Appendix S Noise and Vibration Assessment Report – Malaga to Ellenbrook

MORLEY-ELLENBROOK LINE

Noise and Vibration Assessment Report
Malaga to Ellenbrook

Prepared for:

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BASIS OF REPORT

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
675.11323-R03-v1.0	11 June 2020	Steven Walker	Luke Zoontjens	Luke Zoontjens

EXECUTIVE SUMMARY

The Morley-Ellenbrook Line (MEL) project (the Project) involves the operation of passenger rail services between Bayswater and Ellenbrook. The MEL between Bayswater and Ellenbrook is approximately 21 kilometres (km) in length with passenger rail services within approximately 8 km of the existing railway corridor and the Tonkin Highway transport corridor between Bayswater and Malaga and a newly constructed rail corridor, approximately 13 km in length, between Malaga and Ellenbrook.

The introduction of the project will lead to a shift in transport noise and vibration emissions in its vicinity. This document presents a desktop assessment of the future noise and vibration levels for the new rail line proposed between Malaga and Ellenbrook. The assessment considers the noise and vibration from the future passenger rail services, road upgrades, bus loops and car parking associated with the new stations proposed at Malaga, Whiteman Park and Ellenbrook.

Key findings - noise

The MEL is a potential source of future transport noise from passenger rail services and the associated road upgrades and station infrastructure to support bus movements. To manage potential transport noise emissions associated with the project, noise targets have been adopted based on State Planning Policy 5.4: Road and Rail Noise (SPP5.4), industry guidelines and relevant past projects.

In regard to forecast airborne noise levels from rail operations between Malaga and Ellenbrook;

- The predicted rail noise levels at the nearest receptors to the alignment in Bennett Springs, Brabham and Ellenbrook trigger a detailed investigation of reasonable and practicable measures to reduce noise levels with an objective of achieving the target noise levels.
- The transport noise targets adopted from SPP5.4 are predicted to be achieved at the majority of residential receptors without the requirement for specific mitigation measures. Prior to specific noise mitigation;
  - 61 receptors (approximately15% of those facing the railway) are forecast to be up to 11 B above the daytime noise target.
  - 70 receptors (approximately 17% of those facing the railway) are forecast to be up to 12 dB above the night-time noise target.
- Noise levels from the road assets and stations associated with the Project are expected to achieve the relevant noise assessment criteria at nearest receptors.
- To control rail noise levels the Project is likely to require the implementation of noise mitigation measures such as noise walls within the rail corridor, rail web dampers and/or at Ellenbrook, sound absorptive panels to control reflected sound within the dive structure. Modelling shows that the SPP5.4 targets can be practicably achieved through a combination of such treatments.

Whilst road and railway noise from the Project is assessed separately under SPP5.4, there is potential for combined transport noise to adversely impact the ambient noise environment at the nearby residential communities. The assessment has identified scenarios where road and rail noise has the potential to result in a cumulative increase to ambient environment at Malaga and between Dayton and Ellenbrook where the NorthLink WA and new Lord Street/Drumpellier Drive road projects have recently been completed.

Key findings – vibration

The pass-by of trains can generate vibration that may be perceptible at nearby residential receptors. To assess and manage the potential for disturbance the assessment has adopted targets for ground-borne vibration and ground-borne noise (rumbling noise produced by vibration of internal building surfaces).

In regard to forecast vibration levels from MEL rail operations,

- The ground-borne noise and vibration levels are expected to be achieved at sensitive receptors greater than 100 m from the alignment.
- There are 48 sensitive receptors where potential ground-borne vibration levels were calculated to exceed the ground-borne vibration objective by up to 11 dB. At 114 sensitive receptors the calculated ground-borne noise levels exceed the ground-borne noise objective by up to 15dB.
- To control ground-borne noise and vibration levels consistent with the adopted assessment criteria, the design may require the application of suitable under ballast matting and/or under sleeper pads with suitable trackform. Generally, such controls if correctly specified and implemented (noting they have already been installed on other sections of the Perth network) can achieve at least a 10 dB reduction in vibration levels, so compliance with recommended vibration investigation trigger levels is considered reasonably practicable.

Recommendations

Based on the outcomes of the assessment, the following are recommended to be considered during the detailed design and construction of the MEL:

- Conduct further assessment of noise and vibration associated with the operation of the Project to verify the outcomes of this assessment.
- As-required, review and optimise the mitigation and control measures discussed in this report.
- Prepare and implement a Noise and Vibration Management Plan for the operation of the Project.
- Undertake consultation with community stakeholders where there may be specific concerns over noise and/or vibration impact.

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1 Introduction

1.1 Project overview

The Morley-Ellenbrook Line (MEL) project (the Project) involves the operation of passenger rail services between Bayswater and Ellenbrook. The new railway line will serve Perth's north-east suburbs to support existing communities with improved public transport connections and create new transit-oriented developments at station precincts. There will be ultimately seven passenger stations on the route to connect communities in Morley, Noranda, Malaga, Bennett Springs, Whiteman Park and Ellenbrook.

The Project is approximately 21 kilometres (km) in length with passenger rail services within approximately 8 km of existing railway and Tonkin Highway transport corridors between Bayswater and Malaga and a newly constructed rail corridor, approximately 13 km in length, between Malaga and Ellenbrook.

The Project design has been developed in response to environmental, engineering and social constraints. The design objectives were to minimise environmental impacts, minimise disturbance to existing infrastructure and utilities and meet the engineering design criteria. The key components of the Project include:

- Approximately 21 km of rail line for passenger services between seven stations.
- For integrated public transport there will be provision for new bus loops, including 'kiss and ride' areas.
- Bridges and viaducts so the route can traverse existing infrastructure and the local rail and road networks.
- The upgrade and re-alignment of local road networks at Beechboro Road North and the intersection of Gnangara Road and Drumpellier Drive.
- The constructions of structures, such as embankments and cuttings, to maintain the required level of the rail tracks, particularly in the sections of newly constructed rail line.
- Ancillary works including road and public utility crossings and realignments, signage and fencing and provision of services within the corridor.

1.2 Railway noise and vibration assessment report

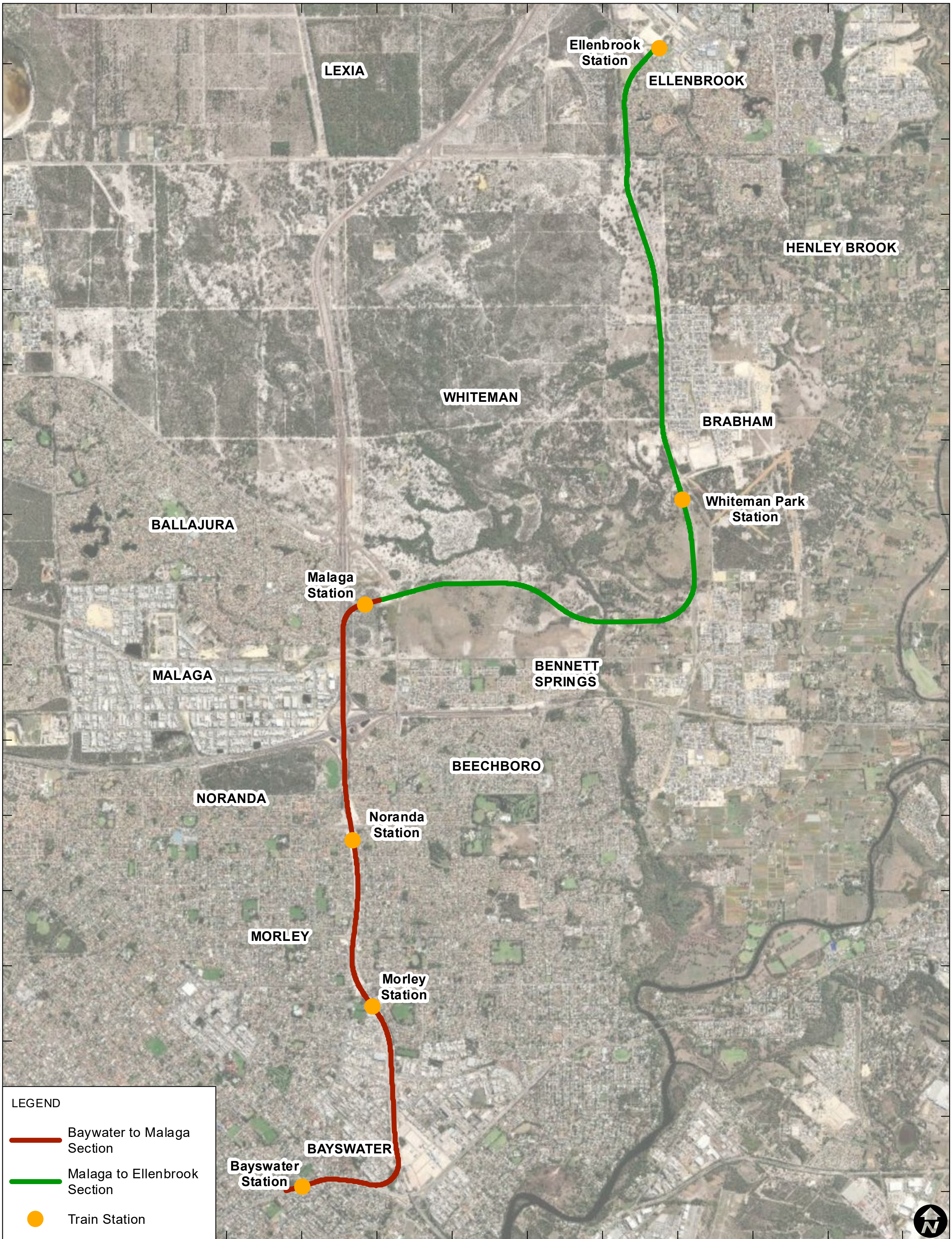
The operation of passenger rail services and associated infrastructure on the Project is a source of noise and vibration that could impact sensitive receptors and the surrounding environment. The preliminary designs for the Project have been subject to desktop assessment of noise and vibration emissions to inform the reasonable and practicable control of noise and vibration from the operation of the Project.

For the purpose of assessing noise and vibration the Project is considered in two Parts:

- Part 1: Rail operations between Bayswater Station and Malaga Station; and
- Part 2: Rail operations between Malaga Station and Ellenbrook Station.

An overview of the indicative Project alignment and its relationship to the assessment is detailed in **Figure 1**.

This report focuses on the operational rail and road noise and vibration impacts for Part 2 between Malaga Station and Ellenbrook Station.



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SLR

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0 1 2 km

Coordinate System:	GDA 1994 MGA Zone 50
Scale:	1:65,000 at A4
Project Number:	(675.11323)
Date:	19-May-2020
Drawn by:	(PW)
Reviewed by:	(PW)

Data Source:
ESRI Basemap

WESTERN AUSTRALIA PUBLIC TRANSPORT AUTHORITY

Alignment of the Proposed Morley to Ellenbrook Line

FIGURE 1

This report prepared by SLR Consulting Australia (SLR), on behalf of the Public Transport Authority (PTA), provides an assessment of noise and vibration associated with Part 2:

- 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 associated with the new stations at Malaga, Whiteman Park and Ellenbrook.

The report also discusses potential impacts with regard to:

- The influence of noise and vibration from road and rail traffic upon the amenity of the environment, referencing the Environmental Protection Authority (EPA) Social Surroundings Guideline[1]; and,
- Commentary on potential cumulative road and rail transport noise and the potential change in ambient noise levels adjacent to the Project.

1.3 Report limitations

The findings of this report are based on the preliminary railway and road designs and may change as the Project design progresses. Should the final design or conditions vary from the basis of this assessment, noise and vibration levels and associated impacts may vary from the findings presented in this report.

Preliminary mitigation measures for railway noise and vibration have been presented in this assessment based on the adopted assessment criteria, identified sensitive receptors and the forecast noise and vibration emissions associated with the proposed future railway operations of the Project.

As the Project progresses through its detail design and construction phases, a final set of mitigation measures will be developed. This is expected to require further assessment of railway noise and vibration and the monitoring of railway noise and vibration as part of the project delivery.

[1] Environmental Protection Authority, 2016. Environmental Factor Guideline – Social Surroundings, dated 13 December 2016.

2 Review of legislation and guidelines

The following table outlines the proposed noise and vibration assessment framework for this project.

Table 1 Morley-Ellenbrook Line Noise and Vibration Assessment Framework

Aspect / Source	Statutory / Government Policy	Australian / International Standards	Industry best practice / SLR recommendation
Operational environmental noise			
Airborne noise from trains, rail operations	SPP5.4[2] EPA EFG Social Surroundings[3]	-	SPP5.4 NSWRING[4]
Road vehicle movements (scheduled roads)			SPP5.4
Car parking areas, bus loops, kiss and ride areas	EPNR1997[5]	EU Parking Area Noise 2007[6]	EPNR1997
Station mechanical ventilation plant Crowd noise Public address systems Outdoor driver communications		AS2107:2016[7]	
Operational vibration effects			
Ground-borne vibration (GBV) from rail operations	-	AS/ISO 2631.2:2014[8] BS 6472:2008 ISO 14837[9]	AS 2670.2:1990[10] NSWRING NSW DEC Guidelines[11] ASHRAE 2011[12] FTA guidelines[13]
Ground-borne noise (GBN) ('regenerated noise') noise from rail operations	-	-	NSWRING

These aspects are discussed further in the following subsections.

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[2] Western Australia State Planning Policy 5.4, Road and Rail Transport Noise 2019 ("SPP5.4", "The Policy").
[3] Environmental Protection Authority 2016, Environmental Factor Guideline: Social Surroundings, EPA, Western Australia. Available from http://www.epa.wa.gov.au/policies-guidance/environmental-factor-guideline-social-surroundings
[4] New South Wales Rail Infrastructure Noise Guideline, NSW EPA, May 2013.
[5] Western Australia Environmental Protection (Noise) Regulations 1997 ("EPNR1997", "The Regulations") as amended under the *Environmental Protection Act 1986* (EP Act).
[6] Bayer, Landesamt für Umwelt 2007, *Parking Area Noise - Recommendations for the Calculation of Sound Emissions of Parking Areas, Motorcar Centers and Bus Stations as well as of Multi-Storey Car Parks and Underground Car Parks*, Bayerisches Landesamt für Umwelt, Parkplatzlämstudie 6, Aufl., August 2007.
[7] Australian/New Zealand Standard 2107:2016 'Recommended design levels and reverberation times for building interiors'.
[8] AS ISO 2631.2:2014 Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Vibration in buildings (1 Hz to 80 Hz).
[9] International Standard ISO 14837-1 2005 "*Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General guidance*".
[10] Australian Standard AS 2670.2 1990 "*Evaluation of Human Exposure to Whole Body Vibration - Part 2: Continuous and Shock Induced Vibration in Buildings (1 Hz to 80 Hz)*".
[11] Department of Environment and Conservation NSW, "Assessing Vibration: a technical guideline" (2006) http://www.environment.nsw.gov.au/resources/noise/vibrationguide0643.pdf
[12] American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2011, HVAC Applications – SI Edition, Chapter 47.
[13] Federal Transit Administration 2006, Transit Noise and Vibration Impact Assessment, Report FTA-VA-90-1003-06.

2.1 Airborne railway noise targets

Sound from operation of the Project as experienced by nearby residents is here termed 'airborne noise', assuming the sound is by default not wanted and travels via air pathways only.

In Western Australia (WA), airborne noise from new or major upgrades of roads and railways is addressed in State Planning Policy 5.4[14] (SPP5.4), which is administered under Part Three of the *Planning and Development Act 2005*[15].

SPP5.4 provides outdoor noise level targets for the management of transport noise at sensitive receptors and land-uses. At the planning stage, the Project is applying the SPP5.4 rail noise targets in **Table 2** as non-mandatory criteria. Where rail noise levels are above the targets, the Project will investigate reasonable and practicable mitigation measures with the aim of reducing noise levels to meet the targets and minimising potential noise impacts at sensitive receptors and land-uses.

The railway noise targets are specific to the daytime period of 6.00 am to 10.00 pm and the night-time period of 10.00 pm to 6.00 am. The noise targets are lower for the night-time period due to the greater sensitivity of communities to noise during the night. There are different targets for new railways and for upgrading existing railway infrastructure; the targets for new railways are 5 dB lower (more stringent) based on the assumption that noise mitigation can be more readily implemented on newly constructed sections of railway infrastructure.

In addition to the SPP5.4 noise targets, as part of a review of best practice, the Project has also considered rail noise targets from other railway noise guidelines in use within Australia, in particular the NSW Rail Infrastructure Noise Guideline[16] (NSW RING).

Table 2 Railway noise level targets

Type of development	Policy/ reference	Daytime period average	Night-time period average	Maximum passby level per period
New railway	SPP5.4	$L_{Aeq,day}$ 55 dB (6.00 am – 10.00 pm)	$L_{Aeq,day}$ 50 dB (10.00 pm – 6.00 am)	None prescribed
New rail line development	NSW RING	$L_{Aeq,(15hr)}$ 60 dB (7.00 am – 10.00 pm)	$L_{Aeq,(9hr)}$ 55 dB (10.00 pm – 7.00 am)	L_{ASmax} 80 dB (for 95% of events)
Existing railway	SPP5.4	$L_{Aeq,day}$ 65 dB (6.00 am – 10.00 pm)	$L_{Aeq,day}$ 60 dB (10.00 pm – 6.00 am)	None prescribed
		Practicable noise management and mitigation measures should be considered […] having regard to: • the existing transport noise levels; • the likely changes in noise emissions resulting from the proposal; and, • the nature and scale of the works and the potential for noise amelioration.		
Redevelopment of an existing rail line	NSW RING	Development increases existing $L_{Aeq(period)}$ rail noise levels by 2 dB or more, or existing L_{Amax} rail noise levels by 3 dB or more And; predicted rail noise levels exceed:		
		$L_{Aeq,(15hr)}$ 65 dB (7.00 am – 10.00 pm)	$L_{Aeq,(9hr)}$ 60 dB (10.00 pm – 7.00 am)	L_{AFmax} 85 dB (for 95% of events)

[14] Department of Planning, Lands and Heritage, 2019. Stage Planning Policy 5.4 – Road and rail noise, 6 September 2019.
[15] Western Australia Government, 2020. Planning and Development Act 2005, as of 1 May 2020.
[16] NSW Environmental Protection Authority, 2013. Rail Infrastructure Noise Guideline, May 2013.

The noise targets are assessed outdoors at 1 m from the main building on a lot associated with a noise sensitive use. Consistent with SPP5.4, they are assessed at ground level locations and, in this report, at all floors where identified from surveys.

The maximum (L_{Amax}) noise parameter is often applied to evaluate the potential for impacts such as disturbance as a result of potential short-lived high noise levels that may occur during train passbys. Whilst the SPP5.4 does not specifically prescribe L_{Amax} noise level targets for rail noise, a L_{Amax} 80 dB noise target has been adopted by the Project to inform the assessment of railway noise and the investigation of reasonable and practicable mitigation measures at the design stage.

The adopted L_{Amax} 80 dB noise target is comparable to maximum noise level targets from current railway noise guidelines in Australia, such as the NSW RING which has been referenced in **Table 2**.

2.2 Airborne road traffic noise targets

The Project includes provision of new bus loop services connected with the new stations. There will also be requirements to upgrade parts of the local road network to provide access to the new stations and to accommodate the newly constructed rail corridor, including major upgrade works to Gnangara Road.

To assess the potential noise impacts associated with future road traffic the Project has adopted the noise targets from SPP5.4, as detailed in **Table 3**.

Table 3 Road traffic noise target levels

Type of development	Policy/ reference	Daytime period average	Night-time period average
Road transport	New	$L_{Aeq,day}$ 55 dB	$L_{Aeq,night}$ 50 dB
	Upgrade	$L_{Aeq,day}$ 60 dB	$L_{Aeq,night}$ 55 dB

Source State Planning Policy 5.4 (SPP5.4).

2.3 Airborne noise from the new stations

The airborne noise targets discussed above are specific to the Project's transport infrastructure. The potential noise emissions from road vehicle movements not on public roads, car parking, community noise from passengers and public address systems have been assessed in accordance with the Western Australian Environmental Protection (Noise) Regulations 1997[17] (EPNR).

The EPNR is subordinate legislation administered under the Western Australia *Environmental Protection Act 1986* (EP Act). To achieve compliance, noise levels at nearby noise sensitive receptors are not to be above specific noise limits, in the form of Assigned Noise Levels. The Assigned Noise Levels are provided in **Table 4**.

The levels are determined with the consideration of 'Influencing Factors' (IF), which account for the amount of commercial, industrial and road transport infrastructure within specific distances to the noise sensitive receptors. The assessment has conservatively adopted an IF of +6 dB for residential receptors within 100 m of the Tonkin Highway and an IF of +2 dB for residential receptors located within 100 m of the other local road networks adjacent to the MEL alignment.

[17] Government of Western Australia, 1997. Environmental Protection (Noise) Regulations 1997.

Table 4 Indicative Assigned Noise Levels

Type of receptor	Time of day	Assigned Noise Level[1], dB		
		LA10	LA1	LAmax
Sensitive receptors	7.00 am to 9.00 pm Monday to Saturday	45-51	55-61	65-71
	9.00 am to 9.00 pm Sunday and public holidays	40-46	50-56	65-71
	7.00 pm to 10.00 pm all days	40-46	50-56	55-61
	10.00 pm on any day to 7.00 am Monday to Saturday and 9.00 am Sunday and public holidays	35-41	45-51	55-61
Commercial premises	All hours	60	75	80
Industrial and utility premises	All hours	65	80	90

Note 1 This is the Assigned Noise Level conservatively ignoring any industrial or commercial zoning nearby but is inclusive of the Transport Factor with a lower limit of 0 dB (e.g. no state-significant roads nearby) and upper limit of 6 dB (e.g. within 100 m of major road being over 15,000 vehicles per day).

The EPNR also requires the noise level adjustments in **Table 5** to be considered where the noise levels at the sensitive receptors may include characteristics that could cause disturbance, such as tonality, modulation or impulsiveness.

Table 5 Adjustments for intrusive noise characteristics

Adjustment to noise emission levels at the sensitive receptors (cumulative up to a maximum of 15 dB)		
Where tone(s) are present	Where modulation is present	Where impulsiveness is present
+5 dB	+5 dB	+10 dB

2.4 EPA Social Surroundings guideline and management of cumulative noise

The stated objective of the EPA Social Surroundings guideline listed in **Table 1** is to protect social surroundings from significant harm. Examples of 'social surroundings' adjacent to a development include the general amenity of residential and recreational areas.

In this regard, the Social Surroundings guideline requires consideration of the risk of increased and ongoing exposure to operational noise and vibration for sensitive receptors in residential and recreational areas in close proximity to the railway and associated infrastructure.

However, the EPA's Social Surroundings Guideline does not specify noise and vibration criteria or numerical targets which could be used to judge what is unreasonable in this regard. Furthermore, the noise targets in SPP5.4 do not make specific reference to cumulative noise levels, combined noise from the proposal with existing transport infrastructure or the road and rail transport noise associated with the delivery of the Project.

The guidelines accompanying SPP5.4 state that 'reasonable' mitigation proposals, as part of a noise management plan, do need to consider existing and future noise levels, including changes in noise levels. However, mitigation is considered only in response to situations where target levels are not likely to be met.

This assessment has investigated the potential impacts associated with cumulative transport noise, however this is based on a semi-quantitative assessment of overall transport noise only. At worst, if the noise levels for road traffic and rail traffic components are independently achieved to the same level, the overall noise level could be up to 3 dB greater than the individual contributions. In terms of noise impacts, a 3 dB increase in noise can be considered as not being a perceptible change in loudness where the character of the noise sources are similar.

2.5 Ground-borne vibration

Railway vibration is generated by dynamic forces at the interface of the rail and train wheels. The resultant vibration from ground-level track can be transmitted into adjacent buildings via the intervening ground. If the levels of vibration are sufficiently high, then this vibration can be felt as tactile vibration by the occupants of nearby buildings.

People can perceive floor vibration at levels well below those likely to cause damage to buildings or their contents. Accordingly, the vibration criteria applied to manage potential impacts to human comfort at residences are usually the most stringent and it is generally not necessary to set separate criteria for vibration effects on typical building contents and structures.

The Project has adopted the ground-borne vibration levels in **Table 6** to assess and manage potential impacts from railway induced ground-borne vibration. The target levels were developed with reference to guidelines including the NSW RING and British Standard BS 6472 and the now withdrawn Australian Standard AS 2670.2:1990.

Table 6 Ground-borne vibration trigger levels (intermittent vibration)

Place/ usage	Time period	Preferred[1]	Maximum[1]
Critical working areas (e.g. hospital operating theatres, precision laboratories)	Day or night	0.10 mm/s (100 dB)	0.20 mm/s (106 dB)
Residences	Day	0.20 mm/s (106 dB)	0.40 mm/s (112 dB)
	Night	0.14 mm/s (103 dB)	0.28 mm/s (109 dB)
Offices	Day or night	0.40 mm/s (112 dB)	0.80 mm/s (118 dB)
Workshops	Day or night	0.80 mm/s (118 dB)	1.60 mm/s (124 dB)

Note 1 These values are assessed as one second root-mean-square (RMS) vertical values at the internal floor midspan of a vibration sensitive space. The dB values are referenced to 1 nm/s

The preferred night-time floor vibration goal is $L_{V,RMS,1s}$ 103 dB, with a maximum of $L_{V,RMS,1s}$ 109 dB. To provide assessment of ground-borne vibration consistent with previous rail projects within the Perth metropolitan area, a vibration trigger level of $L_{V,RMS,1s}$ 103 dB is adopted at residential premises regardless of time period. All other sensitive receptors places and uses have been assessed against the relevant 'preferred' criteria.

2.6 Ground-borne noise

The ground-borne vibration from train passbys can be sufficient to cause floors or walls of the structure to vibrate and this can result in an audible low frequency rumble inside buildings. This is termed as ground-borne or regenerated noise. From a review of relevant guidelines and relevant project experiences, ground-borne noise objectives are anticipated to be the main influence on potential impacts and will drive the design of vibration mitigation within the rail corridor.

The Project has adopted the ground-borne noise levels in **Table 7** as trigger levels for the investigation of reasonable and practicable measures to control ground-borne vibration in order to mitigate potential ground-borne noise impacts at sensitive receptors.

Table 7 Ground-borne noise trigger levels

Sensitive land use	Time of day	Internal noise trigger levels, dB
Residential	Development increases existing rail noise levels by 3 dB or more *and* resulting rail noise levels exceed:	
	Day (7.00 am–10.00 pm)	L_{ASmax} 40
	Night (10.00 pm–7.00 am)	L_{ASmax} 35
Schools, educational institutions, places of worship	When in use	L_{ASmax} 40 to 45

Source NSW Rail Infrastructure Noise Guideline (NSW RING), 2013.

For schools, educational institutions and places of worship, the lower value of the range (L_{ASmax} 40 dB) is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening or praying. More stringent objectives may be selected in some cases, particularly where the area is remote and ambient levels are well below L_{Aeq} 30 dB.

3 Basis of Assessment

This section outlines some key inputs assumptions, modelling and assessment methodologies associated with the noise and vibration impact assessment studies for the Project. Further detailed information on the assessment and modelling of noise and vibration is provided in **Appendix B**. To assist the interpretation a glossary of terminology is provided in **Appendix A**.

3.1 Referenced reports

The assessment detailed in this report has referenced noise and vibration assessment reports prepared for the Project and assessment reports undertaken for other projects that have been proposed and delivered within the region of the Malaga to Ellenbrook alignment. The referenced reports and their application in the assessment are summarised in **Table 8**. The 2019 report in the table was based on a concept design prepared for the Business Case for this Project. This assessment report is based on a revised design prepared for the Project Definition Plan. The final design will be prepared by the construction contractor.

Table 8 Referenced technical reports

Referenced report	Application in the assessment
Morley-Ellenbrook Line, Preliminary Design, Noise and Vibration Assessment – Part 2 (2019)	Detailed prediction and assessment of railway noise and vibration levels, and recommended mitigation requirements, for the Malaga to Ellenbrook section of the Project. Based on a concept design prepared for the Morley-Ellenbrook Line Business Case.
Transport Noise Assessment – Perth-Darwin National Highway Project[18] (2015)	Monitored ambient environmental noise levels between Malaga and Ellenbrook to quantify the existing noise environment prior to the introduction of the Project.
Transportation Noise Assessment – Whiteman Edge LSP1C, Brabham[19] (2015)	Predicted road traffic noise levels for the Drumpellier Drive (new Lord Street) at sensitive receptors in Brabham.

[18] Lloyd George Acoustics 2015, "Revised Transportation Noise Assessment – Perth-Darwin National Highway Project", reference number 13122263-01, dated 2 December 2015
[19] Lloyd George Acoustics 2015, "Revised Transportation Noise Assessment – Whiteman Edge LSP1C, Brabham", reference number 13112611-02, dated 31 March 2015

Referenced report	Application in the assessment
Transportation Noise Assessment – Ellenbrook Bus Rapid Transit Project[20] (2016)	Monitored ambient environmental noise levels between Malaga and Ellenbrook to quantify the existing noise environment prior to the introduction of the Project.

The previous assessment reports were prepared to support road transport projects and new residential developments within the area of the MEL project. These reports have been primarily referenced to assist in defining the existing noise environment prior to the construction and operation of the Project. It is noted that SLR has not been provided relevant noise assessment reports for recent road upgrades including Lord Street or Drumpellier Drive and consideration of transport noise associated with these upgrade projects was not considered further.

The reports not specifically developed for the MEL project have some limitations for this assessment. Notably, the 'existing' noise levels were measured in 2015 and 2016, prior to the development of transport infrastructure such as the upgrade of the Hepburn Road near Malaga and Drumpellier Drive adjacent to Drayton and Brabham. The predicted future transport noise levels in the reports would likely have been prepared based on concept design information relevant at the time of assessment (prior to construction).

At the time of this report, surveys to measure the existing noise environment in 2020 were not feasible due to the COVID-19 pandemic restrictions in place in Western Australia. Accordingly, whilst there are some limitations in referencing past monitoring and modelling results, they have been applied as the best available information to support the assessment of environmental noise within the communities surrounding the Project.

3.2 Assessment of impacts to Social Surroundings

The assessment of impacts, as they relate to social surroundings, has been guided by the Environmental Scoping Document (ESD) for the Public Environmental Review to be conducted under Part IV of the *Environmental Protection Act 1986*. as the ESD elements relevant to this noise and vibration assessment are included in **Table 9**.

Table 9 Factors for the assessment of impacts to social surroundings and works to date

Item	Extract	Comments
15.	Undertake noise and vibration monitoring and modelling as appropriate along the proposed alignment to determine ambient noise levels (including vibrational noise) in areas of noise sensitive receptors, including in areas used for recreational purposes. Consideration should be given to construction and operational noise and vibration impacts.	The study is reliant on environmental monitoring data discussed in **Section 3.1**.
16.	Undertake an initial screening assessment and if required a detailed noise and vibration assessment in accordance with relevant guidelines to predict future noise and vibration levels resulting from the proposal on sensitive receptors, including recreational values as appropriate.	Given distances involved and scale of works, a detailed model was constructed in line with SPP5.4 requirements and industry guidelines. Refer **Section 3.4** for further details.

[20] Lloyd George Acoustics 2016, "*Transportation Noise Assessment – Ellenbrook Bus Rapid Transit*", reference number 16053604-01, dated 15 September 2016

Item	Extract	Comments
17.	Assess and analyse noise and vibration impacts along the proposed railway alignment in accordance with 'State Planning Policy 5.4 – Road and Rail Noise' (WAPC, 2019), Australian Standard AS 2670.2-1990 and relevant guidance. Justify the use of any parameters used to monitor and model impacts from noise and vibration along the proposed alignment. Consideration should be given to planned areas of higher density and mixed-use development in close proximity to the proposed stations, including residential dwellings.	This is addressed further in **Sections 3.1** and **4**.
18.	Identify relevant noise and vibration mitigation measures for identified sensitive receptors and describe any proposed mitigation to reduce the potential impacts of construction and operation from the proposal. Provide maps of and justification for the location and number of any proposed mitigation infrastructure.	This is addressed further in **Section 6.**
19.	Include any proposed management and/or monitoring plans for noise and vibration that will be implemented pre- and post-construction to demonstrate and ensure that the EPA's objectives can be met.	This is addressed through a separate project specific noise and vibration management plan based on the reports referenced in **Section 3.1** and this document.
20.	Identify and describe the potential residual impacts (direct and indirect) that may occur following implementation of the proposed mitigation measures and determine the significance of the residual impacts of noise and vibration on the identified sensitive receptors with reference to the residual impact model set out in the WA Environmental Offsets Guidelines.	This is addressed further in **Section 4**.

Source Department of Water and Environmental Regulation, 2020.

3.3 Design assumptions

The assessment of noise and vibration has been based on the proposed designs for the Malaga to Ellenbrook section of the Project as at the date of this report and the forecast passenger rail services and the transport activities associated with the stations. The design information is summarised below in **Table 10**.

Table 10 Summary of key assessment inputs

Design input	Source of information	Application in the assessment
Rail infrastructure design	Project designs and plans provided to SLR	Development of the 3-dimensional representation of the Project designs for the structures and rail tracks in the noise prediction modelling.
Rail infrastructure features	Project designs and plans provided to SLR	Features such as the rail roughness, track conditions, trackform design and curving noise are considered in the noise modelling.
Passenger rail services	Project designs and plans provided to SLR	The forecast daily passenger train services in the noise modelling included: • the number of train services per day; • the speed of the trains along the Project; and, • the type (Series A/ Series B) of trains in operation.

Design input	Source of information	Application in the assessment
Busway transit services and station operations	Project designs and plans provided to SLR	The forecast daily busway, including 'kiss n ride' services in the noise modelling included: • the number of busway movements at each assessed station; • typical daily car parking at each assessed station; • general assumptions for public address systems and patron (crowd) activities.
Source noise emissions	Databases of noise measurements at the Perth passenger rail network	Establishing noise emission sources in the noise modelling: • passenger train passbys on the rail line, including proposed stowage at Ellenbrook; • vehicles arriving and departing from stations and car parking facilities; • general assumptions for public address systems and patron (crowd) activities.
Sensitive receptors	Geospatial Information System (GIS) databases	The buildings for the property and receptors aligning the Project rail corridor were digitised into the noise model. The buildings were defined as sensitive or non-sensitive based on the assumed use and the definition of sensitive receptors from relevant policies and guidelines. Conceptual buildings were included for additional (future) buildings and land-use for approved developments.
Station noise mitigation	Australian Standards	As-required, all public address systems would be designed and operated in accordance with relevant standards to control noise emissions.

3.4 Prediction and calculation of noise and vibration

The methodologies to predict noise and vibration level from the operation of the Project are summarised in this section with further detail on the basis of assessment provided in **Appendix B**.

3.4.1 Airborne noise

The noise emissions from the railway operations on the Project were calculated through detailed noise prediction modelling using the SoundPLAN (version 8.1) noise prediction modelling software.

The noise prediction model included a detailed terrain model to develop a 3-dimensional (3D) representation of the Project and the adjacent communities. The terrain datasets comprised elevation contours of the existing ground and the Project designs to recreate in detail the rail and road civil earthworks and infrastructure and the surrounding environment. The resultant terrain model represented the future environment with the Project.

The vertical and horizontal designs for the Project were digitised in the model, including; cuttings, embankments and the track formation (earthworks and track ballast). The elevated structures for the bridges and viaducts were modelled at the height above ground level consistent with the Project designs. The upgraded road networks, bus loop and car park infrastructure were digitised in the noise model.

The buildings for the sensitive receptors and non-sensitive structures adopted building heights from the referenced geospatial databases. The noise levels are calculated at a height of 1.5 m above the finished floor level of the ground floor and the upper building floors at 2.4 m intervals above the ground floor. The effects of nearby building reflections and the building façades were directly calculated by the software.

Each of the noise sources was assigned a representative noise emission level and calculations undertaken for the forecast operation of the Project.

3.4.2 Ground-borne noise and vibration

The prediction of ground-borne noise and vibration from rail systems is a complex and developing technical field. For this assessment, an assessment model was developed using a combination of theoretical and empirical relationships to determine the propagation of the ground-borne vibration from train passbys.

The Malaga to Ellenbrook section of the Project is an extensive land area along the proposed alignment with no existing railway operations. Accordingly, historical vibration measurement data for passenger rails operating on similar trackform and ground conditions was referenced as a source vibration emission reference.

The assessment model calculated ground-borne noise and vibration levels at sensitive receptors within 100 m of the rail tracks. The potential ground-borne noise and vibration impacts would be limited to receptors located within an approximate 100 m wide corridor above the centreline of the proposed rail alignments.

3.5 Operational scenarios

3.5.1 Railway operations

Consistent with the guidelines in SPP5.4, the assessment of noise and vibration from the Project has been based on forecast 'ultimate' transport operations for the year 2041, which is indicative of 20 years after completion of the Project.

The scenario outlined in **Table 11** was developed to evaluate the railway noise and vibration levels against the adopted criteria and to consider the potential changes to the existing transport noise that may occur with the introduction of the Project.

Table 11 Operational scenarios and train services

Year	Services	Day / night volumes[1]	Comments
2041	Bayswater – Ellenbrook (Series B), including Malaga to Ellenbrook section	74 daytime 16 night-time	For MEL, 3 car trains replaced with 6 car trains in 2041. All services have 10 minute headways except for 15 minute headways in the evening.

Note 1 Normal Monday to Friday services, one way. Daytime period refers to 6.00 am to 10.00 pm period and night-time refers to 10.00 pm to 6.00 am period.

The proportion of train movements between day and night-time periods in **Table 11** suggests that night-time period noise levels may be around 4 dB less than day period levels, whilst the SPP5.4 targets for each time period are 5 dB apart. As a result, with all else being equal, if the day period result is equal to the day period target, the night-time period result may be 1 dB above the night period target. However, the predicted night-time noise levels are considered conservative on the assumption that all trains would have a 6 car configuration. In practice, during the night-time there may be a mix of 3 car and 6 car configurations depending on demand which would lead to lower noise emissions.

The design of mitigation will need to consider both time periods, particularly given other factors during evening periods such as the reduced number of cars per train and modified speeds.

3.5.2 Road activities

Where the Project is proposing to upgrade the local road network, the road traffic noise assessment was based on the scenario detailed in **Table 12**.

Table 12 Scenarios for the upgrade of local road networks

Locality	Asset	Day volumes[1]	Night volumes[1]	Comments
Malaga Station	Beechboro Road North	NB 5,350 at 80 km/h, 7% HV SB 4,150 at 80 km/h, 7% HV	NB 400 at 80 km/h, 7% HV SB 300 at 80 km/h, 7% HV	Tonkin Highway not significantly affected
	Station bus loop (12 bays)	447	23	
Whiteman Park Station	Station bus loop (10 bays)	145	7	Lord Street not significantly affected
Ellenbrook Station	Gnangara Road/ Drumpellier Road intersection	NB 10,150 at 70 km/h => 5,350 @ 80 km/h, 5% HV	NB 500 at 70 km/h => 250 at 80 km/h, 3% HV	Only the intersection has been included in the assessment.
		SB 3,400 at 80 km/h => 8,850 at 70 km/h, 6% HV	SB 250 at 80 km/h => 750 at 70 km/h, 5% HV	
		WB 21,000 at 70 km/h => 22,700 at 80 km/h, 10% HV	WB 2,050 at 70 km/h => 2,200 at 80 km/h, 8% HV	
		EB: 28,800 at 80 km/h => 26,300 at 70 km/h, 14% HV	EB 2,150 at 80 km/h => 1,950 at 70 km/h, 12% HV	
	Station bus loop (12 bays)	216	11	

Note 1 NB is northbound traffic, SB is sound bound traffic, EB is eastbound traffic and WB is westbound traffic. HV is heavy vehicles presented as a percentage of total traffic.

The operation of the busway services and carparking at the Malaga, Whiteman Park and Ellenbrook stations was considered in the noise and vibration assessment. The operational scenarios summarised in **Table 13**, included the forecast potential vehicle movements (sources) that have been included in the assessments.

Table 13 Scenarios for the operation of the busways and car parking

Locality	Asset	Traffic volumes
Malaga Station	Station car park and drop off areas	1,154 parking spaces and 24 pick-up/ drop off bays
Whiteman Park Station		833 parking spaces and 16 pick-up/ drop off bays
Ellenbrook Station		500 parking spaces and 17 pick-up/ drop off bays

Note The scenarios have been developed only for the purpose of assessing potential noise levels from the busway and car parking facilities.

3.6 Sensitive receptors

3.6.1 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.

3.6.2 Receptor Catchment Areas

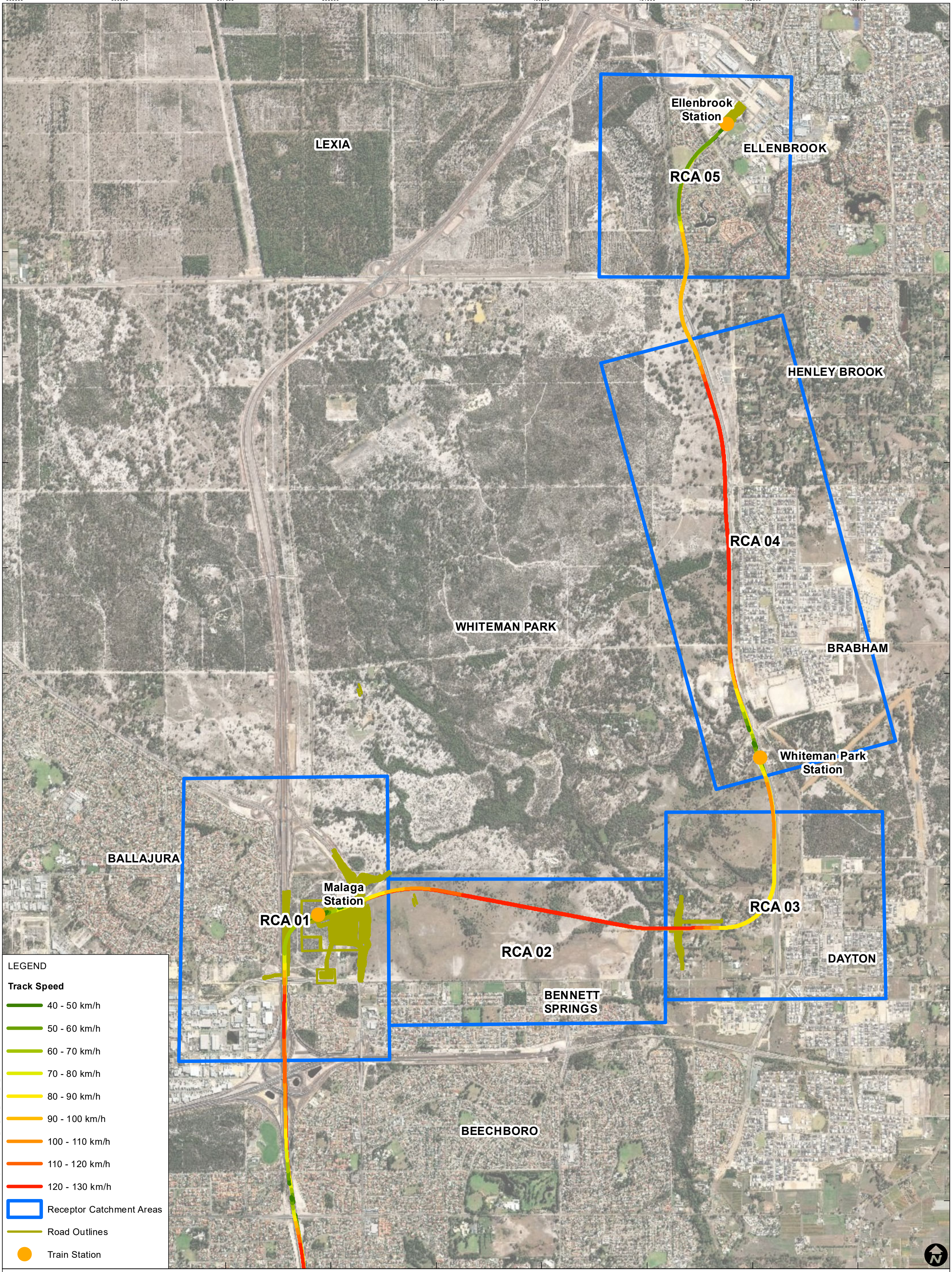
The sensitive receptors included in the assessment were assigned to receptor catchment areas to assist the assessment and interpretation of potential noise and vibration impacts. The objective was to establish the catchment areas so the receptors within each catchment area were equitably assessed based on the local environment and transport noise and vibration both prior to and with the Project.

The catchment areas are described in **Table 14** and presented in **Figure 2**. Each area was developed with consideration to the factors below.

- 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.
- The proximity of the sensitive receptors to the Malaga to Ellenbrook alignment.

Table 14 Receptor Catchment Areas (RCAs)

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 there are no identified sensitive receptors.
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.



SLR

DISCLAIMER: All information within this document may be based on external sources. SLR Consulting Pty Ltd makes no warranty regarding the data's accuracy or reliability for any purpose.

0 0.5 1 km

Coordinate System:	GDA 1994 MGA Zone 50
Scale:	1:32,000 at A4
Project Number:	675.11323.00200
Date:	11-Jun-2020
Drawn by:	(PW)
Reviewed by:	(PW)

Data Source:
ESRI Basemaps

To be read with SLR Report 675.11323.00200

WESTERN AUSTRALIA PUBLIC TRANSPORT AUTHORITY

Max Track Speed & Receptor Catchment Areas

FIGURE 2

4 Assessment of noise impacts along the alignment

The predicted daytime and night-time noise levels associated with the operation of the Project are detailed in **Appendix C** (rail operations) and **Appendix D** (road transport assets) and **Appendix E** (stations). The noise levels are predicted without noise mitigation included in the designs. The noise levels are reported as contours of the noise levels mapped for the environment and communities along the alignment.

The assessment of noise from the rail and proposed road assets of the Project has been discussed for each catchment area. The noise environment is discussed in terms of the current ambient noise levels, based on the review of previous noise studies, and the noise levels associated with the operation of the Project, as predicted in this assessment.

Note that this assessment does not address audibility or effects on soundscape, i.e. how a place may be defined by its ambient sound environment. It is expected that outdoor sound from rail operations will be at least occasionally audible throughout each RCA.

4.1 Receptor Catchment Area (RCA) 01 – Malaga

4.1.1 Existing noise environment RCA 01

In the RCA, the nearest residential communities to the Project are located in Beechboro to the south and Ballajura to west. These communities will be adjacent to the future extension of the Tonkin Highway, part of the NorthLink WA Project, which is currently under construction.

Previous noise studies determined that ambient noise levels adjacent to the Tonkin Highway , prior to NorthLink WA, were $L_{Aeq,day}$ 47 to 50 dB for the daytime and $L_{eq,night}$ 43 to 53 dB for the night-time. The noise environment being primarily influenced from local road traffic noise on Marshall Road and potentially the commercial development to the north of Malaga.

The referenced noise assessments forecast the future road traffic noise with the Tonkin Highway, and the associated intersection with the Reid Highway, in operation in the year 2040. The predicted road traffic noise levels at the nearest residential communities were between to $L_{Aeq,day}$ 55 and 60 dB at the nearest residential receptors within Malaga and Beechboro. Based on the predictions, the future noise environment would be dominated by road traffic noise at levels consistent with the noise targets for new road developments from SPP5.4.

4.1.2 Forecast railway noise levels RCA 01

The noise levels from the daily passenger rail services on the MEL Project are summarised in **Table 15**. The noise levels are presented for the nearest, and potentially most affected, sensitive residential receptors. The predicted rail noise levels can be reviewed in detail from the noise contour mapping in **Appendix C**.

At all of the residential receptors the predicted noise levels are within the noise targets adopted from SPP5.4.

Table 15 Predicted rail noise levels at RCA 01

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB	Maximum L_{Amax}, dB
Ballajura (east of Tonkin Highway)	35 – 50	35 – 45	50 – 70
Beechboro (south of Marshall Road)	35 – 55	30 – 50	50 – ≤80

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

4.1.3 Forecast road transport noise levels RCA 01

The assessment has considered the future road traffic noise associated with the bus loop and local road traffic accessing Malaga Station via Beechboro Road North. The predicted road transport noise levels from the Project are summarised in **Table 16** with the predicted road noise levels can be reviewed in detail from the noise contour mapping in **Appendix D**. The road traffic noise levels do not include the NorthLink WA project.

The predicted road transport noise levels at all receptors are well within the noise targets adopted from SPP5.4.

Table 16 Predicted noise levels from road assets at RCA 01

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB
Ballajura (west of Tonkin Highway)	35 – 40	≤ 35
Beechboro (south of Marshall Road)	30 – ≤ 45	≤ 40

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

4.1.4 Forecast noise levels from the stations RCA 01

The noise associated with the operation of the station at the nearest residences in this RCA has been predicted to be less than daytime $L_{A10,day} \leq 40$ dB and night-time $L_{A10,night} < 30$ dB. The noise levels at all receptors are well within the noise criteria adopted from the EPNR. On this basis the Project would not need to investigate specific measures to reduce and control noise from the operation of the new station proposed at Malaga.

These received levels are at least 10 dB below the forecast rail and road transport noise contributions which will not result in a significant cumulative increase in the level of daytime or night-time noise from the Project.

4.1.5 Future environment noise at RCA 01

The future noise environment has the potential to be influenced by both the Project and the NorthLink WA project. Based on the referenced monitored ambient noise levels, the transport noise from these projects are expected to increase in the daytime and night-time ambient noise levels at the residences within RCA 01.

The MEL and NorthLink WA projects will be designed and operated to achieve the requirements of SPP5.4, including as-required measures to control transport noise levels and mitigate the potential for noise related impacts. Nonetheless, the future noise environment will be primarily influenced by the noise from these new transport projects.

Whilst specific noise contributions will vary for individual receptors, the railway noise is expected to be the main source of noise from the Project and, for most receptors, road traffic noise will be associated with the NorthLink WA project.

The noise predictions infer the cumulative influence of both projects may increase overall transport noise, and potentially increase future ambient noise, by an additional 3 dB. In general terms a 3 dB change in noise is not a perceptible change in loudness when assessed over the 16-hour day and 8-hour night-time periods.

Based on the modelled railway noise contours for the Project the noise targets are achieved approximately 50 m from the rail centreline in RCA 01. The SPP5.4 targets are likely to be achieved where any future residential development within RCA 01 is located beyond 50 m of the railway alignment.

4.2 RCA 02 – Bennett Springs

4.2.1 Existing noise environment RCA 02

The local noise environment to the north of Bennett Springs is expected to be mainly influenced by local road traffic noise from Marshall Road. Previous noise monitoring surveys did not specifically include this area because it is outside of the main area of projects such as NorthLink WA. In lieu of surveyed noise levels, it is reasonable to assume daytime ambient noise levels would be at or below $L_{Aeq,day}$ 55 dB and $L_{Aeq,night}$ 50 dB.

4.2.2 Forecast railway noise levels RCA 02

The noise levels from the daily passenger rail services on the MEL Project are summarised in **Table 17**. The noise levels are presented for the nearest, and potentially most affected, sensitive residential receptors located on Marshall Road. The predicted rail noise levels can be reviewed in detail from the noise contour mapping in **Appendix C**.

The predicted noise levels are within the noise targets adopted from SPP5.4 at the sensitive receptors within this RCA.

Table 17 Predicted rail noise levels at RCA 02

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB	Maximum L_{Amax}, dB
Bennett Springs (Marshall Road)	35 – 45	30 – 40	50 – 65

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

4.2.3 Forecast road transport noise levels RCA 02

The predicted road transport noise from the road assets associated with the Project are below $L_{Aeq,day}$ 35 dB. The road transport noise levels achieve the requirements of SPP5.4 at all receptors within RCA 02. At the nearest receptors to the alignment, the road traffic noise levels are at least 10 dB below the forecast rail transport noise and not likely to result in a cumulative increase in the level of daily transport noise from the Project.

4.2.4 Forecast noise levels from the stations RCA 02

The noise associated with the operation of the stations at the nearest residences has been predicted to be less than L_{A10} 30 dB during the daytime and night-time. The noise levels at all receptors are well within the noise criteria adopted from the EPNR. The noise levels are at least 10 dB below the forecast rail and road transport noise and not likely to result in a cumulative increase in the level of daytime and night-time noise from the Project.

4.2.5 Future environment noise at RCA 02

The Project is introducing new sources of noise within this area and is expected to change the existing ambient noise environment in RCA 02. The daily passenger rail operations would be the primary source of new transport noise.

The existing environment is likely to be influenced by both the Project and the road traffic on Marshall Road. The specific influence will vary for individual receptors depending on their proximity to the Project and Marshall Road. It is reasonable to assume the environmental noise levels will increase at the receptors located within at least 500 m of the Project alignment. The receptors on Marshall Road are typically more than 500 m from the Project alignment and the local road traffic noise may remain the main source of local noise.

Based on the modelled railway noise contours for the Project the noise targets are achieved approximately 100 m from the rail centreline in RCA 02. The SPP5.4 targets are likely to be achieved where any future residential development within RCA 02 is located beyond 100 m of the railway alignment.

4.3 RCA 03 – Bennett Springs and Dayton

4.3.1 Existing noise environment RCA 03

The area of RCA 03 includes the receptors at Bennett Springs and Dayton which are approximately 100 m to 500 m from Drumpellier Drive (new Lord Street) road corridor. The road traffic on Drumpellier Drive is a potential source of transport noise and a key differentiator to the noise environment to the west within RCA 02.

It is assumed that Drumpellier Drive has been designed for road traffic noise levels to not be above the target levels from SPP5.4. Previous noise assessments predicted road traffic noise levels of at least $L_{Aeq,day}$ 55 to 60 dB at 100 m from Drumpellier Drive. For the receptors typically set more than 500 m from Drumpellier Drive or more than 200 m from Marshall Road, the future ambient noise environment would likely be at or below $L_{Aeq,day}$ 55 dB and $L_{Aeq,night}$ 50 dB.

4.3.2 Forecast railway noise levels RCA 03

The noise levels from the daily passenger rail services on the MEL Project are summarised in **Table 18**. The noise levels are presented for the nearest, and potentially most affected, sensitive residential receptors located adjacent to the alignment at Bennett Springs and Dayton. The predicted rail noise levels can be reviewed in detail from the noise contour mapping in **Appendix C**.

The predicted noise levels are within the noise targets adopted from SPP5.4 at the majority of sensitive receptors. There are isolated receptors immediately adjacent to the alignment to the east of Drumpellier Drive, where due to proximity to the alignment, the noise levels would require to be controlled by approximately L_{Aeq} 5 dB to achieve the daytime and night-time noise targets.

Modelling indicates that mitigation in the form of rail web dampers and/or noise walls will suffice in meeting the relevant SPP5.4 targets for a new railway.

Table 18 Predicted rail noise levels at RCA 03

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB	Maximum L_{Amax}, dB
Bennett Springs (off Marshall Road)	30 – 40	30 – 35	60 – 70
Bennett Springs (Drumpellier Drive)[2]	35 – ≤60	35 – <55	70 – ≤80
Dayton (adjacent Drumpellier Drive)	30 – <50	30 – <45	55 – ≤70

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.
Note 2 Includes individual residences located on local roads to the west of Drumpellier Drive.

4.3.3 Forecast road transport noise levels RCA 03

Road works associated with the Project will be undertaken at Beechboro Road North and Whiteman Drive East, which are located around 1 km or more from sensitive receptors within RCA 03. At this distance, the predicted road traffic noise associated with the Project is less than $L_{Aeq,day}$ 25 dB, and well within the SPP5.4 noise targets. Therefore, road transport associated with the Project is not expected to increase transport noise above the future railway noise at these receptors.

4.3.4 Forecast noise levels from the stations RCA 03

The proposed stations on the Project are over 2 km from the residential receptors in RCA 03. At this distance predicted transport noise from the stations would be well within the noise targets and not expected to be an influence on the local noise environment.

4.3.5 Future environment noise at RCA 03

Depending on the location of individual receptors, the noise environment will be influenced by the passenger rail operations on the Project and/ or road traffic on Drumpellier Drive.

The MEL and Drumpellier Drive projects will be designed and operated to achieve the requirements of SPP5.4, including as-required measures to control transport noise levels and mitigate the potential for noise related impacts. The SPP5.4 would likely determine that noise levels from rail operations had been reasonably controlled as part of the management of cumulative transport noise. Nonetheless, the future noise environment will be primarily influenced by the noise from these new transport projects.

Whilst specific noise contributions will vary for individual receptors, the noise environment at receptors immediately adjacent to the Project is likely to be primarily influenced by rail operations. For the receptors that are closer to Drumpellier Drive than the MEL project, the road traffic noise from Drumpellier Drive would likely be the main influence on environmental noise levels.

The noise predictions infer the cumulative influence of both projects may increase overall transport noise, and potentially increase future ambient noise, by not more than 3 dB. In general terms a change of 3 dB or less is not a perceptible change in loudness when assessed over the 16-hour day and 8-hour night-time periods.

Based on the modelled railway noise contours for the Project the noise targets are achieved approximately 100 m of the rail centreline in RCA 03. The SPP5.4 targets are likely to be achieved where any future residential development within RCA 03 is located beyond 100 m of the railway alignment. Should a new station be introduced and train speeds are lower as a result, these distances would reduce to around 50 m in the vicinity of the station.

4.4 RCA 04 – Brabham

4.4.1 Existing noise environment RCA 04

The nearest noise sensitive receptors in Brabham are located to the east of the Drumpellier Drive road corridor. The first row of existing and proposed future residential developments are within 100 m of Lord Street and Drumpellier Drive.

Previous noise studies identified that future road traffic noise levels with Drumpellier Drive would be $L_{Aeq,day}$ 60 dB or less at the adjacent sensitive receptors and achieve the requirements of SPP5.4. Specific prediction of night-time road traffic noise levels was not always undertaken, for the purpose of this assessment it has been assumed the noise levels would achieve SPP5.4 and not be greater than $L_{Aeq,night}$ 55 dB.

For the receptors set further away from the main road corridors, typically more than 500 m from Drumpellier Drive, the ambient noise environment would likely be at or below $L_{Aeq,day}$ 55 dB and $L_{Aeq,night}$ 50 dB.

4.4.2 Forecast railway noise levels RCA 04

The predicted railway noise levels at the sensitive receptors are relatively consistent through RCA 04 as the existing and future residential receptors and land uses are parallel to the railway alignment. The nearest receptors in Brabham are located approximately 100 m to the east of the alignment, and the trains are modelled at speeds in excess of 120 km/h.

The noise levels from the daily passenger rail services on the MEL Project are summarised in **Table 19**. The predicted rail noise levels can be reviewed in detail from the noise contour mapping in **Appendix C**.

Table 19 Predicted rail noise levels at RCA 04 prior to mitigation

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB	Maximum L_{Amax}, dB
Brabham (east of the rail line)	45 – <60	40 – ≤55	40 – 83
Brabham (south of Gnangara Road)	45 – ≤50	35 – ≤45	≤75

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

At many of these receptors the daytime and night-time noise levels are predicted to be at or above the noise targets. Prior to mitigation, period average noise levels are typically within 5 dB of the target levels and the maximum (L_{Amax}) noise target level is achieved to within 3 dB.

At all of the residential receptors located to the immediate south of Gnangara Road, the predicted noise levels are within the night-time noise targets adopted from SPP5.4.

4.4.3 Forecast road transport noise levels RCA 04

At the northern extent of RCA 04, the Project is undertaking major road upgrade works at the intersection of Drumpellier Drive and Gnangara Road. The predicted road traffic noise levels from the road upgrade are summarised in **Table 20**. The predicted road noise levels within RCA 04 can be reviewed in detail from the noise contour mapping in **Appendix D**. The road traffic noise levels do not include the road traffic noise levels from the local road network.

The nearest residential receptors in RCA 04 to the intersection upgrade are located south of Gnangara Road, approximately 190 m from the road upgrade. At this distance noise levels are predicted to be less than L_{Aeq} 55 dB and would achieve the road noise targets from SPP5.4.

Table 20 Predicted noise levels from road assets at RCA 04

Location	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB
Brabham (south of Gnangara Road)	< 55	40 – 50

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

The additional road traffic noise introduced by the Project may increase existing road traffic noise levels by 1 to 2 dB, this is not expected to be a perceptible change to daily noise levels.

At the southern extent of RCA 04, the bus loop and local traffic access at the new station at Whiteman Park are a potential source of road traffic noise associated with the Project. The predicted road traffic noise levels are less than L_{Aeq} 30 dB at the nearest residential land use to the north-east of the station and achieve the SPP5.4 noise targets. For the nearest sensitive receptors to the station, the railway noise levels will be the primary source of transport noise and cumulative road and rail transport noise from the Project is not anticipated.

4.4.4 Forecast noise levels from the stations RCA 04

The proposed new station at Whiteman Park is located within the southern extent of RCA 04. The nearest existing receptors at the south of Brabham are approximately 500 m to the north of the station, with potential for future residential development to be approximately 250 m from the station.

The noise associated with the operation of the station at the nearest residences has been predicted to be less than daytime $L_{A10,day}$ 40 dB and night-time $L_{A10,night}$ 35 dB and therefore within the criteria adopted from the EPNR. On this basis the Project would not need to investigate specific measures to reduce and control noise from the operation of the new station proposed at Whiteman Park.

These noise levels are at least 10 dB below the forecast rail and road transport noise levels and not likely to result in a cumulative increase in the level of daytime and night-time noise from the Project.

4.4.5 Future environment noise at RCA 04

The previous noise assessments determined that road traffic noise from Drumpellier Drive would be at the relevant SPP5.4 noise targets at the nearest receptors and as a new major transport infrastructure development is expected to increase the ambient noise levels in the local environment.

The noise levels from Drumpellier Drive, including at the future upgraded Gnangara Road intersection, are expected to be controlled to achieve the SPP5.4 noise targets at residential receptors. The MEL project is also expected to be designed to achieve the noise targets at the same receptors. Based on current predictions, rail noise mitigation would need to reduce L_{Aeq} noise levels by less than 5 dB to meet the target levels.

Modelling indicates that mitigation in the form of rail web dampers and/or noise walls will suffice in meeting the relevant SPP5.4 targets for a new railway. Conceptually the noise walls may be adjacent to the rail corridor (which is elevated in some sections relative to the road sections and could lead to reflected road noise towards residents), or between the road and residential boundary fences (on the residential boundary is likely to be more efficient).

Where both sources of transport noise are at similar noise levels, the overall cumulative daytime and night-time noise levels may represent an increase in transport noise of up to 3 dB. In general terms a change of 3 dB or less is not a perceptible change in loudness when assessed over the 16-hour day and 8-hour night-time periods.

In this region there is existing road traffic noise mitigation for Drumpellier Road in the form of noise walls at sections of the road corridor. The Project may also consider the construction of noise walls at the rail corridor to specifically control the railway noise from passenger train movements. There is potential for these mitigations to further reduce noise levels than those predicted at the planning stage of each project and also assist in controlling the potential audible (perceptible) road and railway noise.

Based on the modelled railway noise contours for the Project the noise targets are achieved approximately 150 m from the rail centreline in RCA 04. The SPP5.4 targets are likely to be achieved where any future residential development within RCA 04 is located beyond 150 m of the railway alignment.

4.5 RCA 05 – Ellenbrook

4.5.1 Existing noise environment

Prior to the introduction of the Project the noise environment at the nearest sensitive receptors in Ellenbrook is expected to be influenced by road traffic on Drumpellier Road. Applying information from the previous assessment of noise, the noise environment at these receptors is expected to be less than $L_{Aeq,day}$ 60 dB daytime and less then $L_{Aeq,night}$ 55 dB night-time.

For the receptors set further away from the major corridors, typically more than 500 m, the ambient noise environment would likely be at or below $L_{Aeq,day}$ 55 dB and $L_{Aeq,night}$ 50 dB. This includes Ellenbrook Christian College and Ellenbrook Secondary College.

4.5.2 Forecast railway noise levels

The predicted railway noise levels at the sensitive receptors are relatively consistent through RCA 05 as the existing and future residential receptors are adjacent to the railway alignment. The noise levels from the daily passenger rail services on the MEL Project are summarised in **Table 21**. The predicted rail noise levels can be reviewed in detail from the noise contour mapping in **Appendix C**.

Table 21 Predicted rail noise levels at RCA 05 prior to mitigation

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB	Maximum L_{Amax}, dB
Ellenbrook (opposite Drumpellier Drive)	40 – ≤67	40 – ≤60	60 – <95
Ellenbrook (approach to the station)	40 – ≤60	35 – ≤55	60 – <90

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

To the north of the Drumpellier Drive-Gnangara Road intersection the rail alignment is within 50 m of residential property to the west of Ellenbrook. Due to the proximity of the receptors to the rail line it is challenging to achieve the noise targets from SPP5.4 without the consideration of mitigation such as noise walls. The predicted noise levels at the majority of the first row of residential receptors either side of the rail corridor are above the noise targets.

The predicted noise levels in **Table 21**, identify that L_{Aeq} noise levels would need to be reduced in the order of 5 dB to achieve the daytime and night-time noise targets and the maximum (L_{Amax}) noise levels by 10 to 15 dB. The predicted noise levels also account for two story properties where the upper level is likely to have an unobstructed line of sight to the rail corridor.

Modelling indicates that mitigation in the form of rail web dampers and/or noise walls will still lead to some properties above the relevant SPP5.4 target for a new railway by up to 2 dB. In a section of approximately 200 metres length, conceptually the noise walls may need to be of the order of 4-5 metres in height which carries risks in regard to visual impact and access to natural light.

Curving noise (squeal, flanging noise) is also a risk factor in the vicinity of this track section. Subject to rail engineering requirements, this risk can be reduced through increased superelevation (raising the outside rail height relative to inside rail to assist steering) and reduced curvature. The use of an increased height wall may be necessary to offset this risk.

4.5.3 Forecast road transport noise levels

The proposed upgrade of the intersection between Drumpellier Drive and Gnangara Road is a source of road traffic noise from the Project at the southern extent of RCA 05. The predicted road traffic noise associated with the Project's upgrade of the intersection at Drumpellier Drive and Gnangara Road are summarised in **Table 22**.

The predicted road noise levels within RCA 04 can be reviewed in detail from the noise contour mapping in **Appendix D**. The road traffic noise levels do not include the road traffic noise levels from the local road network. The noise predictions identify the target levels from SPP5.4 for road upgrade projects would be achieved.

Table 22 Predicted noise levels from road assets at RCA 05

Location[1]	Daytime $L_{Aeq,day}$, dB	Night-time $L_{Aeq,night}$, dB
Ellenbrook (Adjacent to Gnangara Road)	45 – <60	40 – <55
Ellenbrook (Adjacent to Drumpellier Drive)	40 – <55	40 – <50

Note 1 Noise levels have been referenced for the nearest residential communities adjacent to the MEL Project.

At the nearest residential receptors in Ellenbrook to the north of the Drumpellier Drive-Gnangara Road intersection are likely to experience rail noise levels approximately 5 dB greater than the road traffic noise level.

4.5.4 Forecast noise levels from the stations

The proposed new station at Ellenbrook is located at the northern extent of the rail line. The nearest existing receptors are to the south, approximately 200 m and greater from the station.

The noise associated with the operation of the station at the nearest residences has been predicted to be less than daytime $L_{A10,day}$ 40 dB and night-time $L_{A10,night}$ 35 dB, well within the noise criteria adopted from the EPNR. On this basis the Project would not need to investigate specific measures to reduce and control noise from the operation of the new station proposed at Ellenbrook.

The noise levels are at least 10 dB below the forecast rail and road transport noise and not likely to result in a cumulative increase in the level of daytime and night-time noise from the Project.

4.5.5 Future environment noise at RCA 05

The modelling has predicted railway noise levels at the nearest sensitive receptors in Ellenbrook to be 5 to 10 dB greater than the anticipated future ambient noise environment, which would likely be influenced by road traffic noise from Drumpellier Road.

On this basis, there is potential for the ambient noise levels to increase primarily as a result of the introduction of railway noise from the Project. Where railway noise levels are controlled to achieve the noise targets from SPP5.4, it is considered to be the reasonable control of environmental noise and further measures are not typically required to control overall transport noise from road and rail sources.

Based on the modelled railway noise contours for the Project the noise targets are achieved approximately 150 m from the rail centreline in RCA 05. The SPP5.4 targets are likely to be achieved where any future residential development within RCA 05 is located beyond 150 m of the railway alignment.

4.6 Summary of the noise assessment

The outcomes of the noise assessment are summarised in **Table 23** . The results are discussed in terms of the number of residential receptors where the predicted noise levels were above the adopted noise targets. Results are presented for the operations of the project in 2040, with and without the recommended mitigation measures for the control of railway noise.

Table 23 Airborne noise results summary

Transport operations	SPP5.4 Noise Target[2]	Build, 2041 (no mitigation)	Build 2041 (with mitigation)
Rail operations	LAeq,day 55 dB	61 receptors (15%) up to 11 dB above target	2 receptors (1%) up to 1 dB above target
	$L_{Aeq,night}$ 50 dB	70 receptors (17%) up to 12 dB above target	4 receptors (1%) up to 1 dB above target
	LAmax 80 dB	89 receptors (22%) up to 16 dB above target	19 receptors (5%) up to 3 dB above target
Road transport	LAeq,day 60 dB	Daytime and night-time noise levels achieve the targets at all receptors	No specific mitigations recommended for road transport noise.
	LAeq,night 55 dB		
New stations	Assigned noise levels[1]	Daytime and night-time noise levels achieve the targets at all receptors	No specific mitigations recommended for the new stations.

Note 1 The assigned noise levels are receptor specific objectives as detailed in **Table 4**.

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 no mitigation’ 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 with mitigation’ scenario), the assessment determined:
  - Airborne rail noise levels are reduced to achieve the target levels at the majority of sensitive receptors. The performance of recommended mitigation was 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.

5 Assessment of ground-borne noise and vibration

The outcomes of the assessment of ground-borne noise and vibration from passenger train passbys are summarised in this section with maps of forecast ground-borne noise and vibration levels in **Appendix E**.

An initial assessment of ground-borne railway noise and vibration was undertaken for each identified sensitive receptor, using historical field data for similar scenarios and basic adjustments for distance, track speed and features. The assessment identified the adopted assessment targets may not be achievable at all of the nearest sensitive receptors in Bennett Springs, Brabham and Ellenbrook. The outcomes of the initial assessment are summarised in **Table 24**.

The assessment considered resilient ballast matting as a specific measure to reduce and control the source of the emission of ground-borne vibration. The consideration of resilient under ballast matting or a pad installed under the rail sleeper was included in the assessment at the locations where the rail vibration may need to be controlled. The predicted ground-borne noise and vibration levels, with conceptual vibration controls, are summarised in **Table 24**.

The assessment determined the application of industry standard vibration control measures would be expected to achieve the target levels for ground-borne noise and vibration at the majority of sensitive receptors.

Due to the proximity of the rail track to receptors in Bennett Spring, Brabham and Ellenbrook there will likely be a requirement to evaluate potential ground-borne noise and vibration levels further during the detailed design stage to establish the appropriate as-source vibration controls.

Table 24 Predicted ground-borne noise and vibration levels with concept mitigations

Usage	Aspect	Objective[1]	Build 2041 scenario (no mitigation)	Build 2041 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	

6 Recommended management measures

6.1 Airborne noise mitigation measures

The assessment determined that the noise emissions from the daily passenger rail services would achieve the noise targets at the majority of the residential receptors adjacent to the alignment between Malaga and Ellenbrook.

At Bennett Springs, Brabham and Ellenbrook there are residential receptors where noise levels would need to be controlled by L_{Aeq} 5 dB and/or L_{Amax} 5 dB for all receptors to achieve the noise targets. Given the site context, airborne noise controls are considered at this design stage to be limited to the measures discussed in the table below.

The determination of noise mitigation on the Project will be considered during the detailed design and construction of the Project. These rail noise treatments will need to suitably interface with controls associated with other projects under construction and the reasonable and practicable mitigation design may include a combination of the mitigation examples.

Table 25 Example noise mitigation measures

Noise mitigation option	Comments
Noise walls	To achieve effective noise reductions, noise barriers may be located either within the rail reserve, on defined property boundaries, or in place of existing walls (as a potential upgrade). Generally, wall(s) located closer to the noise source (or receptor) are more effective.
	Whilst noise walls are an industry standard noise control practice, the application of noise walls on the Project will require detailed consideration of a range of factors, including; engineering feasibility, cost, environmental impacts, impacts to visual amenity and management of surface water flows.
Sound absorptive panels	Within the Ellenbrook area there are several locations where noise received at sensitive receptors is due to reflected noise paths from within dive structures and not just via the most direct pathways. Here the solution would be to use sound absorptive panels to control these reflections within the dive structure.
Rail web dampers	Field trials commissioned by the PTA in 2017 indicate a noise reduction potential of between 4 and 5 dB using rail web dampers[21]. The application of rail web dampers is generally more feasible for a newly constructed railway and should be investigated as part of the detailed design of the track form.
	Experience with previous projects involving two parallel railway lines indicates that the likely costs of rail web dampers are likely to be less than noise walls on one or both railway reserve boundaries, once all construction and operational factors are managed such as structural wind loading, fence removal, construction site mobilization, vandalism, lighting, accessibility around crossings and visual impacts.
	The installation of rail dampers carries risks of increased maintenance costs in removing dampers for major trackwork activities (such as rail replacement). However, installation also carries benefits in terms of reduced rates of rail roughness and corrugation growth, which in turn is expected to lead to fewer major trackwork events and therefore reduced maintenance costs.

6.2 Ground borne noise and vibration controls

This assessment has identified that under-ballast matting or under-sleeper pads may provide effective control of vibration during train passbys. The outcomes of this report will need to be verified during detailed design with consideration of all major influencing factors, including range of geotechnical and rail conditions along the alignment, as well as the performance specifications of mitigation measure options.

It is important to note that once the rail alignment and trackform is fixed, options to reduce vibration emissions are limited to rail support stiffness, 'above rail' assets (rolling stock) and operational measures.

6.3 Noise and vibration management plan

A Noise and Vibration Management Plan (NVMP) shall be prepared to document the management and administrative procedures for the control of noise and vibration from the operation of the Project. A key outcome of the plan is to advise relevant local government authorities of the agreed approach for railway sections within their jurisdiction.

[21] SLR Consulting 2017, *Rail web damper trials – noise and vibration assessment*, SLR Report 675.11094. Ballasted track with RP65221 pads.

The NVMP is expected to detail the following:

- Identification of the noise and vibration sensitive receptors.
- Prescribed standards, guidelines, performance criteria and objectives.
- Details of the specific noise and vibration management and mitigation measures to be implemented, including timeframes for their implementation.
- Monitoring of noise and vibration levels once road traffic and rail operations commence on the Project.
- Auditing and performance evaluation to ensure the management measures remain appropriate for the potential impacts associated with the noise and vibration from the Project.
- Roles and responsibilities for personnel with respect to the implementation of the management and auditing of the measures.
- Details of the complaint management procedure.

7 Discussion

Based on the outcomes of this assessment a summary of the key aspects to be considered in the detailed design phase is provided in **Table 26**.

Table 26 Review of residual factors

RCA	Recommendations for detailed design
Project-wide	It is recommended that the noise targets from SPP5.4 are adopted as one set of noise targets for all transport infrastructure associated with the Project, including; passenger rail services, road traffic from the road assets and the car parking at the stations. Applying one set of noise targets with the same noise parameters would enable the associated road, rail and car parking noise to be assessed and managed as a cumulative source of noise. This would be consistent with the way noise may be perceived by, and potentially impact, the sensitive receptors. The recommended approach should be reviewed against the potential legislative requirements for noise associated with the stations to be managed under the EPNR.
RCA 01 Malaga	Further consideration should be given to the potential for increases in ambient transport noise from the Project (including the MEL south of Malaga) and the NorthLink WA project.
RCA 02 Bennett Springs	The assessment determined the predicted noise and vibration levels achieved the targets without the requirement for specific mitigation measures.
RCA 03 Bennett Springs - Dayton	Noise mitigation is recommended to control railway noise at the individual residential receptors adjacent to the alignment. Further consideration should be given to the potential for increases in ambient transport noise from the Project and the road traffic on Drumpellier Drive.
RCA 04 Brabham	Noise and vibration mitigation should be reviewed for the residential receptors located to the east of the alignment. Vibration mitigation is likely to be considered only where receptors are within 100m of the alignment. Further consideration should be given to the potential for increases in ambient transport noise from the Project and the road traffic on Drumpellier Drive.
RCA 05 Ellenbrook	Noise and vibration mitigation should be reviewed for the residential receptors located to the east and west of the alignment. Vibration mitigation is likely to be considered only where receptors are within 100 metres of the alignment

8 Summary and recommendations

The assessment of potential noise and vibration from the passenger rail services and road assets associated with the Malaga to Ellenbrook section of the MEL determined:

- The transport noise targets adopted from SPP5.4 are predicted to be achieved at the majority of residential receptors without the requirement for specific mitigation measures.
- The predicted rail noise levels at the nearest receptors to the alignment in Bennett Springs, Brabham and Ellenbrook trigger a detailed investigation of reasonable and practicable measures to reduce noise levels with an objective of achieving the target noise levels.
- Noise levels from the road assets and stations associated with the Project are expected to achieve the relevant noise assessment criteria at nearest receptors without the requirement for specific mitigation measures.
- To control rail noise levels the Project is likely to require the implementation of measures such as noise walls within the rail corridor, rail web dampers and, at Ellenbrook, sound absorptive panels to control reflected sound within the dive structure.
- To control ground-borne noise and vibration levels at sensitive receptors the Project should consider under-ballast matting or under-sleeper pads where sensitive receptors are within 100 m of the surface alignment.
- The outcomes of this study are to be verified through further noise and vibration modelling and assessment during the detailed design and construction phases of the Project.

APPENDIX A

Glossary of terms

Abbreviated terms

The following table lists key nomenclature used in this report.

Table A.1 Abbreviations

Parameter	Description
a, a_w	(Vibration) acceleration, the subscript 'w' refers to weighting / frequency correction used. Units are m/s^2.
dB	Decibel, a unit of sound or vibration which is described as a ratio of the result to a fixed reference value. All sound pressure levels (LpA, LA, LAeq etc.) quoted in this report are referenced to 20 micro Pascals (dB re 20µPa).
	Vibration velocity levels (L_v) quoted in this report are referenced to 1 nanometre per second (dB re 10-9 m/s), noting that some US criteria use dB re 10^{-6} in/s.
Guidelines	Implementation Guidelines for State Planning Policy 5.4 Road and Rail Transport Noise and Freight Considerations in Land Use Planning
L_{Amax}	The "typical maximum noise level" for a train pass-by event. For operational rail noise, L_{Amax} refers to the maximum noise level not exceeded for 95% of rail pass-by events (5th highest percentile) measured using the 'slow' (sometimes denoted by subscript 'S') response setting on a sound level meter.
L_{A1}	The A-weighted noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given period.
L_{A10}	The A-weighted noise level exceeded for 10% of a given measurement period and is utilised normally to characterise average maximum noise levels.
L_{Aeq}	The A-weighted average noise level. It is defined as the steady noise level that contains the same amount of acoustical energy as a given time-varying noise over the same measurement period.
L_{A90}	The A-weighted noise level exceeded for 90% of a given measurement period and is representative of the average minimum background noise level (in the absence of the source under consideration), or simply the "background" level.
L_v	Unweighted vibration velocity level, see dB.
$L_{v,RMS,1s}$	Maximum unweighted RMS vibration velocity level over a 1 second period.
L_w, L_{wA}	'Sound power' (L_w) refers to the total rate of sound generation of a given item of plant. This quantity is independent of the distance from the plant item (analogous to the wattage power of a light-bulb) and allows direct comparison of the relative acoustic 'size' of different plant items. From this data, the sound pressure level (or noise level) at any offset distance from the plant can be calculated (analogous to the light intensity from a light-bulb – the greater the distance, the less intense).
Policy	State Planning Policy 5.4 – Road and Rail Transport Noise and Freight Considerations in Land Use Planning
RMS	Root Mean Square, a parameter used to estimate the average energy level of a continuous signal.
a, a_w	(Vibration) acceleration, the subscript 'w' refers to weighting / frequency correction used. Units are m/s^2.

Noise

The terms "sound" and "noise" are almost interchangeable, except that in common usage "noise" is often used to refer to unwanted sound. Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing.

The human ear responds to changes in sound pressure over a very wide range. The following table presents examples of typical noise levels.

Table A.2 Guide to sound pressure level ranges for selected environments (dB re 20µPa)

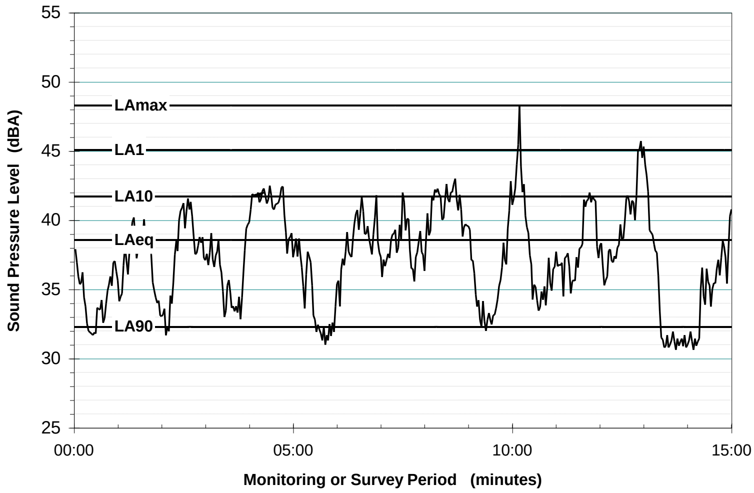
Subjective Evaluation	L_{Aeq}	Comments / Examples
Intolerable. Onset of pain. Exceeds daily exposure limit in under a second.	140	Military jet engine at 30 metres
	130	2kW disaster warning siren at 1 metre
Very loud. Risk of exceeding daily noise exposure limit in under a minute.	120	Jet aircraft take-off at runway edge
	110	Rock concert; freight train main horn at 25 metres
Loud. Onset of risk to exceeding daily recommended noise exposure limit.	100	225mm angle grinder at 1 metre, car horn at 3 metres
	90	Heavy industrial factory interior
Noisy	80	Shouting at 1 metre, kerb side of busy street
	70	Freeway at 20 metres
Moderate	60	Normal conversation at 1 metre, department stores
	50	General office areas
Quiet	40	Office air conditioning background level
Very quiet	30	Bedroom in quiet suburban area
Almost silent	20	Whisper, rural bedroom at night
	10	Human breathing at 3 metres
	0	Threshold of typical hearing

The loudest sound pressure to which the human ear responds is 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 symbol 'A' represents A-weighted sound pressure level (SPL): the weighting is designed to better represent the hearing ability of the average listener at each frequency.

The ability to discern a change in noise level varies between individual listeners, however it is reasonable to suggest that a change of up to 3 dB in the level of a sound is difficult for most people to detect, and 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 and is readily noticeable.

L_{Aeq} values represent an energy average of sound over time and are basic indicators of loudness. There other ways to statistically represent sound and common noise level descriptors that are illustrated in the following figure. The L_{Amax} parameter is used to describe the highest noise level over a relatively short period (typically 1 second), and the L_{A90} (90^{th} percentile A-weighted result) indicates ambient or background noise levels.

Figure A.1 Example of typical noise indices (1 second logging)



Ground-borne ('regenerated') noise and vibration

Vibration is the term used to describe the oscillating or transient motions in physical bodies. This motion can be described in terms of vibration displacement, vibration velocity or vibration acceleration. Most ground borne vibration (GBV) assessments are of human response / comfort first, as the risk of cosmetic and structural damage to buildings occurs at vibration levels that are orders of magnitude higher.

Vibration and sound are intimately related. Vibrating objects can generate (radiate) sound and, conversely, sound waves (particularly at lower frequencies) can also cause objects to vibrate. Noise that propagates through a structure as vibration and is radiated by vibrating wall, ceiling and floor surfaces is termed "ground-borne noise" (GBN), "regenerated noise", or sometimes "structure-borne noise".

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

- L_{vSmax}: The "typical maximum vibration level" for a train passby event, being the highest 1 second maximum root-mean square (RMS) value in dB re 1 nm/s. For operational rail GBV, this similarly refers to the 5th highest percentile of L_{vSmax} results.
- L_{Asmax}: The "typical maximum noise level" for a train passby event, in dB re 20 µPa. For operational rail GBN, L_{ASmax} refers to the maximum noise level not exceeded for 95% of rail passby events measured using the sound level meter 'slow' (1 second) response setting. Statistically this is the 5th highest percentile of L_{ASmax} results. The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (i.e. A-weighted).

On the basis of guidance in International Standard ISO 14837-1 2005 Mechanical vibration - Ground-borne noise and vibration arising from rail systems – Part 1: General guidance, ground-borne noise levels are evaluated over the 20 Hz to 315 Hz frequency range.

The following figure gives examples of typical vibration levels associated with surface and underground railway projects together with the approximate sensitivities of buildings, people and precision equipment. The vibration levels are expressed in terms of the vibration velocity (in mm/s and in decibels).

Vibration measurements may be carried out in a single axis or as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse. Velocity is commonly described in terms of millimetres per second (mm/s).

Table A.2 Guide to one-second maximum RMS floor vibration level ranges for selected environments

Typical response	mm/s	dB re 1nm/s	Comments / typical events
Visible response in building items, structural damage risk	16	144	High impact events such as blasting or dynamic compaction in close proximity to structures.
	10	140	
	8.0	138	
Cosmetic damage to some buildings possible over extended periods	5.0	134	
	3.0	130	Impact pile driving, 15 metres. Freight trains at 80 km/h, ~10 metres.
Noticeable. Minor cosmetic damage is feasible to buildings that are in fragile condition / an existing state of disrepair	2.0	126	
	1.0	120	Rock breaking at 15 metres. Vibratory roller at 10 metres.
	0.8	118	Typical target for workshops.
	0.4	112	Freight trains at 80 km/h, ~40 metres. **Regenerated noise highly likely** in typical residential buildings.
Barely noticeable	0.3	110	
	0.2	106	Typical residential daytime target for continuous vibration.
Threshold of human perception to vibration	0.15	104	Passenger trains at 80 km/h, ~30 metres.
Not felt	0.10	100	Operating rooms, surgeries.
Impacts to microscopic and precision equipment	0.050	94	Recommended criterion for bench microscopes < 400x magnification
	0.030	90	
	0.025	88	Micro-surgery devices, eye surgery.
	0.012	82	Electron microscopes <30,000x magnification.
	0.010	80	
	0.006	76	Electron microscopes >30,000x magnification.
	0.003	70	Photolithography to 0.25 microns.

APPENDIX B

Basis of Assessment

Railway airborne noise

Methodology

Given the early stages of planning, this study uses previously established railway noise emission levels to forecast both existing and future noise emission levels. A 3D noise model was constructed to account for varying topographic conditions, shielding and reflecting effects from building structures, planned rail movements and noise emission input data for individual train movements. The development and validation of this model is described further below.

The Nordic Rail Traffic Noise Prediction Method (Kilde 130) has been used for rail noise assessments. This method has been refined since its introduction in 1984 and is commonly utilised for rail noise assessments within Western Australia. It calculates emission noise level based on the scheduled train operational parameters including speed, length and number of train movements, and it can predict both equivalent (L_{Aeq}) and the maximum noise levels (L_{Amax}) as required.

Further details regarding the airborne noise modelling methodologies, including reference source levels and environmental model inputs are detailed below.

Source noise levels

For both existing and build modelling scenarios, the reference noise emissions adopted for Type A and Type B passenger trains on ballasted track are presented in the following table.

Table 1 Reference railway noise emissions, ballasted track, 15 m distance

Rolling stock	Reference Conditions		Reference Noise Emissions		Source
	Length, m	Speed, km/h	L_{50} L_{AE}, dB	L_5 L_{Amax}, dB	
Series A trains (4 cars)	86	80	89	89	Historical measurements Refer Appendix A for adjustments due to local track factors
Series B trains (6 cars)	146	80	89	88	
		30 (stowage areas)	78	75	

The reference noise emission values are based on historical noise measurements of train passbys undertaken by SLR at a number of locations in the Perth metropolitan area. These measurements have been analysed to establish the above reference noise emissions for typical rolling noise under the ballasted trackform.

Track condition

The modelled track conditions assume the track will be constructed on ballast. It has been assumed that the rail tracks are in good condition and the running surface of the rail head is free of audible defects, and tracks being constructed with welded rail joints which does not cause any increase in train passby noise level.

Turnouts

Turnouts/switch points allow trains to move from one track to another at the entry and exit to the passing loops. Each turnout was modelled as swing nose type with a 6 dB increase in noise emissions over a 10 m distance.

Risk of curving noise

Noise model corrections were not applied for curved track (i.e. less than 600 m radius but more than 300 m radius). It is noted that trains entering passing loops may navigate relatively sharp curvature which under certain conditions can generate additional curving noise (wheel squeal or flanging noise).

To manage the potential for curving noise, it has been assumed the design will maximise the curvature of track where practicable and consider the use of superelevation to assist with steering. Typical local controls, such as wayside friction modifier systems and close fitting noise walls, could be installed in practice if there are issues during service.

Propagation factors

Outside the rail reserve, the environmental factors relevant to noise propagation of moving sources were modelled as follows:

- Topography dataset of existing conditions for the assessment area was sourced from Landgate, and the 3D rail alignment was provided by the PTA.
- Given the relatively short propagation distances, weather conditions for each time period were considered neutral as 20°C, with no wind or temperature gradient effects.
- Conservatively, for the entire project area 50% of the ground between source and receptor is assumed to be hard reflective, with the exception of significant road and sealed concrete surfaces which are modelled as 90% hard reflective.

Receptor adjustments

Receptors (noise affected premises considered in this assessment) were modelled as follows:

- The noise receptors were identified using aerial imagery surveys dated October 2018 as provided by Landgate and free online map resources.
- Point receptors were placed at 1 m from the most exposed habitable façade of the nearest residential buildings and 1.5 m above ground level (and higher for multi-storey developments). The effects of nearby building reflections were directly calculated instead of the default façade correction (+2.5dB).
- The forecasts are made in terms of L_{Amax}, $L_{Aeq,Day}$ and $L_{Aeq,Night}$ for comparison with set objectives.

Conceptual noise wall mitigation

Information for the existing noise barrier and fence heights and locations were sourced as follows:

- Residential fencing separating properties were generally not modelled unless determined to be critical to receptor results at the most exposed properties. This is because the condition and effective height of all such boundary walls is generally unknown.
- Locations of existing road traffic noise walls were sourced from Landgate and reviewed with necessary corrections being made to reflect their realistic existing conditions. The modelling was then carried out on the basis that these fences and barriers are acoustically solid, i.e. they perform as effective noise barriers, being of suitable construction to sufficiently reduce noise transmission.

The consideration of noise wall mitigation in the modelling adopted the following principles:

- Targeted to reduce and control noise to achieve the objective of meeting the noise level targets detailed in **Section 2.1**.
- Walls are located in plan either on the expected rail reserve boundary, on principle shared path fence lines, or at least 3.5 metres from the nearest rail centreline (subject to final approval).

- Generally, for flat ground, closer fitting walls do not need to be as tall as those on the boundary. Only in some locations such as where the rail line is in a cutting are walls on the boundary (at the top of the cutting) likely to be more cost effective.

Road and station facilities noise

In consideration to the noise modelling recommendations with the 'Implementation Guidelines' for the SPP5.4, SLR predicted road traffic noise levels utilising a site specific SoundPLAN noise prediction model. The prediction of road traffic noise included the following factors:

- A road surface correction of -1 dB for an Open Grade Asphalt road surface.
- A +2.5 dB correction for noise levels at the building façade.
- Buses noise emissions were referenced from SLR's previous measurement of buses in Perth. The noise predictions from the buses were verified to the previous noise measurements.
- Noise levels were predicted with the Calculation of Road Traffic Noise algorithms within the SoundPLAN software.

Station loops

Bus vehicles have been modelled using Nordic Traffic Noise Prediction 1996 with the following parameters:

- 16 buses per hour typical day at a speed of 35 km/hr max.
- As rolling and exhaust noise is dominant, changes in level from arriving/ idling/ departure at the station (as assessed at nearest noise sensitive location) is considered insignificant and not modelled. Publicly accessible road sections along Lake Valley Drive or its intersections are not included.
- Category 2a vehicles up to 12.5m length with noise emissions of approximately L_{Amax} 75 dB, L_{AE} 78 dB at 7.5 m and 35 km/hr. The use of articulated buses is not considered to significantly affect these results given the number of movements per period and minor differences in noise emissions.

Vehicle parking areas

The passenger vehicle facilities consists of two carparking areas and several drop off points (including drop off 'Kiss and Ride' areas). EU Parking Area Noise 2007[22] guidelines have been used to provide an indicative level of noise emissions on surrounding areas. These guidelines allow for car door slamming, low speed movements and engine idling (note that all vehicles are modelled with internal combustion engines, i.e. no electric vehicles).

- Vehicle movement rate for P&R facilities over 20km from CBD (A vehicle entering or exiting a parking bay is one movement, so the same vehicle arriving and departing on the same day completes two movements):
  - 0.30 per hour per parking bay (6.00 am to 10.00 pm).
  - 0.10 per hour per parking bay (10.00 pm to 6.00 am).
- Impulse correction K_I 4dB; L_{w0} 63dB (standardised vehicle sound power level).

[22] Bayer, Landesamt für Umwelt 2007, *Parking Area Noise - Recommendations for the Calculation of Sound Emissions of Parking Areas, Motorcar Centers and Bus Stations as well as of Multi-Storey Car Parks and Underground Car Parks*, Bayerisches Landesamt für Umwelt, Parkplatzlämstudie 6, Aufl., August 2007.

Crowd/patron noise

Average crowd and patron noise levels in the context of the design criteria and other environmental noise sources are considered insignificant. The arrangement of the station has passenger waiting areas on the platform, busway waiting areas and pick up points at distances over 40 m from residences and/or generously spaced open environments.

Providing this level of distance separation and low crowd densities is expected to ensure that any sustained crowd/ patron noise levels (conversations, walking) as individually L_{Aeq} 60dB at 1 m and below L_{Aeq} 30dB at 40 m will be at a cumulative level that is inaudible at nearby residential locations against other background environmental noise.

Public address systems

The public address system will need to be designed to be sufficiently audible (involving both sound level and speech intelligibility) to meet relevant provisions of Australia Standard 1670.4, Fire Detection, Warning, Control and Intercom Systems - System Design, Installation and Commissioning - Sound Systems and Intercom Systems for Emergency Purposes (AS 1670.4) such that patrons can be advised in case of emergencies. An active PA system which regulates speaker volume depending on actual ambient sound level conditions to maintain intelligibility is recommended.

Vibration

Methodology

The ground-borne noise and vibration modelling for this project was conducted using an SLR-developed modelling process, the assessment was undertaken using the following assumptions:

- The source vibration levels in are based on measurements for track and rollingstock in Perth, with the train tracks and wheel in good operational condition (i.e. no wheel-flats, corrugation etc.).
- Study area considers all representative receptors within 100 m from the centreline of each railway, in 5 m segments, based on historical field data demonstrating compliance typically within 50 m.
- Reasonable similarity in ground propagation effects between the locations used for baseline measurements and those near receptor positions.
- The analysis is based on vibration measured in the vertical direction only with adjustments for transverse / longitudinal vibration components (which are considered to be of minimal consequence at extended distances as captured in the design uncertainty).
- Reasonable assumptions on building amplification effects based on previous vibration studies in Perth. In practice, building response effects will vary.
- Inclusion of resilient ballast matting to contain the ballast which, based on transport noise and vibration guidelines, can achieve overall 10 dB reductions to the vibration source emissions from rail operations.

Key factors

- An adjustment of +6 dB was applied for track sections within 5 m of turnouts.
- For the movement of trains, the vibration levels typically increase by 6 dB for doubling of train speed.
- In lieu of detailed geotechnical information, the ground is treated as isotropic and homogenous in structure, with constant distance loss rates across the study area.

- For geometric spreading of vibration energy, trains were represented by point sources spaced at 5 m intervals, with the distance attenuation from each point calculated according to:
- Vibration incident on building structures will undergo a coupling loss, usually resulting in lower levels of vibration in the building's footings than in the surrounding ground.
- The GBN and vibration levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. The majority of receptors are typically either 1 to 2 storey established residences with some commercial properties near the station.
- Adjustments for vibration entering and propagating within buildings:
  - **Coupling loss between structure and groundsoil** – this is the change in level as vibration enters a structure.
  - **Floor to floor adjustment (per floor above ground)** – this is designed to estimate the reduction in vibration level as it transfers into upper floors.
  - **Amplification adjustment** – this factor represents the estimated worst case change (increase) in noise and vibration levels due to building resonance effects. In practice, levels will significantly vary depending on location within the receiving space, e.g. whether the measurement position is near a structural wall or is at the mid-span of a floor.
- The indoor ground-borne noise level is calculated from the floor vibration levels using a theoretical adjustment of -27 dB in line with historical guidelines; however, an adjustment of -32 dB is likely to be more appropriate in the experience of the author and subject to further study of local conditions.

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