructure such as signalling,

A preliminary summary of proposed out of hours works is provided in Section 7.4 (Table 7.7) of Volume 1 of the Environmental Assessment.

6.4 General Approach to Noise Modelling

SoundPLAN V6.3 software was used for modelling the construction noise. The model includes ground topography, buildings and representative noise sources as discussed below. At the relatively small distances between construction sites and receivers, weather effects have little influence on noise propagation and hence neutral meteorological conditions were assumed.

The calculated construction noise levels will inevitably depend on the number of plant items and equipment operating at any one time and their precise location relative to the receiver of interest. Predicted noise levels have been calculated for both "typical" construction activities and "worst case" activities, assuming plant operating in the area closest to the respective receivers.

In practice the noise levels will vary due to the fact that plant and equipment will move about the work sites and will not all be operating at the same time. In some cases, reductions in noise levels will occur when plant are located in cuttings or behind embankments or buildings.

6.5 Typical Sound Pressure Levels

Sound pressure levels for typical items of plant required to carry out the works are listed in **Table 18**. These noise levels are representative of modern plant operating with noise control measures in good condition.

Table 18 Sound Pressure Levels for Plant Items

Item	Typical Plant Type	Noise Level at 7 m (dBA)	
		Typical Maximum Level	Noise Level for Modelling (L_{A10})
Heavy Rockbreaker	On excavator KATO 750	103	98
Excavator KATO	KATO 750	86	83
Boring Rig (Diesel)	-	85	82
Bulldozer	Caterpillar D9	88	83
Skidsteer	-	85	82
Crane	60 t crawler or truck mounted	85	80
Backhoe/FE Loader	Wheeled	86	82
Semi Trailer	25-28 tonne	87	82
Dump Truck	15 tonne	83	82
Product Truck	12-15 tonne	83	82
Vibratory Pile Driver	-	96	90
Impact Piling Rig	-	109	105
Generator	Diesel	79	78
Concrete Saw	-	95	92
Jackhammer	Hand held	88	84
Lighting Tower	Lunar Lighting Tower	55	55
Flood Lights	Daymaker	75	75
Concrete Truck	-	88	85
Concrete Pump	-	84	82
Concrete Agitator	-	80	78
Ballast Regulator	-	96	93
Ballast Tamper	-	96	93
Franna Crane	-	85	80
400t Crane	-	85	80
100t Crane	-	85	80
Road Profiler	-	83	82
Asphalter	-	83	82
Auger Piling Rig	-	85	82

6.6 Construction Noise Modelling Scenarios

On the basis of the construction program and methodology discussed in Section 3 of the *Preliminary Concept Design Report*, the *Draft Preliminary Assessment of Constructability, Cost, D&C Program and Program Risk Report* and Chapter 7 of the Environmental Assessment, it is anticipated that construction noise levels would be highest during the following scenarios.

The modelled construction scenarios are indicative only and are intended to identify the likelihood of any significant noise impacts that will need to be considered in further detail at a later design stage. Construction noise has been modelled at representative receivers in close proximity to the major construction zones. The Contractor will be required to prepare detailed Construction Noise and Vibration Impact Statements for each work site prior to commencement of construction activities. It is understood that certain works, such as track laying, overhead wiring installation and excavation will not be constrained to one construction zone. The potential noise impacts of such activities are dealt with in **Section 6.7.2**.

It is also understood that piling works will form an integral part of the retaining wall construction process. An indicative retaining wall construction scenario located away from other major construction zones has been modelled. The scenario is described below under Work Area 5.

Piling, Bridge and Station Works

- **Work Area 1 – City side of Beverly Hills Station, Beverly Hills**
  - **Scenario 1: Storm Water Canal Underbridge Construction.** This scenario involves the use of a 60 tonne mobile crane, bored piling rig, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.
- **Work Area 2 – King Georges Road Overbridge, Beverly Hills**
  - **Scenario 1: Overbridge Modifications**. This scenario involves the use of a 400 ton crane, semi-trailers, generator, concrete saw, jackhammer, concrete truck and concrete pump.
  - **Scenario 2: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi-trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 3 – Broad Arrow Road, Narwee**
  - **Scenario 1: Underbridge Widening and Modification.** This scenario involves the use of a 400 tonne crane, 100 tonne crane, franna crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.
- **Work Area 4 – Broad Arrow Road, Narwee**
  - **Scenario 1: Pedestrian Underbridge Widening and Modification.** This scenario involves the use of a crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.
- **Work Area 5 – Karne Street, Narwee**
  - **Scenario 1: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 6 – Bonds Road, Riverwood**
  - **Scenario 1: Underbridge Widening and Modification.** This scenario involves the use of a 400 tonne crane, 100 tonne crane, franna crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.

- **Work Area 7 – Belmore Road, Riverwood**
    - **Scenario 1: Overbridge Modifications.** This scenario involves the use of a 400 tonne crane, semi-trailers, generator, concrete saw, jackhammer, concrete truck and concrete pump.
    - **Scenario 2: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi-trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 8 – Webb Street Riverwood**
    - **Scenario 1: Underbridge Widening and Modification.** This scenario involves the use of a 400 tonne crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck, concrete vibrators, pile boring rig, excavator, backhoe, road profiler, roller, asphalter and concrete pump.
    - **Scenario 2: Bridge Construction over Salt Pan Creek.** This scenario involves the use of a river barge, excavator, concrete vibrators, roller, asphalter, crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.
    - **Scenario 3: Piling Works.** This scenario involves the use of a front end loader, semi-trailer, concrete trucks, pile barge, vibratory pile driver, auger piling rig and impact piling rig.
- **Work Area 9 – Davies Road, Padstow**
    - **Scenario 1: Overbridge Modifications.** This scenario involves the use of a 400 tonne crane, semi-trailers, generator, concrete saw, jackhammer, concrete truck and concrete pump.
    - **Scenario 2: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi-trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 10 – Padstow Station, Padstow**
    - **Scenario 1: Overbridge Modification.** This scenario involves the use of a 400 tonne crane, semi-trailers, generator, concrete saw, jackhammer, concrete truck and concrete pump.
    - **Scenario 2: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi-trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 11 – Doyle Road, Padstow**
    - **Scenario 1: Overbridge Modification.** This scenario involves the use of a 400 tonne crane, semi-trailers, generator, concrete saw, jackhammer, concrete truck and concrete pump.
    - **Scenario 2: Piling Works.** This scenario involves the use of a pile boring rig, backhoe, semi-trailer, generator, concrete pump, concrete agitator and franna crane.
- **Work Area 12 – Revesby Station**
    - **Scenario 1: Footbridge and Concourse Construction**. This scenario involves the use of a crane, semi-trailer, generator, concrete saw, jackhammer, concrete truck and concrete pump.

Corridor Earthworks and Track Works

The following three scenarios are representative of typical activities and plant during track works. The duration of noisy work in close proximity to individual receivers will only be a fraction of the overall project duration as the construction works will move progressively along the rail corridor.

- **Scenario 1: Excavation and Compaction.** This scenario involves the widening and modification of embankments and cuttings and general earthworks in preparation for the laying of new track. Typical plant items may include excavators, graders, dump trucks, front end loaders, 5 and 10 tonne vibratory rollers, dewatering pumps and water carts. Construction of new retaining walls and drainage structures will form part of this scenario. It is anticipated that bored piling will be used to form the footings of the retaining walls. Vibratory sheet piling or rock breaking could potentially be required, subject to conditions found on site, but will not be typical activities in this scenario.
- **Scenario 2: Over Head Wiring (OHW) and Signalling.** This scenario involves the installation of over head wire and supporting structures. Typical plant items include an excavator, boring rig, concrete mixer, mobile crane and an elevated work platform.
- **Scenario 3: Track Laying.** This scenario involves the laying of new track. Typical plant items include a work train, track laying machine, a tamper, a ballast regulator, generator, mobile crane, dump truck, rail dump carts and a rail grinder. Under normal conditions, only one of these machines would be operated at a time in the immediate vicinity of any given residence.

6.7 Predicted Construction Noise Levels

6.7.1 Bridge and Station Construction

Typical offset distances between the construction sites and residential receivers range from 20 m to 200 m.

Indicative construction noise levels at representative sensitive receiver locations in the vicinity of bridge and station work sites are shown in **Table 19**. The predicted L_{A10} noise levels at the nearest locations exceed the construction noise goals by clear margins (at some locations by more than 40 dBA). In order to reduce the potential impact of the construction noise emissions, the noise mitigation and management measures in **Section 6.8** should be implemented, where feasible and reasonable.

The highest noise levels are predicted to generally occur during piling works. This is due to the operation of noisier items such as the rock breaker and impact piling rig. These works will generally be limited to daytime use only, including weekend track possessions. Where possible, bored piling will be used in lieu of sheet piling to reduce noise intrusion into the surrounding community. Indicative noise levels at sensitive receiver locations in the vicinity of piling operations are shown in **Table 19**.

Due to the close proximity of residential receivers to the works, the construction noise objectives will be exceeded at many locations along the corridor. This is relatively common on major infrastructure projects, particularly where there is no opportunity to provide a large buffer zone.

It is recognised that such exceedances may be of concern for surrounding residents and particular effort should be directed towards the implementation of all feasible and reasonable noise mitigation and management strategies. For new track sections, construction works will be limited to daytime hours only (unless essential for traffic management or safety reasons) in order to reduce any potential impacts as much as possible.

The fact that noise criteria exceedances have been identified does not necessarily indicate that the works should not proceed, but rather, highlights the importance of managing the works to minimise both the noise levels and duration of the predicted exceedances. Mitigation measures are discussed further in **Section 6.8**.

Table 19 Predicted LA10 Construction Noise Levels – Piling, Bridge and Station Works

Work Area & Scenario	Description of Nearest Receiver Locations to the Proposed Construction Sites	Distance from Site	LA10 Daytime[1] Construction Noise Objective (dBA)	Predicted LA10 Daytime Construction Noise Levels (dBA) [2]
1.1 Beverly Hills Station (City Side) (Bridge Construction)	49 Cahill Street, Beverly Hills	35 m	58	73
	64 Cahill Street, Beverly Hills	40 m		71
	78 Tooronga Terrace, Beverly Hills	50 m		69
2.1 King Georges Road Overbridge, Beverly Hills (Bridge Construction)	141 Morgan Street, Beverly Hills	70 m	58	69
	4-6 Edgbaston Road, Beverly Hills	70 m		73
	Beverly Hills Girls High School	70 m		73
2.2 King Georges Road Overbridge, Beverly Hills (Piling Works)	141 Morgan Street, Beverly Hills	120 m	58	60
	4-6 Edgbaston Road, Beverly Hills	70 m		67
	Beverly Hills Girls High School	60 m		67
3.1 Broad Arrow Road, Narwee (Road) (Bridge Construction)	20 Kardella Crescent, Narwee	40 m	63	75
	23 Bryant Street, Narwee	45 m		72
	39 Broad Arrow Road, Narwee	60 m		71
4.1 Broad Arrow Road, Narwee (Pedestrian) (Bridge Construction)	140 Hannans Road, Narwee	70 m	63	72
	39 Kardella Crescent, Narwee	80 m		69
	42 Broad Arrow Road, Narwee	90 m		68
5.1 Karne Street, Narwee (Piling Works)	1 Karne Street, Narwee	25 m	44	74
	12 Huntingdale Avenue	30 m		73
	2 Ventura Ave, Narwee	10 m		81
6.1 Bonds Road, Riverwood (Bridge Construction)	216A Bonds Road, Riverwood	15 m	56	86
	2A Bonds Road, Riverwood	15 m		84
	68 Josephine Street, Riverwood	35 m		70
7.1 Belmore Road, Riverwood (Bridge Construction)	1 Morotai Avenue, Riverwood	70 m	44	70
	3 Phillip Street, Riverwood	50 m		76
	54 Thurlow Street, Riverwood	40 m		78
7.2 Belmore Road, Riverwood (Piling Works)	1 Morotai Avenue, Riverwood	70 m	44	67
	3 Phillip Street, Riverwood	80 m		65
	54 Thurlow Street, Riverwood	70 m		67
8.1 Webb Street, Riverwood (Road) (Bridge Construction)	40 Lillian Road, Riverwood	50 m	45	74
	91 Webb Street, Riverwood	40 m		76
	95 Webb Street, Riverwood	30 m		77
8.2 Webb Street, Riverwood (Creek) (Bridge Construction)	2 Meager Avenue, Padstow	185 m	45	56
	40 Lillian Road, Riverwood	80 m		63
	95 Webb Street, Riverwood	45 m		70
8.3 Webb Street, Riverwood (Creek) (Piling Works)	2 Meager Avenue, Padstow	175 m	45	75
	40 Lillian Road, Riverwood	90 m		66
	95 Webb Street, Riverwood	70 m		85

Work Area & Scenario	Description of Nearest Receiver Locations to the Proposed Construction Sites	Distance from Site	LA10 Daytime[1] Construction Noise Objective (dBA)	Predicted LA10 Daytime Construction Noise Levels (dBA) [2]
9.1 Davies Road, Padstow (Bridge Construction)	68 Davies Road, Padstow	15 m	50	88
	70 Davies Road, Padstow	30 m		76
	89 Davies Road, Padstow	15 m		87
9.2 Davies Road, Padstow (Piling Works)	68 Davies Road, Padstow	15 m	50	82
	70 Davies Road, Padstow	55 m		71
	89 Davies Road, Padstow	60 m		71
10.1 Padstow Station (Bridge Construction)	32 Alice Street, Padstow	75 m	50	72
	49 Cahors Road, Padstow	65 m		71
	59 Howard Road, Padstow	45 m		74
10.2 Padstow Station (Piling Works)	32 Alice Street, Padstow	110 m	50	63
	49 Cahors Road, Padstow	70 m		69
	59 Howard Road, Padstow	35 m		74
11.1 Doyle Road, Padstow (Bridge Construction)	1 Bradley Street, Padstow	30 m	49	77
	153A Arab Road, Padstow	30 m		79
	93 Doyle Road, Revesby	25 m		75
11.2 Doyle Road, Padstow (Piling Works)	1 Bradley Street, Padstow	55 m	49	67
	153A Arab Road, Padstow	40 m		74
	93 Doyle Road, Revesby	20 m		77
12 Revesby Station (Station Construction)	143 The River Road, Revesby	190 m	46	59
	48 Simmons Street, Revesby	65 m		71
	7 Macarthur Avenue, Revesby	150 m		63

Note 1 Daytime construction noise objectives are presented in this table as most works will occur during this time period. Night-time noise objectives are listed in Table 17 and are typically 10 dBA lower than the daytime objectives. Out of hours works are discussed further in **Section 6.3** and **Section 6.7.6**.

Note 2 Shaded cells indicate a significant exceedance of 20 dBA or more above the daytime LA10 construction noise goal, for receivers surrounding each work site.

6.7.2 Corridor Earthworks and Track Works

The offset distances between the earthworks and track works and the nearest receivers range between 10 m and 190 m.

Noise emissions from the proposed track works, including earthworks, overhead wiring, signalling and track laying will progressively move along the railway corridor in stages, such that most residential receivers will not be exposed to high levels of construction noise emissions for periods longer than approximately one month at a time. Depending on the locations of access points, construction traffic may continue to pass individual receivers for a longer duration.

The construction noise levels in **Table 20** represent the predicted LA10 noise levels during operation of typical plant items.

Table 20 Noise Levels during Corridor Earthworks and Track Construction versus Offset Distance from Receiver Locations

Offset Distance to Receiver (m)	L_{A10} Track Construction Noise Level (dBA)		
	Earthworks [1] (Excavation and Compaction)	Overhead Wiring, Signals and Cable Duct Installation	Track Installation
10	82	80	90
20	79	77	84
30	76	74	81
40	74	72	79
100	66	64	73

Note 1 Rock breakers will generally not be required for excavation works, as the cuttings are predominantly in clay and shale. If required, noise from a rockbreaker would be 10 dBA to 15 dBA higher than predicted for earthworks (Although this may be reduced by shielding if the works are being undertaken at the base of a cutting).

Although some track construction activities will have only a short duration at any given location, the long term criteria have been applied for this assessment, in recognition of the overall duration of the project.

For short periods of time, criterion exceedances of over 20 dBA and up to 40 dBA are likely at the nearest receivers, with the greatest exceedances occurring during the track laying activity. Noise levels during other activities are predicted to be 5 dBA to 10 dBA lower, but may occur over a longer period of time than the track works. In all cases, the predicted noise levels will not be sustained. Lower noise levels will occur when the plant is located away from receivers or is operating on a less noise intensive task.

The fact that noise criteria exceedances have been identified does not necessarily indicate that the works should not proceed, but rather, highlights the importance of managing the works to minimise both the noise levels and duration of exposure. Mitigation measures are discussed further in **Section 6.8**.

6.7.3 On-Site Truck and Vehicle Movements

The maximum (L_{Amax}) noise emission of a typical truck in good condition is in the order of 83 dBA at 7 m. Skidsteer loaders generate similar noise levels. This level applies only when the truck engine is at high load. The $L_{A10(15minute)}$ or average maximum noise levels would always be somewhat lower. Depending on the numbers of trucks operating, their positions and the general intensity of movements, the $L_{A10(15minute)}$ noise levels would be approximately 5 dBA or more lower than the L_{Amax} levels.

Noise sources associated with truck operations also include the short-term noise events of material being dumped into stockpiles or into the trucks. While trucks move about on worksites, nearby receivers tend to associate truck noise emission with that of other construction equipment on the site. Hence, representative truck noise sources have been included in each of the site noise models.

Spoil will be re-used where possible, but precise details of spoil management and re-use plans are not known at this early stage. A Spoil Management Plan will be developed as part of the detailed construction design process, and will also include a Traffic Noise Impact Assessment.

6.7.4 Noise from Construction Traffic on Local Roads

On the local roads immediately adjacent to the site, the community may associate truck movements with the Kingsgrove to Revesby Quadruplication construction works. Once the trucks move onto collector and arterial roads the truck noise is likely to be perceived as part of the general road traffic.

Access to work areas would be provided by the existing vehicle gates along the rail corridor. Some additional access gates may be added where streets or reserves adjoin the rail corridor or some existing gates could be relocated. Construction traffic will be dependent on the active work areas, minimising the number of days of heavy vehicle traffic at each access point.

Where possible, construction traffic will utilise major roads, including King Georges Road, Belmore Road, Davies Road, The River Road and Canterbury Road, however to access most worksites, construction vehicles will need to travel short distances on local roads.

The EPA (now part of DECC) published the Environmental Criteria for Road Traffic Noise 1999 (ECRTN) and are appropriate for assessing road traffic noise. The criteria for arterial, collector and local roads are set out in **Table 21**.

Table 21 DEC Road Traffic Noise Criteria

Development	Day (7.00 am to 10.00 pm)	Night (10.00 pm to 7.00 am)
Land use development with potential to create additional traffic on existing freeways / arterials	$L_{Aeq(15hour)}$ 60 dBA	$L_{Aeq(9hour)}$ 55 dBA
Land use development with potential to create additional traffic on collector roads	$L_{Aeq(1hour)}$ 60 dBA	$L_{Aeq(1hour)}$ 55 dBA
Land use development with potential to create additional traffic on local roads	$L_{Aeq(1hour)}$ 55 dBA	$L_{Aeq(1hour)}$ 50 dBA

Where L_{Aeq} noise levels already exceed the above targets, a 2 dBA increase in the overall traffic noise levels is normally regarded as an alternative target in order to maintain the general acoustic amenity of the area. In order to achieve this, it is necessary for the noise from the additional traffic to be at least 2 dBA below the existing traffic noise level.

Truck Noise Assessment

Table 12.7 of the Environmental Assessment presents an approximate range of truck movements per day at each of the proposed access points. The number of trucks per day at each access point ranges between 1 and 40. Each access point would be subject to construction related traffic for between 6 and 17 months.

During the bulk earthworks stage, the expected maximum number of daily movements would be 40 trucks, or 80 movements assuming that the trucks leave via the same route as which they arrived. A total of 4 to 8 truck movements per hour are expected in busy periods, with lower numbers during quieter periods.

A summary of the predicted noise contribution of these trucks at various offset distances is presented in **Table 22**.

Table 22 Predicted Off Site Truck Noise

Distance	$L_{Aeq(1hour)}$ Sound Pressure Level (dBA)			
	Predicted (Daytime) [2]	Criteria (Daytime) [1]	Predicted (Night-time) [2]	Criteria (Night-time) [1]
10 m	57	55	51	50
20 m	54	55	48	50
30 m	52	55	46	50
40 m	50	55	44	50
50 m	49	55	43	50

Note 1 ECRTN local road criteria as shown in **Table 21**.

Note 2 2 trucks per hour were assumed for the night-time scenario and 8 trucks per hour were assumed for the daytime scenario.

The predictions show that off site truck noise levels would comply with the relevant road traffic noise criteria at offset distances greater than 20 m. Whilst individual truck noise events will be clearly perceptible, the L_{Aeq} assessment indicates that they will not have a major impact on the acoustic amenity of this area.

The following mitigation measures are recommended in order to minimise the risk of exceeding the criteria at residential receiver locations, particularly where the offset distance is 20 m or less:

- All trucks to have mufflers and any other noise control equipment in good working order.
- Truck drivers are to avoid heavy acceleration and braking as far as is practicable.
- Truck drivers are to avoid compression braking as far as is practicable.
- Speed is to be minimised as far as is practicable.
- Truck movements are to be restricted to the daytime period to furthest extent possible.

Noise from idling trucks near construction sites can also impact on amenity in some instances. For this reason, it is recommended that any queuing of trucks awaiting entry to the site outside normal construction hours should be restricted to locations away from residences and that if trucks are required to queue in such locations during construction hours, engines should be shut down. The finalised construction traffic arrangements will be reviewed during the CNVMP assessment.

6.7.5 Increase in Road Traffic Noise Due to Traffic Diversions During Construction

An increase in local traffic volume of 80% corresponds to a noise increase of approximately 2.5 dBA for a given receiver, assuming other factors such as speed and percentage of heavy vehicles remains the same.

The DECC's ECRTN (Environmental Criteria for Road Traffic Noise) recommends that developments creating additional traffic on existing roads should be designed in such a way as to not increase the existing road traffic noise levels by more than 2 dBA.

Table 12.3 of the Environmental Assessment provides a summary of the proposed road closures to occur during the construction program. Also provided is a list of roads to remain open during a particular bridge closure. It is evident that bridge closures would be staged so as minimise the impact on traffic flows to the fullest extent possible.

On this basis and since the predicted traffic volumes are only a temporary increase during construction works, and that in most cases the increase is likely to be much less than 80% (and therefore less than 2 dBA), it is not anticipated that there would be a significant noise impact from the predicted traffic diversions.

6.7.6 Works Outside of Normal Construction Hours

As discussed in **Section 6.3**, there are a number of work activities that will be required to be undertaken outside of normal construction hours.

Where out of hours work is required, the works should be managed to avoid any unnecessary noise emission. Where programming permits, noise intensive activities should be scheduled during the daytime period.

For out of hours work, the more noise intensive activities would potentially exceed the night-time construction goals by significant margins. Activities such as rock breaking, pavement sawing and ballast tamping/regulating should therefore be scheduled during daytime hours, where possible.

The following would need to be undertaken in relation to out of hours work:

- A detailed out of hours noise impact assessment, would be required to be undertaken by the contractor when the specifics of the work type, sites and timing are known.
- Nearby sensitive receivers should be provided with appropriate notice of all out of hours work.
- The noisiest construction activities should take place before 10:00 pm wherever feasible, and the contractor should endeavour to undertake as much preparation work as feasible during the day-time period.
- The identification of feasible and reasonable mitigation measures should be identified and implemented in accordance with TIDC's *Construction Noise Strategy for Clearways Projects*.

6.7.7 Occupational Health and Safety Noise Criteria

There is also a requirement to protect the occupational health and safety (OHS) of passers by, patrons and staff during construction activities for the subject works.

Noise induced hearing loss generally occurs when individuals are exposed to excessive noise levels for extended periods of time (normally several years) or when exposed to extremely loud noise levels for a short period of time.

The Occupational Heath and Safety Regulation 2001 states, in Section 49, that:

(1) An employer must ensure that appropriate control measures are taken if a person is exposed to noise levels that:

(a) exceed an 8-hour noise level equivalent of 85 dB(A), or

(b) peak at more than 140 dB(C).

It is generally possible to maintain construction noise levels below these limits, however the specific measures required to achieve this need to be determined and documented during the process of preparing the Construction Noise and Vibration Management Plan (CNVMP).

6.8 Potential Noise Mitigation

In view of the predicted noise criteria exceedances during construction, noise mitigation is recommended to minimise the impact of construction noise at nearby residential receivers.

It will be necessary for the contractor(s) to prepare and implement a site-specific Construction Noise and Vibration Management Plan (CNVMP) including consideration of the measures listed below and any other initiatives identified to minimise the noise impacts.

- Noise intensive construction works would be carried out during normal construction hours wherever practicable. Where works involving the operating line need to be carried out during track possessions, noise intensive activities should be scheduled to occur during the daytime, where possible.
- Quietest available plant suitable for the relevant tasks would be used.
- The duration of noise intensive activities would be minimised insofar as possible.
- Where feasible and reasonable, site hoardings or temporary noise barriers would be used to provide acoustic shielding of noise intensive activities.
- Rock breakers (if required) would be of the "Vibro-silenced" or "City" type, where feasible and reasonable.
- Activities resulting in highly impulsive or tonal noise emission (eg rock breaking) would be limited to 8 am to 12 pm Monday to Saturday and 2 pm to 5 pm Monday to Friday (except where essential during track possessions).
- Noise awareness training would be included in inductions for site staff and contractors.
- Noise generating plant would be orientated away from sensitive receivers, where possible.
- Notification would be provided to residents via newspaper advertising and letterbox drops, advising of the nature and timing of works, contact number and complaint procedures.
- Noise monitoring would be carried out to confirm that noise levels do not significantly exceed the predictions and that noise levels of individual plant items do not significantly exceed the levels shown in **Table 18**.
- Deliveries would be carried out within standard construction hours, except as directed by the Police or RTA.
- Non-tonal reversing beepers or equivalent would be fitted and used on all construction vehicles and mobile plant regularly used on site and other vehicles where possible.
- Trucking routes to be via major roads, where possible.
- Trucks would not be permitted to queue near residential dwellings with engines running.

As discussed in **Section 6.7.6**, for work outside of normal construction hours:

- A detailed construction noise impact assessment when the specifics of work type, sites and timing are known.
- Council and other stakeholders to be provided with appropriate notice of all out of hours work.
- The noisiest construction activities to take place before 10:00 pm wherever feasible, and endeavour to undertake as much preparation work as feasible in the day-time hours.
- The identification of feasible and reasonable mitigation measures should be identified and implemented in accordance with TIDC's Construction Noise Strategy for Clearways projects.

Where possible, noise intensive construction works during the weekend possessions will be undertaken during the daytime periods, with noise emissions during the night-time period being kept to a minimum, except where activities are critical to meeting programme and restoring rail services.

7 CONSTRUCTION VIBRATION

7.1 Operational Vibration Metrics

The three primary metrics used to describe construction vibration are:

PPV "Peak Particle Velocity" evaluated at the building footings and used to assess the risk of damage to structures.

V_{rms} "Root mean squared vibration velocity", a vibration parameter used to assess human response to continuous or intermittent vibration.

eVDV "Estimated Vibration Dose Value", the overall vibration exposure assessed over the daytime or night-time period to assess human response to intermittent vibration.

7.2 Construction Vibration Goals

The DECC's *"Assessing Vibration: a technical guideline"* is based on the guidelines contained in British Standard BS 6472-1992. BS 6472 refers only to the human comfort criteria for vibration, hence the vibration due to construction has been assessed in accordance with the German Standard DIN 4150 Part 3-1999 and British Standard BS 7385 Part 2-1993. These are the standards normally used for assessing the risk of vibration damage to structures.

For continuous vibration or repetitive vibration with potential to cause fatigue effects, DIN 4150 provides the following PPV values as safe limits, below which even superficial cosmetic damage is not to be expected:

- 10 mm/s for commercial buildings and buildings of similar design.
- 5 mm/s for dwellings and buildings of similar design.
- 2.5 mm/s for buildings of great intrinsic value (eg heritage listed buildings).

For short term vibration events (i.e. those unlikely to cause resonance or fatigue), DIN 4150 offers the criteria shown in **Table 23**. These are maximum levels measured in any direction at the foundation <u>or</u> in the horizontal axes, in the plane of the uppermost floor.

Table 23 DIN 4150 - Structural Damage - Safe Limits for Short Term Building Vibration

Group	Type of Structure	Peak Particle Velocity (mm/s)			
		At Foundation			Plane of Floor of Uppermost Storey
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz [1]	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 at 10 Hz increasing to 40 at 50 Hz	40 at 50 Hz increasing to 50 at 100 Hz	40
2	Dwellings and buildings of similar design and/or use	5	5 at 10 Hz increasing to 15 at 50 Hz	15 at 50 Hz increasing to 20 at 100 Hz	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Lines 1 or 2 and have intrinsic value (eg buildings that are under a preservation order)	3	3 at 10 Hz increasing to 8 at 50 Hz	8 at 50 Hz increasing to 10 at 100 Hz	8

Note 1: For frequencies above 100 Hz the upper value in this column should be used.

These levels are "safe limits", up to which no damage due to vibration effects has been observed for the particular class of building. "Damage" is defined by DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls.

Human comfort is normally assessed with reference to the NSW Department of Environment and Conservation document *Assessing vibration: a technical guideline* which is based on British Standard BS 6472-1992 *Evaluation of human exposure to vibration in buildings (1–80 Hz)*. For daytime activities, the limiting objective for continuous vibration at residential or commercial receivers is V_{rms} 0.4 mm/s.

BS 6472-1992 also contains a formula for the Vibration Dose Value (VDV), which can be used to evaluate intermittent vibration or vibration levels that vary significantly over time. As the vibration approaches continuous, this VDV trends to the continuous vibration criterion.

7.3 Ground Vibration - Safe Working Distances for Intensive Activities

As a guide, safe working distances for typical items of vibration intensive plant are listed in **Table 24**. Safe working distances are quoted for both "cosmetic" damage (refer DIN 4150) and human comfort (refer DECC Guideline).

Table 24 Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating/Description	Safe Working Distance	
		Cosmetic Damage (DIN 4150)	**Human Response (DECC Guideline)**
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

The safe working distances given in **Table 24** are indicative and will vary depending on the particular item of plant and local geotechnical conditions. **Table 24** indicates that exceedances of the structural damage criteria (DIN 4150) may occur if a 13 tonne (or larger) roller or a heavy hydraulic hammer is operated within 20 m to 25 m of a residential building. Monitoring at the commencement of vibratory compaction or hydraulic hammering within 30 m of residential buildings will be required to determine compliance or non-compliance. In the event that non-compliance occurs, immediate corrective action should be taken.

The safe working distances apply to structural damage of typical buildings and typical geotechnical conditions. They do not address heritage structures. Vibration monitoring is recommended to confirm the safe working distances at any such specific sites.

7.4 Assessment of Construction Vibration Impact

It is reasonable to assume that the construction activities will be managed such as to avoid structural damage due to vibration. In order to achieve this objective, the recommended safe working distances in Column 3 of **Table 24** should be observed. If it is necessary to work within these zones, vibration monitoring should be undertaken.

The potential impact would thus be primarily in relation to human response.

As indicated in **Table 8**, several plant items have the potential to have an adverse human response impact at receivers close to construction sites (the closest will be typically 10 m to 15 m from these activities). It is recommended therefore, that where necessary, equipment be reselected to reduce the vibration impact (for example by using a smaller vibratory roller) insofar as possible (without compromising the ability to complete the required task). It is recommended that before the commencement of any vibration intensive works (such as vibratory rolling, pile driving or jackhammer), monitoring be carried out to determine acceptable locations and durations of activities.

Ground vibration levels for vibratory sheet piling are likely to comply with the human comfort criteria at distances exceeding 20 m from a building. Vibration levels vary considerably with ground conditions, and vibratory piles are sometimes used at closer distances without significant vibration impact.

Vibration emissions from impact piling activities, if they are required, should be assessed on a case by case basis.

8 SUMMARY OF MITIGATION MEASURES

The following is a summary of the mitigation measures proposed in relation to the proposal.

Operational Noise (refer Section 4.9)

- Construction of noise barriers at 30 sub-catchment locations, varying in height from 1.0 m to 4.0 m. The noise barrier locations are illustrated in **Appendix B** and summarised in **Table 15**.
- Building treatments in the form of alternative ventilation should be considered at 51 locations (see **Appendix I**) to allow residents to close their windows if desired in order to maintain a satisfactory internal noise environment. Details of specific Development Approval requirements for the dwellings identified in **Appendix I** will be investigated by TIDC as part of the detailed design and hence the number of locations requiring building treatments cannot be finalised until this additional information is obtained. Noise measurements may also be undertaken at specific receivers prior to confirming offers of building treatments.
- There are an additional 5 locations representing schools or other noise sensitive non-residential buildings (see **Appendix I**) that should be considered for building treatments to allow occupants to close the windows if desired in order to maintain a satisfactory internal noise environment.
- The feasibility of constructing concrete bridges should be investigated by TIDC as part of the detailed design process.
- A decrease in L_{Amax} and L_{Aeq} noise levels over time can be expected as older rollingstock (such as R-Set and S-Set suburban trains) are retired.

Operational Vibration (refer Section 5)

- At two locations (see **Section 5.6**) resilient ballast mat should be considered on the near track in order to mitigate future vibration levels.

Construction Noise (refer Section 6.8)

- Preparation of site-specific Construction Noise and Vibration Management Plans, including management and monitoring actions.
- Noise minimisation, including use of the quietest suitable plant, site hoardings, respite period when undertaking noise intensive works.
- During possessions, noise intensive activities should be scheduled to occur during the daytime, where possible.
- Duration of noise intensive works to be minimised.
- Community to be advised of the times and durations of noise intensive works and complaint procedures.
- Noise monitoring will be carried out to confirm that noise levels do not significantly exceed the predictions and that noise levels of individual plant items do not significantly exceed the levels shown in **Table 18**.
- Deliveries will be carried out within standard construction hours, except as directed by the Police or RTA.
- Non-tonal reversing beepers or equivalent must be fitted and used on all construction vehicles and mobile plant regularly used on site and other vehicles where possible.
- Trucking routes to be via major roads, where possible.
- Trucks will not be permitted to queue near residential dwellings with engines running.

Construction Vibration (refer Section 7.3 and 7.4)

- Establish buffer zones and limit work within these zones to activities that have been assessed as safe or to activities undertaken in conjunction with strict vibration monitoring.
- Select smallest suitable size of vibratory roller when working close to occupied and heritage buildings to minimise vibration impact.

9 CONCLUSIONS

The purpose of this report is to assess the potential noise and vibration emissions during construction and operation of the proposal. Based on the proposed rail alignment, this report identifies the principle areas where noise or vibration mitigation is considered likely to be required. Detailed barrier optimisation has been undertaken to determine feasible and reasonable mitigation for the proposed operation.

At source noise mitigation measures include continuous welded rail, grinding of new rail to remove mill scale and provide the correct rail profile, and concrete bridges constructed for all new underbridges within the proposal area.

In order to assess the operational noise impacts, computer noise modelling was undertaken for the existing rail operations (Year 2006) and the future rail operations resulting from the proposal ten years after completion (Year 2021).

Compared with the existing situation, the number of residential locations exceeding the overall noise trigger levels in Year 2021 is predicted to increase from 46 to 161 on the Down Side of the track and from 46 to 156 on the Up Side of the track as a result of the proposal.

On the basis of the calculated future noise levels, the predicted increase in L_{Aeq} noise levels at the nearest receivers as a result of the proposal (without mitigation) would be typically 5 dBA in every hour. Similarly, at most locations, the predicted increase in L_{Amax} noise levels as a result of the proposal would be typically 4 dBA. The increase in L_{Aeq} and L_{Amax} noise levels results from the proposed increase in train speeds on the new lines and the reduced offset distance between the new tracks and receiver locations.

As well as the increase in noise levels, the overall level of railway noise also has an influence on the potential noise impact at sensitive receiver locations. On the basis of the predicted future noise levels, the total number of receivers likely to be "annoyed" would increase from approximately 160 to 320, and the total number of receivers likely to be "highly annoyed" would increase from approximately 60 to 120 as a result of the proposal.

On this basis, it is concluded that without mitigation, the percentage of the population "annoyed" or "highly annoyed" by railway noise would be doubled as a result of the project and the consideration of noise mitigation measures to maximise the protection of the environment is warranted.

On the basis of the operational noise trigger levels provided in the *"Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects"* (NSW Government – April 2007), residential and other noise sensitive receivers predicted to exceed the trigger levels have been identified. At these locations, detailed noise barrier design has been conducted and 30 noise barriers have been proposed with a total barrier length of 6,850 m.

At locations where noise barriers are considered to be cost-effective, compliance with the overall noise trigger levels is achieved at the majority of residential receiver locations. At locations where noise barriers are not cost effective or where the proposed barriers are not high enough to achieve significant reductions at the upper levels of residential buildings, building treatments may need to be considered.

Overall, the number of noise sensitive receiver locations exceeding the overall noise trigger levels of L_{Amax} 85 dBA and daytime $L_{Aeq(15hour)}$ 65 dBA in Year 2021 is predicted to be reduced from 161 to 33 on the Down Side of the track and from 156 to 36 on the Up Side of the track as a result of the proposed noise barriers, compared to Year 2021 without any mitigation. It should be noted that this is a slight decrease in trigger level exceedances compared to the existing Year 2006 scenario and building treatments are to be considered at residual locations.

Of the 69 residual trigger level exceedances, on the basis of site observations 13 of these receivers are located within recently constructed developments and a further 5 of these receiver locations are school or community centre buildings. On that basis building treatments may need to be considered at the remaining 51 residual receiver locations.

At this early stage in the assessment process, other factors including community views, overshadowing (due to noise barriers), aesthetic impacts and the wider community benefits of the proposal have not been assessed to the same level of detail. The proposed mitigation measures are indicative only and may change as more detailed project information becomes available and consultation with affected stakeholders occurs.

The reduction in distance to receivers is likely to increase the vibration levels at residential buildings on both the Down side and Up side of the railway corridor. On the basis of measurements undertaken as part of the proposal and proposed alignment of the new track, future vibration levels at two locations are predicted to exceed the vibration dose-based vibration trigger levels. Resilient ballast mat on the near track at each location in order to mitigate future vibration levels.

Construction noise modelling has been undertaken for nineteen different scenarios across a total of twelve major work areas covering activities that are planned to occur during the nominated two and a half year construction programme.

At the majority of locations, the predicted L_{A10} construction noise levels will at times exceed the noise goals when plant and equipment is located in close proximity to residential, educational and commercial receiver locations. This results from the small offset distances, rather than particularly noisy construction plant.

The mitigation measures in **Section 6.8** will be undertaken to minimise potential noise and vibration impacts.