Appendix V Noise and Vibration Management Plan

MORLEY-ELLENBROOK RAIL LINE

PART 2 MALAGA TO ELLENBROOK

Noise and Vibration Management Plan

Prepared for:

Public Transport Authority
PO Box 8125
PERTH BUSINESS CENTRE WA 6849

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BASIS OF REPORT

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
675.11323-R05-v1.0	10 June 2020	Steven Walker	Luke Zoontjens	Luke Zoontjens

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1 Introduction

The Public Transport Authority (PTA) is developing the Morley-Ellenbrook Line (MEL) project which involves the operation of passenger rail services between Bayswater and Ellenbrook. The MEL project is being delivered in two parts; Part 1 is between Bayswater Station and Malaga Station and Part 2 between Malaga Station and Ellenbrook Station.

The operation of the new rail services, along with supporting road transport infrastructure and public transport assets are a potential source of new and additional transport noise and vibration within the local environment. This document details the Noise and Vibration Management Plan (NVMP) for the management of transport noise and vibration associated with Part 2 of the MEL, specifically the operations of the passenger rail main lines between Morley Station and Ellenbrook Station.

The NVMP has been developed in accordance with *State Planning Policy 5.4 Road and Rail Transport Noise* (SPP5.4) and will be administered as a supporting document for the future plan of transport operations.

1.1 Aims

The aims of this NVMP are to

- Identify receptors potentially sensitive to noise and vibration emissions associated with the operation of the MEL;
- Determine the primary noise and vibration sources from operation of the MEL;
- Establish performance objectives and environmental criteria for the management of noise and vibration in accordance with SPP 5.4;
- Document the reasonable and practicable measures required to reduce and control noise and vibration emissions in accordance with the adopted performance objectives and environmental criteria;
- Provide a procedure for reviewing and auditing performance with respect to noise and vibration emissions from operation of the MEL, including response actions should there be legitimate complaints or adverse comment to excessive noise and/or vibration; and
- Document the actions and responsibilities for the implementation of the NVMP.

1.2 Structure

This document has been structured as follows:

- **Section 1** provides a description of the new infrastructure and the operational noise and vibration aspects addressed by this Plan;
- **Section 2** details the assessment criteria and guidelines that have been adopted for the management of noise and vibration impacts;
- **Section 3** describes the locations of sensitive receptors;
- **Section 4** presents a summary of the results from the Part 2 noise and vibration impact assessment;
- **Section 5** identifies reasonable and practicable measures for mitigating airborne noise and vibration from rail operations and transport infrastructure and communication procedures;
- **Section 6** details the persons responsible for implementing the requirements of the NVMP; and
- **Section 7** details the noise and vibration monitoring methodology.

1.3 Overview of the MEL project (Malaga to Ellenbrook)

The MEL project involves the operation of passenger rail services on approximately 21 kilometres (km) in length with passenger rail services within approximately 8 km of existing railway corridor between Bayswater and Malaga and a newly constructed rail corridor, approximately 13 km in length, between Malaga and Ellenbrook.

This NVMP applies to 'Part 2' which involves

- Rail operations servicing the new Malaga, Whiteman Park and Ellenbrook stations; and
- Bus loops, road vehicles and car parking associated with the stations above.

The key infrastructure and transport operations covered by the NVMP include:

- Passenger rail services between Malaga and Ellenbrook;
- Future changes in road alignment and traffic movements on Lord Street and Drumpellier Drive and the major intersections associated with these two roads;
- Car parking areas and vehicle movements at the train stations; and
- New and upgraded bus loops for the new stations at Malaga, Whiteman Park and Ellenbrook.

An overview of the MEL project is provided in **Figure 1** in **Section 3** based on information supplied to date.

1.4 Referenced documentation

The preparation of this plan has referenced the documents in **Table 1** to determine the following key aspects:

- identification of sensitive receptor communities along the alignment;
- establishing criteria for the management of noise and vibration from the operation of the rail services and associated transport assets; and,
- modelled noise and vibration levels with the operation of rail services on Part 2 of the MEL;
- recommendations for management and mitigation of transport noise and vibration emissions; and
- guidelines for the monitoring of and reporting of noise and vibration levels.

Table 1 Referenced documentation

Document	Application in the NVMP
Western Australia State Planning Policy 5.4, Road and Rail Transport Noise 2019 (Western Australian Government, 2019)	Noise and vibration performance objectives and environmental criteria and the requirements for the preparation of the NVMP.
Morley-Ellenbrook Line – Noise and Vibration Assessment Report – Malaga to Ellenbrook (SLR Consulting Australia, 2020)	Identification of sensitive receptors, modelled noise, vibration and ground-borne noise emissions from transport operations and in-principle management and mitigation measures.
Standards Australia 2018, AS 1055: *Acoustics – Description and measurement of environmental noise*. (Standards Australia, 2018)	Guidelines for the equipment and technical specifications for the measurement of environmental noise.
Standards Australia 2002, AS 2377: *Acoustics – methods for the measurement of railbound vehicle noise*. (Standards Australia, 2002)	Guidelines for the equipment and technical specifications for the measurement of railway noise emissions.

1.5 Acoustic terminology

Terms considered important to understanding the technical noise and vibration aspects relating to this Plan are defined in **Table 2**

Table 2 Acoustic terminology

Term	Description
Railway noise	
Airborne noise	The term 'noise' is defined as unwanted sound but is commonly used when discussing all sound within our environment. In this report the term 'noise' refers to all sound pressure levels irrespective of whether it would be defined as 'unwanted'. The most common form of noise experienced by people is termed 'airborne noise', indicating that it propagates between the source and receptor primarily through the air.
Railway noise	For railways, airborne noise emissions are caused by the rolling contact of the wheels on the rails, the train engines and discrete events such as braking noise, curve squeal or impact noise from rail discontinuities such as turnouts, crossovers, joints or rail defects which can increase the level of wheel-rail noise.
Decibels	Noise levels are measured and assessed in terms of decibels (dB). When assessing impacts to people noise levels are filtered (weighted) to the normal human response to loudness perceived by the ear. This is referenced as the A-weighted scale and is denoted with a subscript 'A'. The subscript 'A' indicates that the noise levels are filtered to match normal human hearing characteristics (i.e. A-weighted).
L_{Aeq} noise parameter	The 'energy average noise level' evaluated over a defined time period. The L_{Aeq} can be likened to a noise dose representing the cumulative effects of all the noise events occurring in the relevant time period.
L_{Amax} noise parameter	The maximum LAeq value measured during each train passby using a time interval of one second.
Railway vibration	
Railway vibration	Railway vibration is generated by dynamic forces at the wheel-rail interface and will occur, to some degree, even with smooth wheel and rail contact surfaces. Significantly higher vibration levels can occur due to design and/or maintenance factors such as rail and wheel surface irregularities and discontinuities (e.g. joints or defects). This vibration propagates via the sleepers or rail mounts into the ground or track support structure. It then propagates through the ground into buildings and is then felt as perceptible vibration (or audible noise).
Perceptible vibration	The thresholds of perceptible vibration are much lower than the levels of vibration likely to cause cosmetic damage to buildings and structures. In most cases where ground vibration levels are within levels to avoid impacts to human comfort (disturbance) structural impacts to buildings and structures will be prevented.
L_{Vmax}	the "Maximum Vibration Level" occurring during a train passby event. This is normally defined as the maximum root-mean-square (RMS) vibration level during the train passby averaged over a one second interval. The vibration level is here expressed in dB re 10^{-9} m/s.
Ground-borne noise	
Ground-borne noise	Railway generated vibration entering a building causes the walls and floors to vibrate and radiate noise which can sometimes be audible often with a low frequency 'rumbling' characteristic audible (commonly termed "ground–borne noise" or "regenerated noise"). Although ground-borne noise may be produced in many cases, the noise may pass unnoticed due to the "masking" effect of airborne noise from trains and other nearby activities.
L_{Amax}	The metric applied in the prediction and assessment of ground-borne noise from transport projects is the L_{Amax}. The A-weighted maximum noise level occurring during a pass-by noise event (measured using the 'slow' response setting on a sound level meter).

1.6 Key acoustic considerations

Key elements considered within this NVMP are comprised of the following:

- **Airborne noise**. The major sources for airborne noise emissions from the proposed new rail line include passenger rail operations and some sources near or within proposed train stations, including vehicle movements (within bus loops, kiss and ride areas and carparks), mechanical plants, public address systems and crowd noise etc. Noise from the proposed passenger rail operations is considered as the prime element for the airborne noise assessment, as the proposed rail operations are expected to dominate noise emissions within the rail reserve along the entire alignment;
- **Ground-borne vibration (GBV).** Due to close proximity to existing residential properties from some sections of the proposed new rail alignments, there could be potential for excessive floor vibrations within adjacent residences;
- **Regenerated/ground-borne noise (GBN).** Regenerated noise or ground-borne noise (GBN) and low frequency noise are now widely recognised noise problems and are commonly perceived as vibration due to its low frequency characteristics. Although these elements are not clearly specified within the current state policy framework in Western Australia, there are well developed applicable objectives that have been used in some other states in Australia and internationally; and
- **Existing noise and vibration environment.** To assess the level of impact in relation to noise and vibration impacts as a result of the MEL, the existing environment has been characterised by reviewing available data collected in previous surveys.

2 Transport noise and vibration objectives

The following subsections detail the adopted operational noise and vibration assessment objectives.

2.1 Airborne noise

The table below outlines the adopted noise objective levels for the project in regard to airborne noise during road and rail operations. The objectives are being applied as triggers for the investigation of reasonable and practicable mitigation measures for the control of airborne noise on MEL.

Table 3 Project transport operations noise objectives

Type of development	Objective	Value(s) (Note[1])	Basis
Operations – Noise Generally (N1)	Noise levels from rail operations will be managed as low as is reasonably practicable.	demonstrated	SPP5.4
New Operations – Airborne Noise Target (N2)	Noise mitigation must be provided where the noise level is above this value.	$L_{Aeq,day}$ 55 dB $L_{Aeq,night}$ 50 dB L_{Amax} 80 dB	SPP5.4, L_{Amax} best practice

Note 1 'Demonstrated' means the objective is achieved to the satisfaction of the approval authority. Values are referenced to 20 microPascals (dB re 20µPa)

The airborne noise objectives in **Table 3** are assessed outdoors, 1 metre (m) from the main building on a lot associated with a noise sensitive usage. By achieving these objectives, the intent is to achieve acceptable indoor noise levels in noise sensitive areas (for example, bedrooms and living rooms of houses, and school classrooms) and a reasonable degree of acoustic amenity for outdoor areas appropriate to the land usage.

The objectives are intended to be assessed at all floor levels where identified from surveys, noting that the amount of mitigation to achieve the objectives may not be reasonable or practicable at higher floors.

2.2 Ground-borne vibration

Table 4 presents objectives for ground borne vibration (GBV) and noise (GBN) during operation. Where vibration levels are predicted to be above these objectives, the project will consider the use of reasonable and practicable controls to achieve compliance.

Table 4 Project rail operations GBV and GBN objectives

Parameter	Objective[1]	Value (Note[1])	Basis
Rail Operations – Generally	Vibration levels from rail operations will be managed as low as is reasonably practicable.	demonstrated	Industry best practice
Rail Operations Building Vibration Trigger Level	The level not exceeded by 95% of train passby events, measured at a reasonably representative location of the building occupancy		AS2670.2:1990 ISO2631 ASHRAE[2] guidelines NSWRING
	Medical clinical treatment, surgery or recovery areas, or facilities operating precision equipment	'Curve 1' ($L_{v,RMS,1s}$ ~100dB)	
	Residential and hotel accommodation	'Curve 2' ($L_{v,RMS,1s}$ ~106dB)	
	Commercial premises, Public buildings, Churches and community centres and the like	'Curve 4' ($L_{v,RMS,1s}$ ~112dB)	
	Light and general industrial buildings	'Curve 8' ($L_{v,RMS,1s}$ ~118dB)	
Rail Operations Regenerated Noise/GBN Trigger Level	Mitigation of vibration via ground or structural pathways must be considered where the Rail Operations Regenerated Noise Trigger Level is exceeded as applicable to the 95^{th} percentile train passby event and measured at centre of reasonably representative interior space(s) of each building usage.		Historical Perth transport projects NSWRING
	Residential and hotel accommodation, 10pm to 6am	L_{ASmax} 35dB	
	Residential and hotel accommodation, 6am to 10pm	L_{ASmax} 40dB	
	Commercial buildings, Public buildings, Churches and community centres and the like	L_{ASmax} 45dB	
	Retail and point of sale areas	L_{ASmax} 50dB	
	Occupiable light and general industrial buildings	L_{ASmax} 50dB	

Note 1 'Demonstrated' means the objective is achieved to the satisfaction of the approval authority.

1 Vibration objectives are referenced to 1nm/s (dB re 1nm/s), use the subscript 'v' and are assessed on the basis of 1 second root mean square (RMS) values.

2 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc (ASHRAE), 2011 ASHRAE Handbook - Heating, Ventilating, and Air-Conditioning APPLICATIONS - SI Edition, Atlanta GA http://www.ashrae.org.

3 Noise and Vibration Sensitive Receptors

3.1 Overview

Receptors that are potentially sensitive to noise and vibration from transport are defined from the relevant policy and guidelines, including; residential dwellings, commercial and industrial buildings and 'other' sensitive uses which can include educational institutions, childcare centres, medical facilities and places of worship.

The nearest sensitive receptors for the assessment of noise and vibration on the Malaga to Ellenbrook alignment were identified from geospatial datasets, previous noise and vibration assessments and aerial imagery. Accordingly, the assessment has focused on the nearest sensitive receptors adjacent to the Project as the potential requirements for noise and mitigation will be determined by the noise and vibration levels at the nearest sensitive receptors.

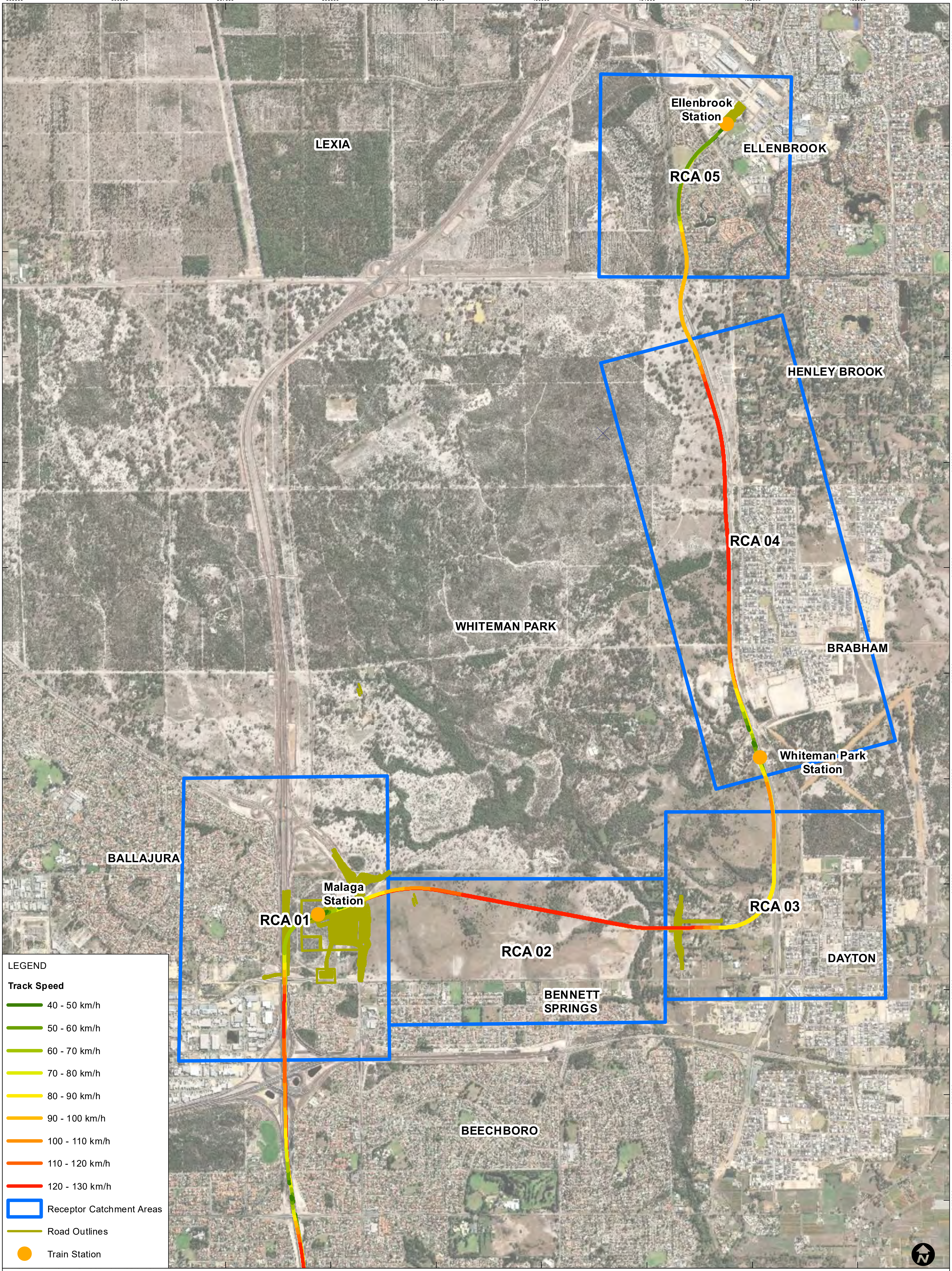
3.2 Receptor catchment areas (RCA)

All sensitive receptors have been assigned to receptor catchment areas (RCA) to assist the assessment and interpretation of potential noise and vibration impacts. In this way, receptors within each catchment area are equitably assessed based on the local environment and transport noise and vibration, both prior to and with the Project in operation. The catchment areas are described in **Table 5** and presented in **Figure 1**. Each area was developed with consideration to.

- The expected ambient noise environment at the sensitive receptor communities adjacent to the Project alignment;
- The grouping of sensitive receptors communities, including the suburban populations and where individual receptors are more widely distributed on larger lots or landholdings; and
- The proximity of sensitive receptors to the railway alignment.

Table 5 Receptor Catchment Areas

ID	Area	General description
RCA 01	Malaga	An area approximately 500 m either side of the proposed alignment at Malaga which includes a mix of residential, commercial and light industrial land uses. The local noise environment at the nearest sensitive receptors to the Project is expected to be influenced by road traffic on Hepburn Avenue and the local commercial/ light industrial premises.
RCA 02	Bennett Springs	The sensitive receptors to the south of the Project alignment would be influenced by local road traffic on Marshall Road. To the north of Marshall Road, the environment is less populated with individual receptors on larger land holdings. Based on the distance to Marshall Road, the noise environment would be less influenced by road traffic noise.
RCA 03	Bennett Springs – Dayton	The suburbs of Bennett Springs and Dayton are separated by Drumpellier Drive (New Lord Street) and Lord Street. The area approximately 500 m either side of the Proposed alignment adjacent to Drumpellier Drive is expected to be influenced by road traffic on the new and existing road network.
RCA 04	Brabham	To the north of Dayton, the relatively new residential communities in Brabham have sensitive residential receptors adjacent to Drumpellier Drive and Lord Street. In these locations the road traffic noise is expected to be the dominant influence on the noise environment at the receptors nearest to the Project. The catchment area includes the land where the current masterplans could be extended with new property developments.
RCA 05	Ellenbrook	At Ellenbrook, the nearest sensitive receptors to the alignment are adjacent to Drumpellier Drive until the region around Santona Boulevard where the alignment diverges within the residential community. In this area the noise environment adjacent to the alignment would be influenced by road traffic on Drumpellier Drive.



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Drawn by:	(PW)
Reviewed by:	(PW)

Data Source:
ESRI Basemaps

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Max Track Speed & Receptor Catchment Areas

FIGURE 1

4 Assessment Results

4.1 Railway noise

The assessment of airborne rail noise undertaken for the preliminary design was based on a preliminary design that did not include specific measures for the control of railway noise, for example at-source mitigations or rail noise barriers/ walls. This was defined as the 'Build" scenario in the assessment.

Results indicate that the rail noise target objectives would be met at the majority of sensitive receptors. **Table 6** presents a summary of the 'Build' scenario results – it indicates that the L_{Aeq} and L_{Amax} targets may be triggered at up to 89 individual sensitive receptors.

The assessment included conceptual noise mitigation options to review the ability for reasonable and practicable mitigations to achieve the target levels. This was defined as the 'Build+M' scenario and the summary outcomes are provided in **Table 6**.

Table 6 Airborne noise forecast results summary

Aspect[1]	Target[2]	Build, 2041 (no mitigation)	Build+M, 2041 (including mitigation)
Item N2 of **Table 3** New Operations – Airborne Noise Target	$L_{Aeq,day}$ 55 dB	61 (15%) up to 11 dB above target	2 (1%) up to 1 dB above target
	L_{Amax} 80 dB	89 (22%) up to 16 dB above target	19 (5%) up to 3 dB above target

Note 1 Definitions are provided in **Section 2.1**.

Note 2 Residential premises only. Note there may be multiple dwellings at the same address or similar noise levels at properties further away from (e.g. not adjacent to) the rail reserve which are not represented in this table.

From the assessment it has been determined:

- Without the consideration of noise mitigation ('Build' scenario), the airborne noise target levels are triggered by up to 16 dB at sensitive receptors adjacent to the alignment in RCA03, RCA04 and RCA05.
- With mitigation measures in place ('Build+M' scenario), the assessment determined:
  - Airborne rail noise levels are reduced to achieve the target levels at the majority of sensitive receptors. The performance of noise walls depend on position and height, but are modelled to typically provide around 5 dB of noise reduction, increasing to 10 dB in some areas;
  - Up to 21 sensitive receptors may experience residual airborne noise levels above the target level, these receptors are located within RCA04 and RCA05; and
  - Where noise levels may remain above the target levels, without further consideration of mitigation, the target levels are triggered by 1 to 3 dB, which is still a reduction of 10 to 13 dB.

4.2 Road transport and Station noise

The potential airborne noise levels associated with the MEL road transport assets, in particular road realignment works, were modelled for the preliminary design. In summary, the assessment determined:

- Environmental noise from stations, bus loops and car parking areas are considered to be compliant with the criteria listed, due to the relatively large separation distances to nearby residential areas;
- The realignment of Gnangara Road away and upward from Ellenbrook residences may not be considered to be a major upgrade of a road under SPP5.4 and its guidelines. mitigation be required to achieve such targets in SPP5.4, options for achieving However, should compliance with the alignment modelled are:

  - Road noise walls of the order of 2.4m in height located near the northern edge of carriageway, and/or;
  - Adoption of quieter road surfaces such as Open Graded Asphalt over Stone Mastic Asphalt as modelled; and;
- No specific noise mitigation is recommended for Beechboro Road North under application of SPP5.4. All other roads were not considered to trigger SPP5.4 policy for further consideration, particularly where they are already existing and not proposed to be significantly altered as a result of the project.

4.3 Vibration

The potential GBN and GBV levels associated with passenger rail services were forecast for the preliminary design. Similar to the assessment of airborne noise, the modelling considered the 'Build" scenario which did not contain specific measures to control GNB and GBV and a 'Build+M' scenario which investigated conceptual options for reasonable and practicable mitigations.

The outcomes of the assessment are summarised in **Table 7**. Where conceptual mitigations were included in the modelling, the number of triggers was substantially reduced to just 15 premises with expectation that detailed design of mitigation could achieve the target levels at all receptors.

Table 7 Forecast GBV and GBN modelled results – 'Build', 'Build+M' scenarios (271 receivers)

Usage	Aspect	Objective[1]	'Build' scenario (no mitigation)	'Build+M' scenario (with mitigation)	Expected outcome
Residential	Ground-borne vibration (GBV)	$L_{v,RMS,1s}$ 106 dB	48 up to 11 dB above objective	1 at 1 dB above objective	OK
	Ground-borne noise (GBN)	L_{Amax} 35 dB	114 up to 15 dB above objective	15 up to 5 dB above objective	Review during detailed design
Non-residential (Commercial/ Industrial)	Ground-borne vibration (GBV)	$L_{v,RMS,1s}$ 112 to 118 dB	1 at 4 dB above objective	All within target level	
	Ground-borne noise (GBN)	L_{Amax} 45 to 50 dB	2 up to 4 dB above objective	All within target level	

Note 1 Refer Table 4.

From these tables it can be seen that as a result of the proposal:

- Without mitigation, 48 residences are predicted to exceed relevant investigation GBV trigger levels by up to 11 dB, and they are distributed near RCA03 (Dulwich Street, Rugby Street), RCA04 (Brabham), and RCA05 (Ellen Ponte Vecchio Boulevard, Valinco Avenue in Ellenbrook);
- With mitigation measures in place ('Build+M' scenario);
  - The number of properties above GBN investigation trigger levels reduces from 114 to 16 and the maximum difference reduces from 15 dB to 5 dB. Of these, several properties in RCA04 are forecast up to 5 dB above relevant targets and the remainder are in RCA05 and these are within prediction uncertainty of the GBN target; and
  - The number of properties above GBV investigation trigger levels reduces from 48 to 1 and the maximum difference reduces from 11 to 1 dB.
- Note that these estimates include emissions from other activities or transport infrastructure outside the scope of MEL which limit the project's ability to achieve any specific limits.

5 Management Measures

The following measures are proposed to be implemented on Part 2 of the MEL project as part of the overall strategy for the management and control of noise and vibration associated with transport operations. These measures are subject to detailed design considerations and feedback from the community and project stakeholders.

5.1 Engineering Controls

The PTA commits to achieving the adopted transport noise and vibration targets as far as is reasonable and practicable to do so via the use of various engineering controls. The detailed assessment of noise and vibration considered reasonable and practicable mitigation options as part of the 'Build+M' scenario.

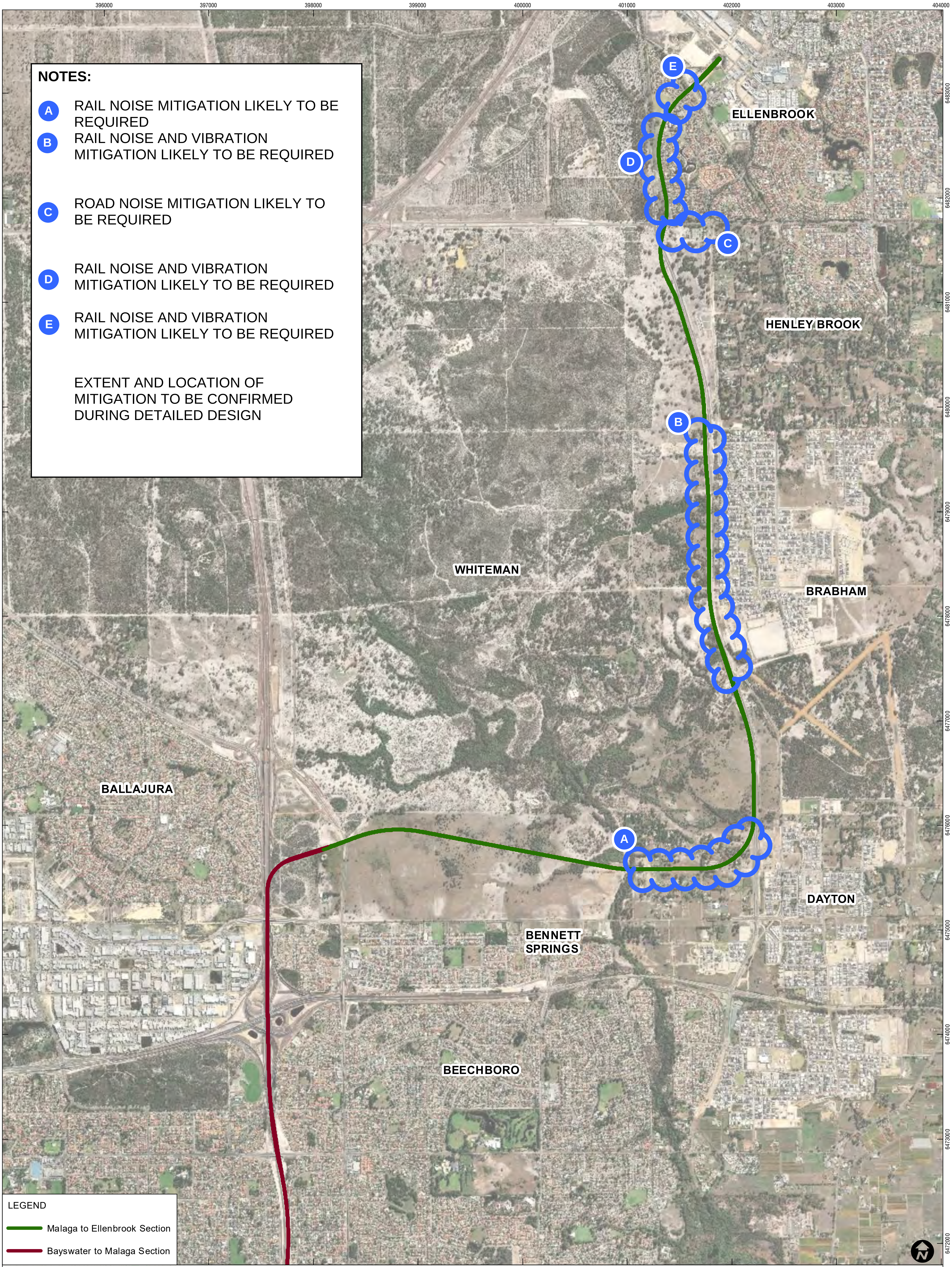
Subject to detailed design, they may include

- noise walls at the boundary of the rail lines to screen noise;
- optimisation of the design to minimise risk for aspects such as curving noise; and
- implementation of under ballast matting (UBM) for the control of GBN and GBV.

The anticipated localities where noise and vibration mitigation is considered likely is presented in **Figure 2**. Final mitigation measures will be determined based on revised modelling of the final design to be prepared by the construction contractor. This NVMP will be reviewed by the PTA once final mitigation measures are confirmed.

5.2 Track Maintenance

The PTA will undertake rail maintenance to reasonably maintain the operational performance of the relevant railway infrastructure and reduce wear to trains. This will involve regular inspection of the rail condition and rail rectification / grinding to remove excessive roughness or corrugation which may develop over time.



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Indicative Mitigation Proposed

FIGURE 2

5.3 Post commissioning verification

The PTA, in co-ordination with the construction contractor, will implement a program of noise and vibration measurements are proposed to be undertaken as part of project commissioning. The purpose of the measurements are to

- Quantify the rail noise and vibration emissions from the daytime and night-time rail operations and determine the noise and vibration levels at the most affected sensitive receptors;
- Assess the Project's compliance with SPP 5.4 relating to noise and vibration emissions from the operation of the MEL;
- Provide an assessment of the effectiveness of any noise and vibration management and mitigation measures implemented on the Project; and
- Identify, if required, further reasonable and practicable noise and vibration mitigation measures to meet the objectives of SPP 5.4.

Given that airborne noise and vibration emissions are controlled by the roughness of rail and wheel running surfaces, measurements should involve a reasonably large number of passbys (to average out wheel condition and train operational factors) and be undertaken at times where the track is not in an unusual state (say from fresh rail rectification.

5.3.1 Airborne noise

Monitoring is proposed with the following timeframes to verify the project has achieved the airborne design objectives:

- Within three months of the commencement of operations, a time after which rail condition of track is considered representative of typical best case; and
- Within 15 months from commencement of operations, a time period over which the track condition may have degraded.

These are indicative timeframes and should be reviewed to ensure the monitoring occurs during rail operations representative of the forecast capacity operations post the commission phase.

At least six (6) monitoring locations will be established at locations reasonably representative of the communities in each area. Subject to accessibility, monitoring is proposed to be undertaken at selected residential properties or public spaces adjacent, in accordance with the methodology outlined in **Section 7.2**.

Additional locations may be used at the PTA's option, depending on feedback from residents once operations have commenced.

5.3.2 Ground vibration

Ground vibration levels will be monitored in parallel with the noise monitoring. Vibration levels will be monitored in accordance with the methodology in **Section 7.3**, following the principles outlined in Section 7 of ISO 14837.1:2005, preferably on the nearest external foundation or lower external wall of a vibration sensitive building, or at a reasonably equivalent interim point of observation with appropriate adjustments.

5.3.3 Corrective actions

Where the above monitoring determines that a specific objective will not be reliably achieved, the steps to review and implement further reasonable and practicable mitigation will include:

- Identifying the locations where the criteria may be exceeded and to what degree;
- Confirming the noise/vibration reduction performance of the mitigation implemented;
- Quantifying the change in noise and/or vibration levels upon commissioning of the project;
- Determining the number of residents affected and severity profile;
- Identifying the key noise sources contributing to the exceedances;
- Undertaking a review of reasonable and practicable mitigation measures available to further reduce and control noise and/or vibration levels; and
- Where reasonable and practicable to do so, implementing additional mitigation.

5.4 Communications

5.4.1 Local authorities

It is expected that local authorities will be provided with scheduled maintenance activities. Local authorities will be notified if significant changes to the scheduled works occur. Emergency works required to address issues of safety or to recommence services may occasionally occur without notice to local authorities. Where possible, notification of noisy emergency works will be provided to local authorities retrospectively to assist in addressing resident complaints.

5.4.2 Community engagement

The PTA has initiated an extensive community engagement program, including the provision of information on likely noise and vibration impacts from the project via the METRONET website www.metronet.wa.gov.au.

As required, information will be routinely updated to inform the community as the project commences construction and as the railway is commissioned. The PTA has also committed to consulting with residents regarding the heights, extents and aesthetics of the noise walls, once final railway design is complete.

Copies of monitoring reports, data or outcomes of complaint investigations may be made available to residents upon specific request where appropriate.

5.5 Complaint Management Procedures

Detailed below are the measures to be implemented in the event a complaint or adverse comment to airborne noise, ground vibration or ground-borne noise is received directly or indirectly by PTA.

5.5.1 Administrative procedures

Requests for information and complaints will be directed to the PTA's Infoline telephone number 13 62 13 or via the comments section at www.pta.wa.gov.au[3]. All calls and emails will be logged and a response provided within 5 days of receipt.

[3] http://www.pta.wa.gov.au/about-us/complaints-and-comments

5.5.2 Investigation

The PTA will investigate all noise and/or vibration complaints received by:

- Investigating the operations at the time of the complaint;
- Substantiated or widespread complaints will be investigated as follows;
- An appropriate number of short-term measurements will be undertaken to accurately determine the cause of substantiated complaint/incidents and to determine how to rectify the situation;
- Review any unattended (logged) noise levels relevant to the complaint or incident;
- Where appropriate, reviewing any immediate measures that could be implemented to address the nature of the complaint;
- File an incident report; and
- Where appropriate, supply a response in writing within 10 working days of the complaint.

6 Responsibilities

The responsibility for carrying out the requirements of this NVMP are detailed in **Table 8**.

Table 8 Management responsibilities

Management commitment	Description	Responsibility
Noise Mitigation Measures	The identification and implementation of mitigation measures	PTA Project Director
NMP requirements	Implementing the NMP requirements	All PTA personnel
Notification to Local Authorities	Notifying local authorities of works programs	PTA Environmental Manager
Notification to Residents	Notifying residents	PTA (operations) and Construction Contractor (construction)
Complaint Response	Taking complaints	PTA Comment line
Noise and vibration measurements	Undertake noise measurements	PTA Environmental Manager
Complaint Follow-up	Following up complaints and informing complainant of actions	PTA
Monitoring of Complaints	Monitoring of complaint numbers and trends to identify common causes for proactive management	PTA Environmental Manager

7 Monitoring Methodology

The following monitoring methodologies provide a recommended approach to the monitoring of airborne noise and ground vibration from future train operations. The methodology may need to be adjusted subject to the specific requirements of each monitoring event.

In accordance with SPP5.4, all monitoring will be conducted by a suitably qualified and experienced acoustic engineer or consultant.

The monitoring of noise and vibration will be undertaken in accordance with the following Standards and guidelines where relevant:

- SPP5.4 guidelines;
- Sound levels meters and noise loggers shall be Class 1 certification as defined in Australian Standard AS IEC-61672.1-2004;
- Sound level meters or noise loggers must be calibrated before and after measurement periods using a calibrator, suitable for a Class 1 instrument, which complies to AS IEC-60942-2004;
- For monitoring ground vibration refer to Australian Standards; AS 2670, AS 2775 and International Standard ISO 14837-1;
- Monitoring guidelines for airborne noise from railways is contained in Australian Standard AS 2377; and
- Monitoring guidelines for ground-borne noise from railways is contained in ISO 14837-1.

7.1 Monitoring approach

The monitoring of noise and vibration should be undertaken with consideration to the following:

- Provide a monitoring strategy consistent with the requirements of relevant acoustic standards and guidelines for monitoring environmental and transport noise and vibration;
- Plan and schedule the monitoring surveys with consideration to:
  - The rail movements during each daytime and night-time period. The survey period shall include the days during which the highest number of train movements would be expected;
  - At locations free from localised buildings and structures (other than noise barriers) that may screen or reflect noise;
  - The condition of the rails and other rail infrastructure; and
  - Weather conditions during the monitoring periods;
- Monitoring should be conducted at the sensitive receptors with the potential for the highest received noise and vibration levels from rail operations;
- Monitoring will be undertaken over a minimum period of seven days at each monitoring location; and
- If the noise and/or vibration levels are above the applicable criteria at any sensitive receptors, allowing for any monitoring and compliance tolerances, the key sources of rail noise and contributing factors (e.g. rail defects, excessive rail roughness levels, turnouts, locomotive engine exhausts) shall be identified to inform the investigation of reasonable and practicable mitigation measures.

7.2 Airborne noise monitoring

Noise monitoring will be in accordance with SPP5.4 guidelines. Locations are proposed to be

- Where the microphone is set at a height of 1.2 to 1.5 m above ground level;
- At 1 m from the most affected building façade adjacent to the rail corridor. Otherwise, the nearest accessible location to the building façade shall be utilised as the monitoring location to best determine the received noise level at the buildings;
- At reasonably representative positions of the receiver with any appropriate adjustments; and
- Free from interference from extraneous sources such as road traffic or air-conditioning units.

The monitoring of airborne noise levels will require:

- Noise loggers shall be deployed at all locations to continuously monitor noise levels for one-week period during standard operations;
- Noise levels to be monitored with the sound level meter and/or noise logger(s) on the 'Slow' response setting;
- Monitoring with sound level meter(s) will include measurement of one-third octave band noise levels to assist the analysis of noise characteristics;
- The L_{Aeq}, L_{Amax}, L_{A1}, L_{A10} and L_{A90} noise metrics are to be monitored at each location;
- When monitoring train passby events it is recommended that the 1-second sound pressure levels or 1-second L_{Aeq} levels are monitored to clearly isolate the contribution from each passby event;
- The monitored noise levels are to be reported in tabular format clearly identifying the time, date and location of each measurement; and
- To assist the identification of rail passby events from the ambient noise environment, audio recordings may accompany the long-term noise monitoring subject to approval from residents.

7.3 Ground vibration monitoring

Due to the complex interactions with the local ground conditions and structures, it is preferential to monitor ground vibration levels at the receptor rather than an intervening location between the receptor and the rail corridor.

Vibration levels are to be monitored at the most affected façade(s) / room(s) of the buildings or reasonably representative equivalent position(s) with suitable adjustments.

8 Review of the NVMP

This plan is to be reviewed upon completion of the final design for construction, and annually following this to ensure the management and monitoring requirements of the NVMP remain relevant to the ongoing noise and vibration emissions from the operation of MEL and the feedback from the community.

APPENDIX A

Glossary of Terms

1. Sound Level or Noise Level

The terms 'sound' and 'noise' are almost interchangeable, except that 'noise' often refers to unwanted sound. Sound (or noise) consists of minute fluctuations in atmospheric pressure. The human ear responds to changes in sound pressure over a very wide range with the loudest sound pressure to which the human ear can respond being ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or LP are commonly used to represent Sound Pressure Level. The symbol LA represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2. 'A' Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an 'A-weighting' filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing. People's hearing is most sensitive to sounds at mid frequencies (500 Hz to 4,000 Hz), and less sensitive at lower and higher frequencies. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dB or 2 dB in the level of a sound is difficult for most people to detect, whilst a 3 dB to 5 dB change corresponds to a small but noticeable change in loudness. A 10 dB change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels.

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (e.g. B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as 'linear', and the units are expressed as dB(lin) or dB.

3. Sound Power Level

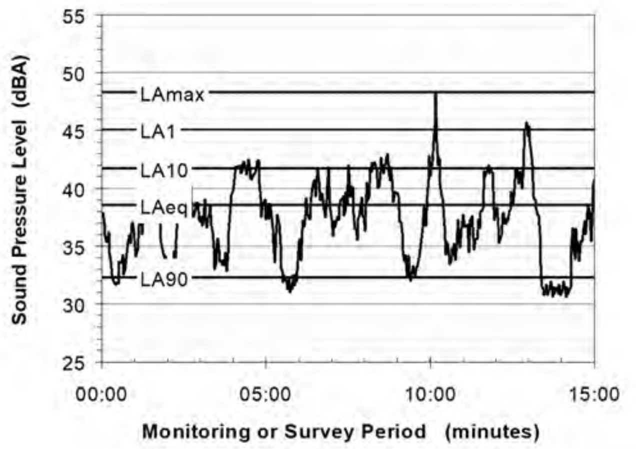
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or LW, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure is like the effect of an electric radiator, which is characterised by a power rating but influences the surrounding environment that can be measured in terms of a different parameter, temperature.

4. Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels LAN, where LAN is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the LA1 is the noise level exceeded for 1% of the time, LA10 the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of relevance, are:

LA1 The noise level exceeded for 1% of the 15 minute interval.

LA10 The noise level exceeded for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

LA90 The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

LAeq The A-weighted equivalent noise level (basically, the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

5. Frequency Analysis

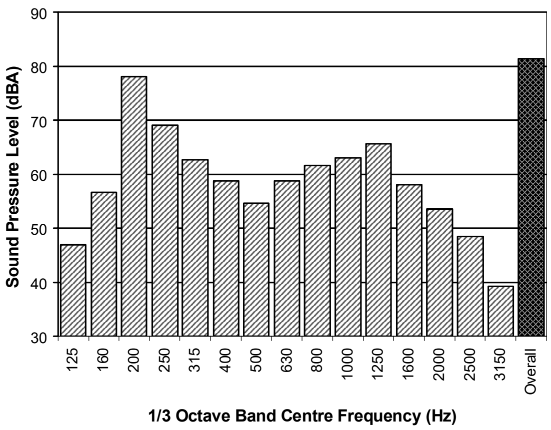
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (three bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



6. Annoying Noise (Special Audible Characteristics)

A louder noise will generally be more annoying to nearby receivers than a quieter one. However, noise is often also found to be more annoying and result in larger impacts where the following characteristics are apparent:

- Tonality - tonal noise contains one or more prominent tones (i.e. differences in distinct frequency components between adjoining octave or 1/3 octave bands) and is normally regarded as more annoying than ‘broad band’ noise.
- Impulsiveness - an impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.
- Intermittency - intermittent noise varies in level with the change in level being clearly audible. An example would include mechanical plant cycling on and off.
- Low Frequency Noise - low frequency noise contains significant energy in the lower frequency bands, which are typically taken to be in the 10 to 160 Hz region.

7. Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of ‘peak’ velocity or ‘rms’ velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as ‘peak particle velocity’, or PPV. The latter incorporates ‘root mean squared’ averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements (i.e. vertical, longitudinal and transverse).The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated.

A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/Vo), where Vo is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used.

8. Human Perception of Vibration

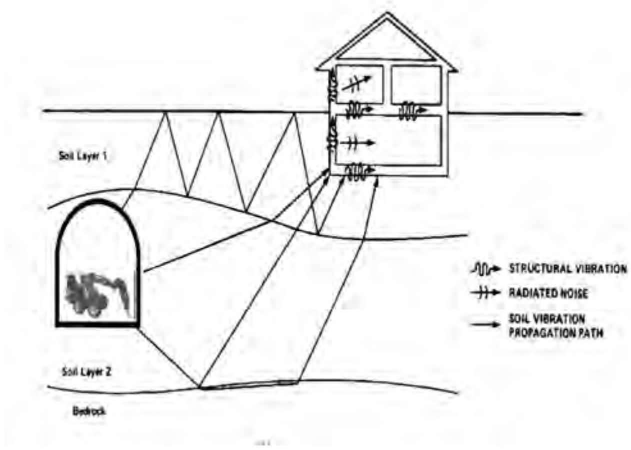
People can ‘feel’ vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience 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.

9. Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed ‘structure-borne noise’, ‘ground-borne noise’ or ‘regenerated noise’. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (e.g. rockbreakers), and building services plant (e.g. fans, compressors and generators).

The following figure presents an example of the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel. Similar effects exist even for surface construction and deep excavation works.



The term ‘regenerated noise’ is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise.

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