APPENDIX

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Operational Railway Noise and Vibration Assessment

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

INLAND RAIL - NORTH STAR TO BORDER

Operational Railway Noise and Vibration Assessment
2-0021-270-EMN-00-RP-0002

Prepared for:

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Inland Rail
Level 16, 180 Ann Street,
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SLR Ref: -R01
Version No: -v0.1
March 2020

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Australian Rail Track Corporation Limited (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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EXECUTIVE SUMMARY

The Melbourne to Brisbane Inland Rail Program is the construction of a 1,700 km rail freight transport network including; 1,200 km of enhanced and upgraded tracks and 500 km of new railways in regional Victoria, New South Wales (NSW) and Queensland (QLD). As part of the Inland Rail program, the North Star to Border (NS2B) project section (the Project) in NSW is a new single track railway, approximately 30 km in length, connecting the Narrabri to North Star and NSW/QLD Border to Gowrie project sections of the Inland Rail Program.

In addition to the 30 km of new rail track, the Project includes 11 bridges and viaducts, including one large rail bridge across the Macintyre River, seven level crossing locations and one crossing loop at Boonal.

The movement of rail freight on the Project is a source of noise and vibration that could impact sensitive receptors and the surrounding environment. This report provides an assessment of potential noise and vibration levels from forecast daily rail freight operations for the Project. The assessment of noise and vibration from the construction of the Project, fixed infrastructure and associated road traffic is detailed separately in *Appendix J – Non-operational Noise and Vibration Technical Report* (of the EIS).

This report has been prepared as part of the Environmental Impact Statement (EIS) for the Project and it addresses the applicable Secretary's Environmental Assessment Requirements for railway noise and vibration issued by the Department of Planning, Industry and Environment.

The report has referenced guidelines from regulatory authorities in NSW and international standards to assess the likely railway noise and vibration levels and inform the appropriate management of railway noise and vibration impacts.

Railway noise

A detailed noise prediction model for the Project designs and the surrounding environment was developed to assess airborne noise from railway operations on the main line tracks, at level crossings and the crossing loop. The noise model covered an area 2 km either side of the alignment, which comprised a total area approximately 120 km^2 in size and 31 individual sensitive receptors.

The model adopted a database of noise emission levels for the specific locomotives and wagons proposed on the Project. Noise modelling approaches were applied to account for the varying rail noise emissions along the alignment, including; the track gradients, train speeds and features such as road crossings and turnouts.

Noise levels for the proposed daytime and night-time railway operations at project opening (2025) and the design year (2040) were predicted to achieve the airborne railway noise assessment criteria from the NSW Rail Infrastructure Noise Guideline (RING) at the majority of the sensitive receptors.

The predicted noise levels were above the noise assessment criteria at three sensitive receptors for railway operations at the project opening (2025) and at five sensitive receptors (an additional two sensitive receptors) at the design year (2040). The predicted noise levels trigger the assessment criteria by less than 5 dBA (decibels) at the majority of these sensitive receptors. The highest forecast railway noise level was 15 dBA above the relevant noise assessment criteria.

Applying the predicted noise levels and the location of the sensitive receptors, the feasible and reasonable measures adopted by ARTC to reduce railway noise impacts, beyond controlling railway noise at its source, are expected to be at-property controls such as architectural property treatments and upgrades to property fencing.

Whether at-property controls or other alternative mitigation options are required will ultimately be determined through detail design of the Project. This will include further railway noise modelling, analysis of engineering and environmental constraints, consultation with directly affected landowners and the verification of railway noise levels once Inland Rail operations commence on the Project.

Vibration from train movements

The operation of the trains on the Project can be a potential source of vibration and associated ground-borne noise. An assessment of ground-borne vibration was undertaken to identify where railway induced vibration and its effects may be a potential source of impact. The ground-borne noise and vibration criteria were predicted to be achieved at all but one sensitive receptor adjacent to the railway alignment.

The predicted levels are relatively low at the sensitive receptors adjacent to the Project, and the noise environment is expected to be dominated by the airborne railway noise. Nonetheless, achieving the criteria does not preclude the potential for ground-borne noise and vibration during train passbys to be occasionally perceptible in the context of the quiet rural areas.

Summary

Assuming the detail design remains consistent with this assessment, the Project is expected to achieve the objectives of the RING for the management of noise and vibration from railway operations. Where the noise criteria are achieved, including with the implementation of mitigation measures, there remains potential for noise to be perceptible (audible) within the environment surrounding the alignment.

Recommendations

Based on the report outcomes, the key recommendations for the management of railway noise and vibration are:

- Review the feasible and reasonable noise and vibration mitigation options discussed in this report during the detail design and construction of the Project. Mitigation options include modifications to trackform and noise screening elements, in addition to at-property treatments for sensitive receptors.
- Allow for the vibration mitigation measures modelled in this report; ballasted track over bridge and viaducts to use suitable resilient matting for ballast retention and vibration isolation.
- Further validate the noise and vibration prediction models and update forecasts during the detail design of the Project.

ACRONYMS

Term	Definition
ARTC	Australian Rail Track Corporation
AS	Australian Standard
B2G	NSW/QLD Border to Gowrie project
BS	British Standard
dBA	A-weighted decibel (referenced 20 µPa)
dBm	Decibel per metre
dBV	Vibration expressed as decibels (referenced level 1 nanometres/second)
DECC	Department of Environment and Climate Change (now NSW EPA)
DIN	Deutches Institut für Normung (German Institute for Standardisation)
EIS	Environmental Impact Statement
EPA&A Act	*Environmental Planning and Assessment Act 1979*
Hz	Hertz
ISO	International Standards Organisation
Km	Kilometres
Km/h	Kilometres per hour
Km^2	Square kilometres
LAeq	Equivalent continuous sound level
LAeq(15hour)	The equivalent continuous sound level for the 15-hour daytime period of 7.00 am to 10.00 pm
LAeq(9hour)	The equivalent continuous sound level for the 9-hour daytime period of 10.00 pm to 7.00 am
LAeq(1hour)	The equivalent continuous sound level for the busiest 1-hour period.
LAmax	The maximum sound level during the measurement or assessment period. The LAFmax or Fast is averaged over 0.125 of a second and the LASmax or Slow is averaged over 1-second.
m	Metres
mm	Millimetres
mm/s	Millimetres per second
m/s	Metres per second
N2NS	Narrabri to North Star project
NSW	New South Wales
OEH	Office of Environment and Heritage (now NSW EPA)
PPV	Peak Particle Velocity
QLD	Queensland
SEL	Sound Exposure Level
TfNSW	Transport for New South Wales
VDV	Vibration Dose Value
Vppv	Vector peak particle velocity, which is the peak particle velocity calculated from the sum of the vibration in three directions; longitudinal, transverse and diagonal.

GLOSSARY OF TERMINOLOGY

Term	Definition
Active level crossing	Where the movement of vehicular or pedestrian traffic across a railway crossing is controlled using signs or devices such as flashing signals, gates or barriers (or combination of these). The device(s) are active prior to, and during, the passage of the train through the crossing.
Airborne noise	Sound (noise) which travels through the air and commonly describes noise experienced within the outdoor environment.
Ballast	Crushed rock and stone used to provide a foundation for railway track. It usually forms the bed on which railway sleepers are laid, transmits the load from the train movements to the formation and restrains the track from movement.
Bunching and stretching	Wagons can touch from coming together or make a noise when they stretch and pull apart.
Consist	The set of wagons or carriages that form the train.
Continuously welded rail	Continuously welded rail shall be constructed on Inland Rail, and due to there being fewer joints, trains can travel faster on continuously welded steel rails than on jointed rails. The continuously welded rail can reduce noise and vibration emissions from passing trains.
Crossing loop	A place on a single line railway where trains travelling in the opposite direction can pass each other.
Culvert	A structure that allows water to flow under a road, railway, track or similar obstruction.
Existing rail corridor	The corridor within existing rail infrastructure are located. The existing rail corridor is defined by ARTC to mean everywhere within 15 metres of the outermost rails; or within the boundary fence (where fences are provided) and are closer than 15 metres. If the property boundary is less than 15 metres, the corridor is defined as the property boundary or a permanent structure such as a fence, wall or level crossing separating the operating rail corridor from other land.
Formation	The earthworks/ material on which the ballast, sleepers and tracks are laid.
Ground-borne noise	Railway vibration in buildings at frequencies typically from about 30 Hz to about 200 Hz, can excite the floors and walls which then radiate a rumbling noise directly into the rooms. This ground-borne (or structure-borne) noise is more commonly associated with track in tunnels, where it occurs without the masking from the airborne rail noise.
Level crossing	A place where rail lines and a road cross at the same elevation.
Passive level crossing	Where the movement of vehicular or pedestrian traffic across a railway crossing is controlled using signs or devices that are not activated by the approach or passage of a train, relying on the road user or pedestrian to detect the approach or presence of a train by direct observation.
Practicable	Relates to engineering considerations, what can practically be built (e.g. safety, access, site constraints).
Rail corridor	The corridor within which the rail tracks and associated infrastructure are located.
Rail dampers	Elements that are attached to the sides of the rails to improve the rail's ability to absorb and dissipate vibration energy that results from the rolling contact between the wheel and rail.
Rail pads	Rail pads are plastic or rubber mats that are inserted between the rails and the sleepers. Their purpose is to evenly distribute the load from passing trains onto the sleepers. They can also act to reduce noise and vibration emissions from passing trains.
Rating background level	The underlying level of noise present in an area once transient and short-term noise events are filtered out.

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1 Introduction

1.1 Project overview

The North Star to NSW/ Queensland Border (NS2B) project (the Project) is a new railway infrastructure project providing a connection between the Narrabri to North Star (N2NS) Inland Rail project and the New South Wales (NSW)/ Queensland QLD Broder to Gowrie (B2G) Inland Rail project.

The Project starts approximately 1.5 km to the north of the town of North Star and the alignment runs north to the NSW/ QLD border. The Project consists of approximately 30 kilometres (km) of standard gauge track with one crossing loop to accommodate double stack freight trains up to 1,800 m long, including a future possible requirement to accommodate trains up to 3,600 m in length.

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 30 km of single track, standard gauge rail line with one crossing loop to accommodate the potential for trains up 3,600 m long, but initially constructed for 1,800 m long trains.
- A series of bridges and viaducts are required so the route can traverse the local topography and cross waterways and other infrastructure.
- Tie-ins to the N2NS and B2G projects on the Inland Rail Program.
- The construction of associated rail infrastructure including maintenance sidings and signalling infrastructure to support the advanced train management system.
- Rail crossings including level crossings, grade separations/road overbridges, occupational/private crossings, fauna crossing structures.
- Significant embankments and cuttings will be required along the length of the alignment.
- Ancillary works including road and public utility crossings and realignments, signage and fencing and provision of services within the corridor.
- Construction worksites, laydown areas and access roads.

Construction of the Project is planned to start in 2020 and is expected to be completed in 2025.

1.2 Relationship to the Inland Rail Program

The Project is one of 13 projects that make up the Inland Rail Program for the delivery of 1,700 km rail line by 2025. It is one of seven Inland Rail projects in NSW and is one of the “missing links” within the Inland Rail Program.

As part of the broader Inland Rail Program, this Project provides a more direct route between Melbourne and metropolitan Brisbane in comparison with the existing inland and coastal road and rail networks and meets the Australian Government’s objective of providing a long-term rail solution for competitive freight movement.

At commencement of operations, the Project will connect to the adjoining N2NS and B2G projects on the Inland Rail Program, and accommodate the use of double-stacked, 1,800 m long freight trains, with future provision to accommodate freight trains up to 3,600 m.

1.3 Operational rail noise and vibration assessment report

The Project has been declared as State Significant Infrastructure (SSI) under the State Environmental Planning Policy (State and Regional Development) 2011 and the *Environmental Planning & Assessment Act 1979* (NSW) (EP&A Act).

A SSI project requires an Environmental Impact Statement (EIS) to be developed in accordance with; Part 5.1 of the EP&A Act, the Environmental Planning and Assessment Regulation 2000 (NSW) and project specific Secretary's Environmental Assessment Requirements (SEARs).

This report, prepared by SLR Consulting Australia Pty Ltd (SLR), details the assessment of potential noise and vibration emissions from the railway operations on the Project. The report addresses the environmental assessment requirements, as they relate to noise and vibration from railway operations, of the SEARs for the Inland Rail Project North Star to NSW/ Queensland Border[1], August 2018.

The baseline noise and vibration surveys and assessment of noise and vibration from non-operational railway aspects of the project, including construction, road traffic and fixed infrastructure, have been addressed in a separate technical report[2].

1.4 Report limitations

The findings of this report are based on the current design and may change as the Project design progresses. Should the final design or conditions vary from the basis of this assessment, the noise and vibration levels and associated impacts may differ 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 by ARTC. This is expected to require further assessment of railway noise and vibration and the monitoring of railway noise and vibration at the opening of the Project.

[1] NSW Department of Planning and Environment, 2018. Secretary's Environmental Assessment Requirements, - Inland Rail Project North Start to NSW/Queensland Border (SSI 18_9371), date of issue 8 August 2018.

[2] Future Freight Joint Venture, 2020. Inland Rail: North Star to Border, Appendix J Non-Operational Noise and Vibration Assessment Technical report.

2 North Star to Border project description

2.1 Overview

The Project includes the establishment of approximately 30 km of new single track, standard gauge railway connecting the N2NS and B2G projects on the Inland Rail Program. The alignment follows the existing disused rail corridor towards Boggabilla and then crosses the Macintyre River at the NSW/ QLD border.

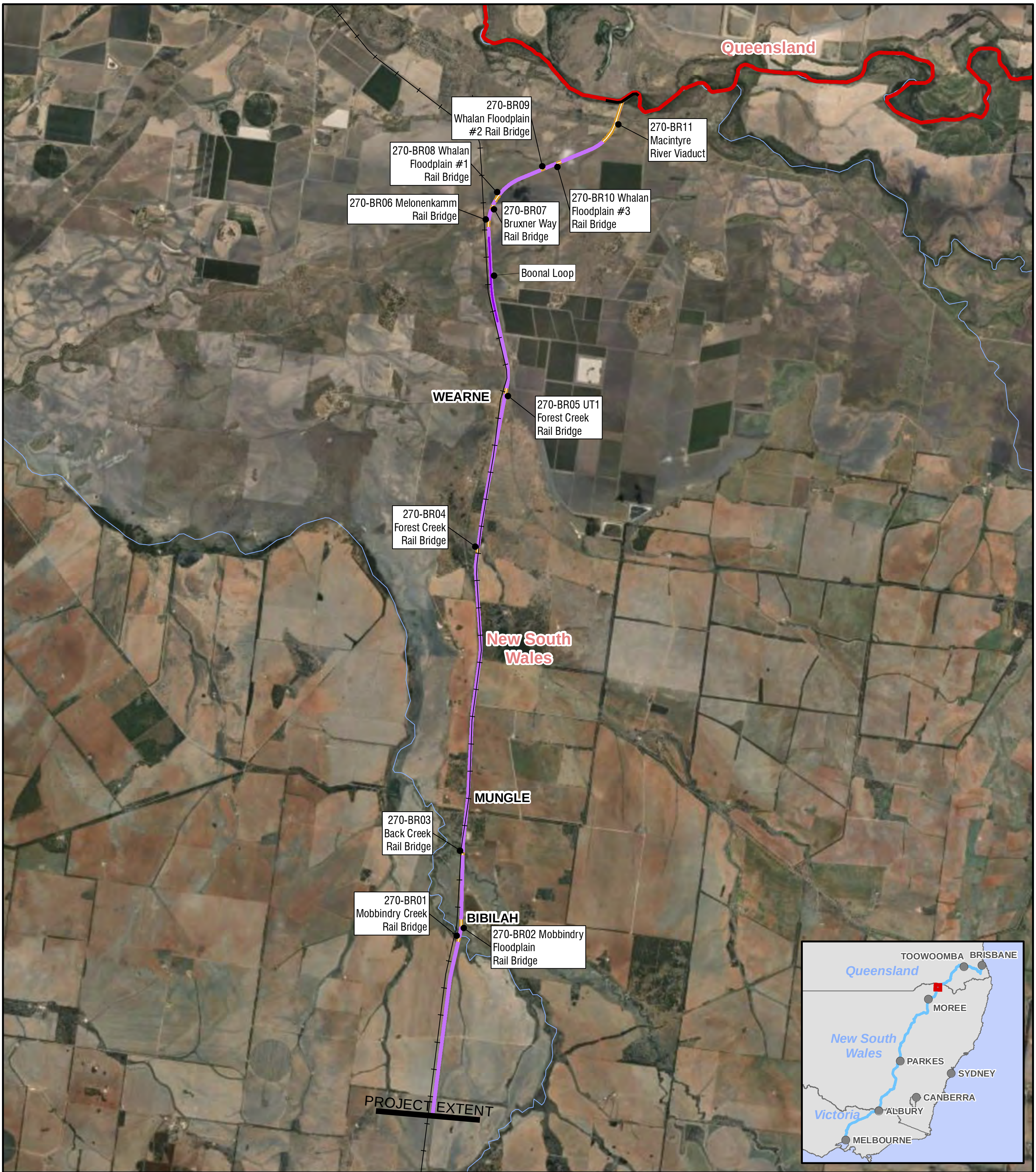
The southern project limit is located at the end of the Cumurra to North Star line, diverges eastward from the non-operational Bobbabilla line and continues east across farmland to the NSW/ QLD border. Whilst utilising an existing disused rail corridor, the proposed Project corridor is classed as 'greenfield' as it will involve newly constructed railway infrastructure.

The design has been developed in response to environmental, engineering and social constraints. The design objective is to minimise environmental and social impacts, minimise disturbance to existing infrastructure and utilities, meet the engineering design criteria and realise Project benefits.

The key components of the Project are summarised in **Table 1**. The maps of the Project alignment along with the bridges and viaducts are presented in **Figure 1**.

Table 1 Key infrastructure for the NS2B project

Key component	
Start and finish point	North Star to the NSW/ QLD border
Local government areas	Gwydir Shire Council and Moree Plains Shire Council
Length of alignment	30 km
Track dimensions	Rail corridor approximately 65 m wide, consisting of a single-track dual gauge railway line to facilitate rail traffic in both directions.
New level crossings	7 including 2 active level crossings and 5 passive level crossing
New rail bridges and viaducts	11 bridges and viaducts for crossing roads and waterways
Crossing loops	1 loop initially up to 1,800 m in length at Boonal.



NORTH STAR TO BORDER

Overview of the Project

FIGURE 1

5 km

Coordinate System: GDA 1994 MGA Zone 56

Paper: A4 Scale: 1:140,000
Date: 24-Mar-2020
Author: JG

- Project Extent
- Watercourses
- Existing Railway
- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- State Boundary

ARTC InlandRail

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation, in partnership with the private sector.

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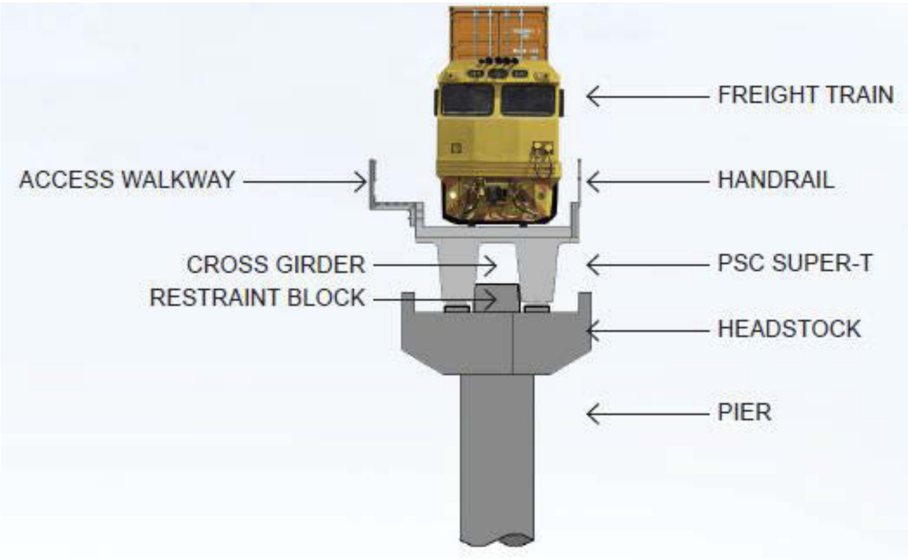
Service Layer Credits: Imagery ARTC 2015 and 2017

2.2 Rail bridges and viaducts

The Project requires 11 new bridge and viaduct structures for rail to cross over roads and waterways including one large bridge crossing the Macintyre River. The bridge and viaduct superstructures include the track system, walkways, guard rails and barriers as appropriate, and are typically founded on piles supporting in-situ reinforced concrete substructures.

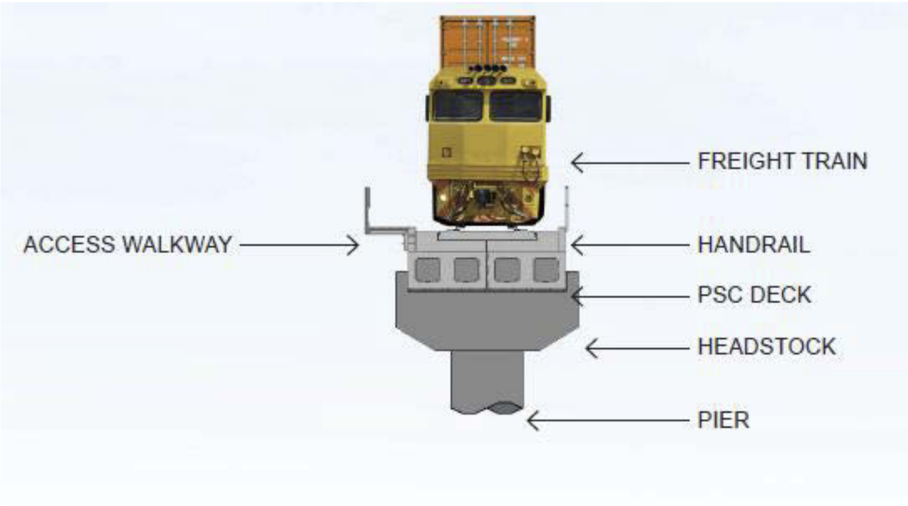
Currently the designs indicate that the deck spans will typically be between 14 m and 46 m in length, noting that most bridges are made up of multiple spans. The sub-formation and ballast height will be approximately the same as the deck edge resulting in minimal screening of noise by the bridge structures. The bridges can be Super-T girders or pre-stressed concrete slab spans as illustrated in **Figure 2** and **Figure 3**.

Figure 2 Typical pier with pre-stressed concrete Super-T girder



Note Not shown to scale.

Figure 3 Typical pier with pre-stressed concrete slab span



Note Not shown to scale.

The details of each of the 11 bridges and viaducts is provided in **Table 2** and presented in **Figure 1**.

Table 2 Rail bridges and viaducts on the Project

Bridge name	Crossing type	Bridge length, m
Mobbindry Creek Rail Bridge	Waterway	112
Mobbindry Creek Floodplain Rail Bridge	Waterway and floodplain	182
Back Creek Rail Bridge	Waterway	70
Forest Creek Rail Bridge	Waterway	154
UT1 Forest Creek Rail Bridge	Waterway	138
Melonenkamm Rail Bridge	Crossing existing rail line	161
Bruxner Way Rail Bridge	Road crossing	114
Whalan Creek Floodplain 1 Rail Bridge	Waterway and floodplain	184
Whalan Creek Floodplain 2 Rail Bridge	Waterway and floodplain	126
Whalan Creek Floodplain 3 Rail Bridge	Waterway and floodplain	126
Macintyre River Viaduct	Waterway and floodplain	1,750[1]

Note 1 The total length of the Macintyre River Viaduct includes the progression of the structure into the B2G project section in QLD.

2.3 Level crossings

Level crossings are typically applied to facilitate vehicle and pedestrian access where public and private roads interface with rail corridors. For safety purposes, the level crossings can require alarm bells at each crossing and a requirement for each train to sound its horns as it approaches the crossing. The Project is proposing to include nine level crossings, which can be either passive or active, as defined below.

- Passive – have static warning signs (e.g. stop and give way signs) that are visible on approach. There are no mechanical aspects or light devices.
- Active – flashing lights and audible alarm bells with or without boom barriers for motorists, and automated gates for pedestrians. These devices are activated prior to and during the passage of a train through the levels crossing.

The location of the level crossings on the Project are summarised in **Table 3**.

Table 3 Level crossings on the Project

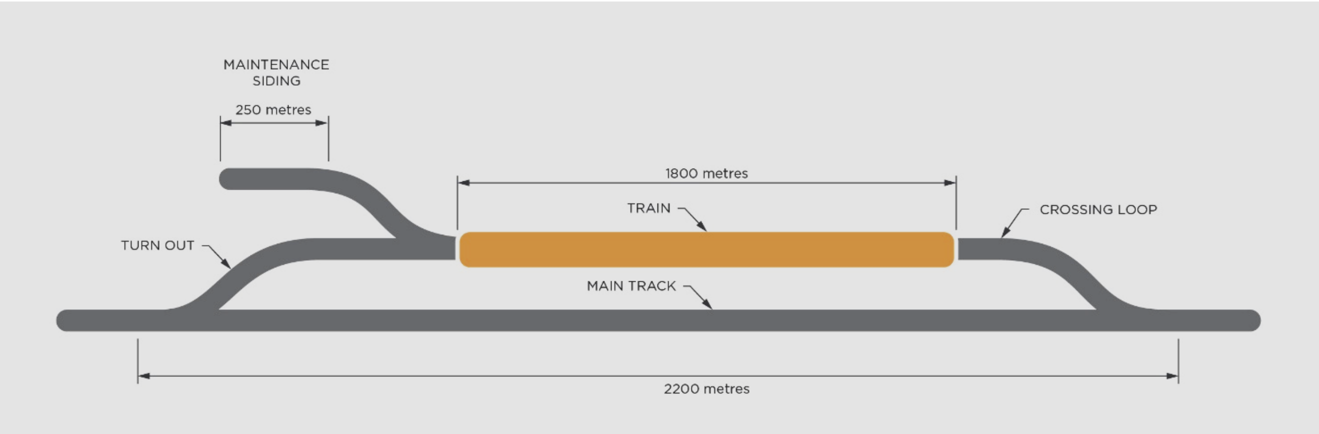
Road name	Treatment
Private crossing	Passive level crossing
North Star Road	Active level crossing
Forest Creek Road	Passive level crossing
Private crossing	Passive level crossing
Private crossing	Passive level crossing
Private crossing	Passive level crossing
North Star Road	Active level crossing
Private crossing	Passive level crossing
North Star Road	Active level crossing

2.4 Crossing loops

Crossing loops enable a train to move from the main line track and allow another train to pass through on the main line. The crossing loops are used to manage train movements on the network, such as trains travelling in the opposite direction or trains travelling at different speeds. The Project incorporates one new crossing loop at Boonal, designed to accommodate an 1,800 m train length, with consideration of future provision for a 3,600 m train length. The crossing loop will be connected to the main line track at both ends so the crossing loops can be accessed by trains travelling in either direction.

The loop would be a new sections of track parallel to the existing track at a distance of approximately 4.5 m spacing from the mainline track and incorporate a 250 m maintenance siding to enable maintenance of rollingstock without obstructing the track. The proposed location of the crossing loop is shown in **Figure 1** and the indicative design of the crossing loop and maintenance siding is shown in **Figure 4**.

Figure 4 Indicative design for crossing loop and maintenance siding



2.5 Turnouts

A turnout is a point where a train can leave a given track for a branching or parallel track. The turnouts on the Project are expected at the crossing loop, each turnout on the Project alignment is detailed in **Table 4**.

Table 4 Location of turnouts on the Project

Turnout details	Project reference
1 in 18.5 left hand turnout	Boonal crossing loop
1 in 10.5 right hand turnout	Boonal crossing loop
1 in 18.5 right hand turnout	Boonal crossing loop

3 Environmental impact assessment requirements

3.1 Secretary's Environmental Assessment Requirements

The SEAR's for the Project were issued by the Department of Planning, Industry and Environment (DPIE). The SEARs for the noise and vibration assessment area detailed in **Table 5**.

Table 5 SEARs for the railway noise and vibration

Key issue & desired performance outcome	Specific assessment requirement	Addressed in this report
3. Assessment of Key Issues Key issue impacts are assessed objectively and thoroughly to provide confidence that the project will be constructed and operated within acceptable levels of impact.	1. The level of assessment of likely impacts must be proportionate to the significance of, or degree of impact on, the issue, within the context of the proposal location and the surrounding environment. The level of assessment must be commensurate to the degree of impact and sufficient to ensure that the department and other government agencies are able to understand and assess impacts 2. For each key issue the Proponent must: (a) Describe the biophysical and socio-economic environment, as far as it is relevant to that issue; (b) describe the legislative and policy context, as far as it is relevant to the issue (c) identify, describe and quantify (if possible) the impacts associated with the issue, including the likelihood and consequence (including worst case scenario) of the impact (comprehensive risk assessment), and the cumulative impacts (d) demonstrate how potential impacts have been avoided (through design, or construction or operation methodologies); (e) detail how likely impacts that have been avoided through design will be minimised, and the predicted effectiveness of these measures (against performance criteria where relevant); and (f) detail how any residual impacts will be managed or offset, and the approach and effectiveness of these measures.	Operational noise and vibration have been assessed in accordance with the SEARs. The assessment criteria and guidelines are detailed in **Section 4**. Refer to the following assessment sections of this report: **Section 8** and **9** (airborne noise), **Section 10** (ground-borne vibration) and **Section 11** (ground-borne noise). Mitigation and management of impacts is detailed in **Section 14**. Residual impacts are discussed in **Section 15**.

Key issue & desired performance outcome	Specific assessment requirement	Addressed in this report
13. Noise and vibration – amenity. Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity. Increases in noise emissions and vibration affecting nearby properties and other sensitive receptors during operation of the project are effectively managed to protect the amenity and well-being of the community.	1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines.	Operational noise and vibration have been assessed in accordance with the SEARs, as detailed in **Section 8** and **9** (airborne noise), **Section 10** (ground-borne vibration) and **Section 11** (ground-borne noise).
		The assessment of noise and vibration from construction of the NS2B project is provided in a separate technical report (Appendix J of the EIS).
	2. The assessment must include consideration of impacts to sensitive receptors including small businesses, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Receptors potentially sensitive to noise and vibration are identified in **Section 6** and **Appendix A**.
		The characteristic of rail noise is discussed in **Section 10.6**
		An assessment of sleep disturbance in provided in **Section 10.4**
	3. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	No blasting is required for operation of the project.
14. Noise and vibration – structural Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on structural integrity of buildings and items including Aboriginal place and environment heritage. Increases in noise emissions and vibration affecting environmental heritage as defined in the *Heritage Act 1977* during the operation of the project are effectively managed.	1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers including small businesses, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Noise and vibration from the construction has been assessed separately in Appendix J of the EIS.
	2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	No blasting is required for operation of the project.

Source NSW Department of Planning and Environment, SEARs – Inland Rail Project North Star to NSW/Queensland Border (SSI 18_9371), 2018.

3.2 Referenced documentation

Based on the requirements of the SEARs, the assessment of noise and vibration from railway operations was undertaken with consideration to the guidelines listed in **Table 6**.

Table 6 Referenced noise and vibration guidelines

Document	Publisher	Application in the assessment
NSW Rail Infrastructure Noise Guideline (NSW RING), 2013.	NSW Environmental Protection Authority (NSW EPA)	- Noise assessment criteria for railway infrastructure projects. - Ground vibration assessment criteria for railway infrastructure projects. - Guidelines for the measurement, prediction and mitigation of railway noise.
Assessing Vibration: a technical guideline, 2006.	Office of Environment and Heritage (formerly NSW Department of Environment and Conservation)	- Establishment of assessment criteria for ground vibration. - Assessment methodologies for ground vibration.
Development near rail corridor and busy roads – Interim guideline. NSW DoP, 2008	NSW DPIE	Whilst included in the SEARs, this guideline does not apply to proponents of new or redeveloped rail infrastructure.

Source NSW Department of Planning and Environment, SEARs – Inland Rail Project North Star to NSW/Queensland Border (SSI 18_9371), 2018.

4 Environmental assessment criteria

4.1 Airborne noise

The most common form of noise experienced by people is termed 'airborne noise', indicating the noise travels through the air between the source, such as a railway, and the receptor. This is the primary form of noise that occurs adjacent to above ground level railway tracks.

Guidelines for the identification and assessment of airborne noise from railway operations are discussed below, including the airborne noise criteria applied by ARTC for the assessment and management of railway noise from the Project.

4.1.1 Rail Infrastructure Noise Guideline

The NSW Rail Infrastructure Noise Guideline (RING) has been used to assess (airborne) rail noise from the railway operations on the Project. Noise from railways and railway infrastructure covered under the RING includes:

- Train movements during the daytime and night-time, which includes noise from the propulsion of the rolling stock (usually diesel or electric locomotives) and wheel-rail noise associated with trains running on the tracks.
- Level crossing bells/alarms at road intersections and the use of train horns as safety and warning devices.
- The influence of specific track features such as bridges, tight-radius curves, turnouts and crossings.

The RING provides non-mandatory railway noise assessment criteria for sensitive receptors. Where the rail noise levels are above the assessment criteria, ARTC will investigate feasible and reasonable mitigation measures with the aim of reducing noise levels to meet the criteria and minimising potential noise impacts at sensitive receptors.

The project is categorised as a new rail line and the corresponding RING noise trigger levels for residential receptors are shown in **Table 7**.

Table 7 Airborne noise trigger levels for residential receptors

Type of development	Noise trigger levels (External)	
	Day (7.00 am to 10.00 pm)	Night-time (10.00 pm to 7.00 am)
New rail line development[1]	Predicted rail noise levels exceed:	
	$L_{Aeq(15hour)}$ 60 dBA	$L_{Aeq(9hour)}$ 55 dBA
	L_{AFmax} 80 dBA	L_{AFmax} 80 dBA

Note 1 A new rail line development is a rail infrastructure project on land that is not currently an operational rail corridor.

The railway noise criteria are specific to the daytime period of 7.00 am to 10.00 pm and the night-time period of 10.00 pm to 7.00 am. The noise assessment criteria are lower for the night-time period due to the greater sensitivity of communities to noise during the night-time.

The RING includes rail noise criteria for sensitive receptors other than residential land uses. The noise criteria for these receptors types is detailed in **Table 8**.

Table 8 Airborne noise assessment criteria for other sensitive receptors

Other sensitive receptors	Noise assessment criteria (when receptor premises are in use)[1]
Schools, educational institutions and childcare centres	$L_{Aeq(1 hour)}$ 40 dBA (internal)
Places of worship	$L_{Aeq(1 hour)}$ 40 dBA (internal)
Hospital wards	$L_{Aeq(1 hour)}$ 35 dBA (internal)
Hospital other uses	$L_{Aeq(1 hour)}$ 60 dBA (external)
Open space – passive use (e.g. parkland, bush reserves)	$L_{Aeq(15hour)}$ 60 dBA (external)
Open space – active use (e.g. sports field, golf course)	$L_{Aeq(15hour)}$ 60 dBA (external)

Note 1 A new rail line development is a rail infrastructure project on land that is not currently an operational rail corridor.

4.2 Ground-borne vibration guidelines

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.

4.2.1 Ground-borne vibration criteria for sensitive receptors

For intermittent events such as train passby events, the vibration dose value (VDV) is applied to assess potential impacts to human comfort. The VDV provides a cumulative measure of the vibration levels associated with all railway operations in a daytime or night-time assessment period. The VDV considers the combined effects of the level of the ground-borne vibration and the duration of vibration generating events and, as such, is suited for the assessment of transient sources such as train passbys.

The RING refers to the EPA's *Assessing Vibration: a technical guideline* (2006) for vibration criteria for rail projects, which are sources of intermittent vibration. The 'preferred' and 'maximum' VDVs for human comfort are shown in **Table 9**.

Table 9 Ground-borne vibration criteria for sensitive receptors

Building Type	Assessment Period	Vibration Dose Value[1] ($m/s^{1.75}$)	
		Preferred	Maximum
Critical Working Areas (eg operating theatres or laboratories)	Day or night-time	0.10	0.20
Residential	Daytime	0.20	0.40
	Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	Day or night-time	0.40	0.80
Workshops	Day or night-time	0.80	1.60

Note 1: The VDV accumulates vibration energy over the daytime and night-time assessment periods and is dependent on the level of vibration as well as the duration.

The vibration criteria in **Table 9** are for sensitive receptors buildings, some scientific equipment (for example, electron microscopes and microelectronics manufacturing equipment) can require more stringent design goals than those applicable to human comfort. A review of the current buildings in the noise assessment study area did not identify that vibration sensitive scientific equipment would likely be in use at the sensitive receptors.

4.2.2 Ground-borne vibration criteria for heritage sites

Buildings which possess architectural, aesthetic, historic or cultural values may have certain sensitivities to vibration with respect to their long term preservation. In lieu of specific ground-borne vibration criteria for heritage sites in the documents referenced in the SEARs, a discussion of various standards relevant to vibration and its effects on buildings is provided in **Table 10**.

The Peak Particle Velocity (PPV) metric is applied as a measure of the maximum movement of the particles in the ground as a result of vibrations created from sources such as train passbys. It is commonly applied to evaluate the potential response of buildings and structures when exposed to vibration energy.

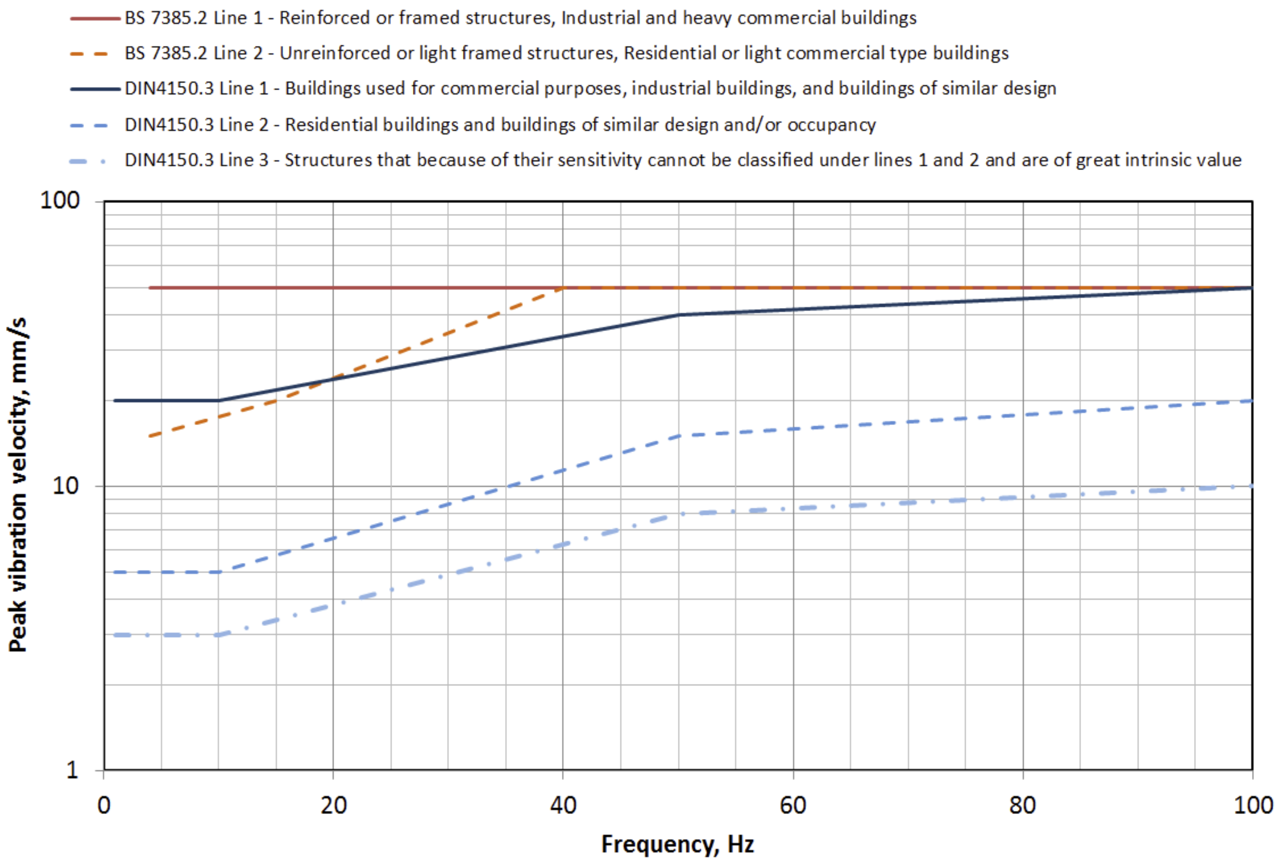
At the EIS stage, it is not possible to forecast with reasonable certainty the dominant (or resonant) frequencies of vibration at each building during train passby events. A vibration criteria, irrespective of frequency, essentially the lowest value, is an appropriate assessment objective.

Based on **Table 10**, the relevant PPV guidance values for assessment of ground-borne vibration at heritage sites are presented in **Figure 5**. From this figure it can be seen that Line 3 of German Standard DIN 4150.3 is the lowest, most conservative vibration level, including where the vibration levels for Line 2 of British Standard BS 7385.2 are reduced by 50% where there is concern over continuous vibration generating 'dynamic magnification' resonance effects.

Table 10 Referenced standards associated with cosmetic building damage risk

Reference	Notes
British Standard BS 5228.2[3] British Standard BS 7385.2[4]	This standard notes that BS 7385-2 and BS ISO 4866:2010 provide guidance on vibration measurement, data analysis and reporting as well as building classification and guide values for building damage. BS 7385.2:1993 provides frequency dependent threshold levels which are judged to give a minimal risk of vibration-induced damage.
German Standard DIN 4150.3[5]	DIN 4150.3 prescribes levels as “safe limits”, up to which no damage due to vibration effects has been observed for the class of building. “Damage” is defined by DIN 4150.3 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls DIN 4150.3 also states that when vibration levels higher than the “safe limits” are present, it does not necessarily follow that damage will occur. Site specific criteria may be determined in conjunction with professional civil and/or structural engineering input based on the existing level of building condition and serviceability.

Figure 5 Guidance values for short term vibration



3 British Standard BS 5228.2-2009/2014-Code of practice for noise and vibration control on construction and open sites–Part 2: Vibration
4 British Standard, BS7385-2:1993 Evaluation and measurement for vibration in buildings
5 DIN 4150-3 2016 Structural Vibration Part 3 – Effects of vibration on structures

The German Standard DIN 4150.3 recommends a V_{PPV} objective of 3 mm/s at low frequencies increasing to around V_{PPV} 8 mm to 10 mm/s at frequencies above 50 Hz for sensitive structure with great intrinsic value (refer Line 3 DIN 4150.3). The 3 mm/s vibration level has been adopted as the vibration objective to provide conservative assessment of potential impacts to heritage sites.

4.3 Ground-borne noise guidelines

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 a low frequency rumble inside buildings. This is termed as ground-borne or regenerated noise.

The RING provides ground-borne noise vibration criteria for rail infrastructure projects which apply where internal ground-borne noise levels are higher than noise transmitted through the air. The ground-borne noise trigger levels are provided in **Table 11**.

Table 11 RING ground-borne noise trigger levels

Sensitive Land Use	Time of Day	Internal Noise Trigger Level (dBA)
Development increases existing rail noise levels by 3 dBA or more ***and*** resulting rail noise levels exceed:		
Residential	Day (7am to 10pm)	$L_{Amax(slow)}$ 40
	Night (10pm to 7am)	$L_{Amax(slow)}$ 35
Schools, educational institutions, places of worship	When in use	$L_{Amax(slow)}$ 40 - 45

The RING does not include specific ground-borne noise criteria for other sensitive land uses. Based on assessment of ground-borne noise on other rail infrastructure projects, the ground-borne noise design objectives in **Table 12** have been used to assess the potential impacts at other sensitive receptors other than those identified in the NSW RING.

Table 12 Ground-borne noise objectives for other sensitive receptors

Receptor type	Time of day	Noise trigger level
Medical institutions	When in use	$L_{Amax(slow)}$ 40 to 45 dBA
Retail areas	When in use	$L_{Amax(slow)}$ 50 dBA
General office areas	When in use	$L_{Amax(slow)}$ 45 dBA
Private offices and conference rooms	When in use	$L_{Amax(slow)}$ 40 dBA
Cinemas, public halls and lecture theatres	When in use	$L_{Amax(slow)}$ 35 dBA

Note The above criteria have been adopted by SLR as a guide to identifying potential impacts based on the sensitive of the receptor type.

5 Assessment methodology

The assessment of noise and vibration from the railway operations applied the following methodology.

- A desktop survey was undertaken to identify sensitive receptors within a 2 km radius of the Project alignment. An area greater than 120 km^2 (>12,000 hectares) was applied as the initial assessment area for railway noise and vibration.
- The 2 km study area was constrained to the limits of the Project extents. Railway noise and vibration levels at sensitive receptors near to the Project extents are being assessed on the corresponding N2NS and B2G projects on Inland Rail.
- The applicable assessment criteria for airborne noise, ground-borne noise and ground-borne vibration were determined with reference to the relevant regulatory guidelines defined in the SEARs.
- Noise and vibration assessment scenarios were determined for the proposed rail operations based on the project description and the requirements of the SEARs. The year 2025 was applied for assessment of noise and vibration at the commencement of operations and the year 2040 was adopted as the year where rail operations would be at the designed freight capacity.
- The principle sources of airborne noise, ground-borne noise and ground-borne vibration from the operation of rollingstock were identified and each source was assigned an appropriate emission level.
- A detailed noise prediction model was developed for the calculation of airborne railway noise levels from rollingstock operations and associated sources of noise, including; level crossings and idling trains at crossing loops.
- The potential ground-borne vibration and ground-borne noise levels from rollingstock operations on the ground-level track were calculated based on ground-borne vibration levels from comparable rail freight movements.
- The predicted airborne noise, ground-borne vibration and ground-borne noise levels were evaluated against the assessment criteria and the requirements of the SEARs.
- The investigation of feasible and reasonable mitigation measures was triggered where the predicted levels were above the assessment criteria.
- The consideration of mitigation measures was not constrained by compliance to the assessment criteria, options for mitigation have been recommended as part of the overall strategy to minimise the potential noise and vibration impacts of the Project through the implementation of best practice environmental management.
- The potential for residual impacts at sensitive receptors, after mitigation is implemented, was evaluated and recommendations were prepared for future noise and vibration assessment and monitoring works through the detail design stage.

6 Existing environment

6.1 Sensitive receptors

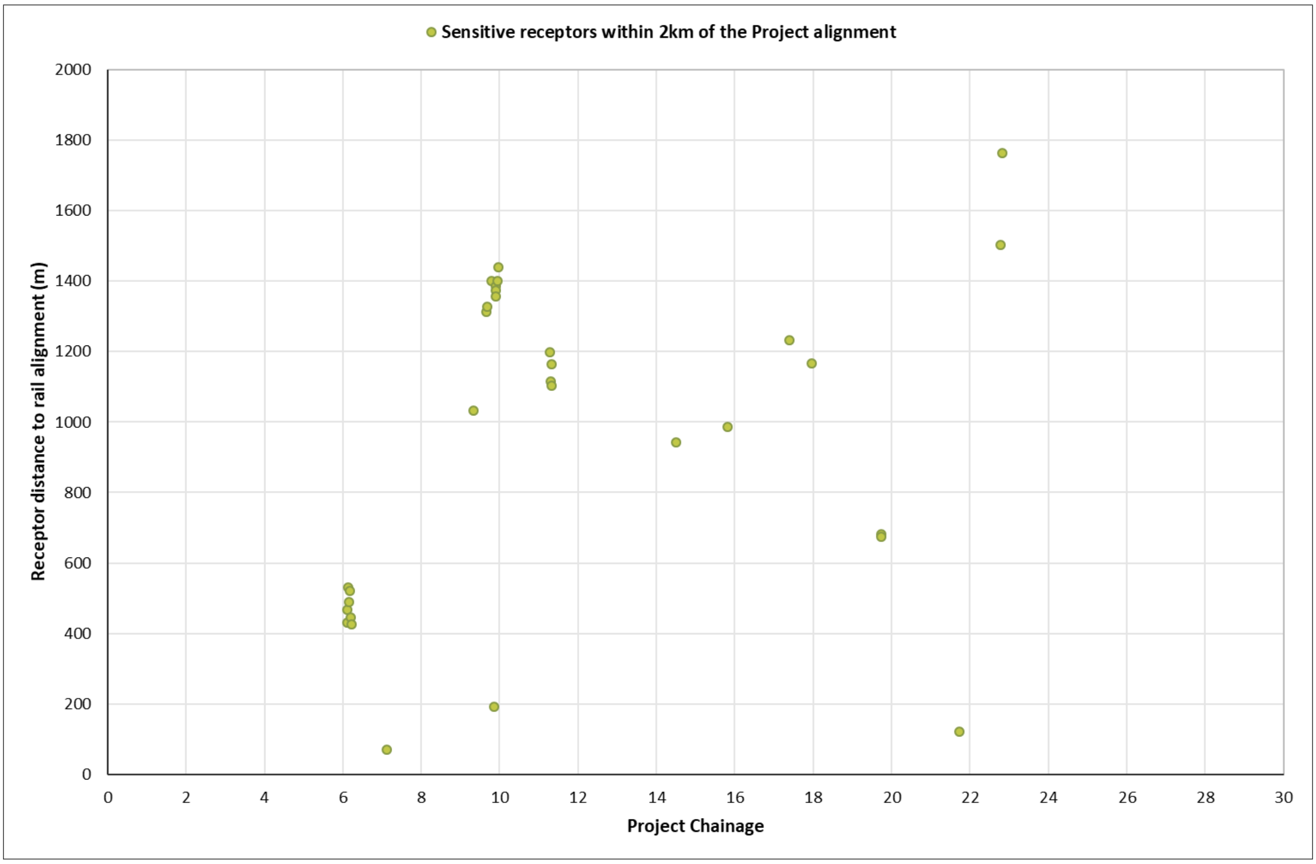
Receptors potentially sensitive to noise and vibration have been categorised as residential dwellings, commercial/industrial buildings, or 'other sensitive' land uses which can include educational institutions, childcare centres, medical facilities, places of worship and alike.

To determine the sensitive receptors included in the assessment of railway noise and vibration, all buildings over 9 m^2 within the 2 km radius of the Project alignment were identified using a national geospatial dataset of buildings from 2018. A total of 85 buildings were identified within the 2 km study area and each building was assigned a unique identification number for the purpose of the assessment.

The buildings that were clearly identified from aerial imagery as non-sensitive, such as hoppers, sheds and warehouses were retained in the assessment as they could provide screening of rail noise levels at nearby sensitive receptors. Railway noise and vibration levels were not assessed at the non-sensitive buildings.

Of the buildings identified, a total of 31 receptors were identified as being potential noise and vibration sensitive receptors within the 2 km study area. The majority of the assessed sensitive receptors are within 1 km of the Project alignment. The location of these sensitive receptors along the Project railway alignment is presented in **Figure 6**. The individual sensitive receptors are detailed in the route maps provided in **Appendix A**.

Figure 6 Distribution of sensitive receptors along the Project alignment



Note Some receptors are in the same location and the markers in the above scatter plot may represent more than one receptor.

6.2 Heritage sites

The cultural heritage assessment for the Project identified the 17 non-indigenous sites in **Table 13** as sites of potential heritage significance. Details of each site are provided in *Appendix F: Non-Indigenous Cultural Heritage Technical Report*[6] prepared for the EIS.

The Boggabilla Station site was located over 10 km from the NS2B track centreline and at this distance was not subject to an assessment for potential vibration impacts. A further 13 sites were identified as being within the either the disturbance footprint of the Project or the future rail corridor. It is assumed these sites will either be removed or mitigated as part of the Project and were not considered further in this assessment.

The remaining three sites (NS2B-19-H3, NS2B-19-H5 and NS2B-10-H6) were a tree with a marking and former shearer facilities now in substantial disrepair.

Table 13 Non-Indigenous heritage sites

Site ID[1]	Site name	Site description	Proximity to the Project
NS2B-19-H1	Boggabilla Train Station	Railway infrastructure	10 km from the NS2B alignment
NS2B-19-H2	Logger's Camp	Small ceramic artefacts	Within the rail corridor
NS2B-19-H3	Survey Mark	Tree with markings	65 m
NS2B-19-H4	Whalan Creek Rail Bridge	Railway infrastructure	Within the rail corridor
NS2B-19-H5	Shearing Shed	Shed and windmill in disrepair	Within the disturbance footprint and 120 m from the rail corridor.
NS2B-19-H6	Shearer Accommodation	Shed and windmill in disrepair	
NS2B-19-H7	Modern Roadside Memorial	Metal cross with flowers	Within the disturbance footprint
NS2B-19-H8	Old Boggabilla/ North Star Road	Disused road and culvert	Intersects with the rail corridor
NS2B-19-H9	Wearne Siding	Remnants of the platform	Within the disturbance footprint
NS2B-19-H10	Wearne Siding Sign	Street sign	Within temporary disturbance footprint
NS2B-19-H11	Fettlers Camp 1	Industrial artefacts	Within the rail corridor
NS2B-19-H12	Fettlers Camp 2	Industrial artefacts	Within the rail corridor
NS2B-19-H13	Fettlers Camp 3	Industrial artefacts	Within the rail corridor
NS2B-19-H14	Fettlers Camp 4	Industrial artefacts	Within the rail corridor
NS2B-19-H15	Mingle Siding	Railway infrastructure	Within the rail corridor
NS2B-19-H16	Back Creek Rail Bridge	Railway infrastructure	Within the rail corridor
NS2B-19-H17	North Star Siding Sign	Street sign	Outside the NS2B project area

Source Appendix F: Non-Indigenous Cultural Heritage Technical Report.

6.3 Existing noise environment

A baseline environmental noise survey was undertaken in 2018 to quantify and characterise the noise environment surrounding the Project alignment. The noise survey was conducted by the Future Freight Joint Venture to support the assessment of noise from the construction of the Project. A summary of the survey is provided below with the noise monitoring survey detailed in the Non-operational Noise and Vibration technical report (Appendix J of the EIS).

[6] Inland Rail: Inland Rail North Star to NSW/QLD Border, Appendix F – Non-Indigenous Cultural Heritage Technical Report.

Existing noise levels were monitored at five locations selected to be representative of the nearest communities to the Project. The monitoring surveys were principally to define the daily environmental noise levels rather than specifically quantify existing railway noise levels. The Rating Background Levels (RBL) determined from the monitoring survey are summarised in **Table 14** and confirm that the existing noise levels are generally low, typically below 40 dBA during the daytime and evening and below 35 dBA during the night-time.

The RBLs are characteristic of the steady-state rural noise environments where the main sources of noise are local road traffic, residential activities and natural sources, such as windblown vegetation and bird song. The noise levels highlight the potential sensitivity of the environment to the introduction of additional sources of noise and this was considered by ARTC when proposing the noise management criteria for the Project.

Table 14 Existing environmental noise levels

Monitoring location	Rating background levels, dBA			Ambient LAeq noise levels, dBA		
	Daytime	Evening	Night-time	Daytime	Evening	Night-time
NS2B_NL_01	34	32	25	57	53	48
NS2B_NL_02	26	28	34	47	49	45
NS2B_NL_03	30	26	23	51	46	45
NS2B_NL_04	32	46	30	56	55	49
NS2B_NL_05	33	31	26	54	52	52

Note 1 Daytime is 7.00 am to 6.00 pm, evening is 6.00 pm to 10.00 pm and night-time is 10.00 pm to 7.00 am.
Source Inland Rail: North Star to Border, Appendix J Non-Operational Noise and Vibration Assessment Technical report.

7 Railway noise modelling

7.1 Prediction of railway noise

The noise emissions from the railway operations on the Project were calculated through detailed noise prediction modelling using the SoundPLAN (version 7.4) noise prediction modelling software. To calculate noise emissions from the operation of rollingstock, the model applied the Nordic Rail Traffic Noise Prediction Method (Kilde 130) methodology[7]. Both the SoundPLAN modelling software and the Nordic prediction methodology are widely applied in Australia for the prediction of railway noise levels.

The noise prediction model included a detailed terrain model to develop a 3-dimensional (3D) representation of the Project and the 2 km study area. The terrain datasets comprised elevation contours of the existing ground and the Project designs at 0.5 m to 2 m intervals to recreate in detail the rail and road civil earthworks, Project 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 base of the elevated structures was digitised to represent the concrete spans that form each bridge and viaduct with the rail track (inclusive of ballast) modelled on top of the spans.

[7] M. Ringheim, 1984, *Kilde Report 130 – Background Material for the Nordic Rail Traffic Noise Prediction Method*.

The buildings for the sensitive receptors and non-sensitive structures were set to the mean ground height. Building heights were determined from the referenced geospatial database, where the building height was not reported a 5 m building height was adopted as being representative of the single storey residences that are common in rural areas. The adopted building height would be conservative for non-sensitive buildings and structures, such as grain hoppers, sheds and warehouses which could shield railway noise.

Railway noise levels are typically calculated at a height of 1.5 m or 1.8 m above the finished floor level of the ground floor. In lieu of the known building construction for the 31 sensitive receptors a conservative approach was adopted to assess noise levels at 2.4 m above ground level at the centre of each façade on the sensitive receptor buildings.

The adopted receptor calculation height considered that many properties in the rural environment are elevated on stilts or stumps. As such, the ground floor of the properties is likely to be above the conventional 1.5 m or 1.8 m receptor heights.

Furthermore, the majority of the rail tracks on the Project are elevated above the surrounding ground level, either on constructed earthworks or the bridges and viaducts. The 2.4 m receptor calculation height also facilitated calculation of railway noise with a more direct line of sight between the rails and the receptor facades.

All external railway noise predictions were adjusted by +2.5 dBA to determine the façade corrected noise level, as required by the RING.

The immediate area 600 m either side of the rail corridor was modelled with a ground absorption coefficient of zero (0) to be representative of a hard, reflective ground surface. Further than 600 m from the rail corridor a ground absorption coefficient of 0.6 was adopted to be representative of the mixed soft and hard ground areas within the rural environment beyond the rail corridor.

To confirm the suitability of the noise modelling on the NSW sections of the Inland Rail program, a survey of existing railway noise levels was undertaken in 2019 at three locations in southern NSW where existing rail freight operations are comparable to the proposed rail freight on the Project. Details of the monitored railway noise levels and the noise model verification are provided in **Appendix B**.

7.2 Daily railway operations

The daytime and night-time train movements on the Project were provided by ARTC for the assessment of operational railway noise for the year the Project commences (2025) and the design year (2040). The daily train movements associated with the Project are detailed below and applied the following principles.

- The daily train numbers include the existing freight services that will be accommodated on the Project rail corridor.
- The train movements in each time period are the combined northbound and southbound movements. For the purpose of the assessment, the northbound and southbound rail movements were evenly distributed in each direction.
- The noise assessment only considers whole trains so the train movements in each daytime and night-time period were rounded up to integers. The approach resulted in the daily train numbers being marginally higher than the actual daily train movements forecast for the Project.

The daily train movements detailed in **Table 15** for project opening in year 2025.

Table 15 Daily train movements on the Project (year 2025)

Train services	Train movements[1]		
	Daytime	Night-time	Total 24-hour
Year 2025 project commencement			
Inland Rail Express	2	2	4
Inland Rail Superfreighter	5	3	8
Narrabri Export Containers	1	1	2
Queensland grain, Narrabri to Fisherman Island	1	1	2
Queensland cotton	0	1	1
Daily totals year 2025	**9**	**8**	**17**

Note 1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

The daily train movements are detailed in **Table 16** for the design year (year 2040).

Table 16 Daily train movements on the Project (year 2040)

Train services	Train movements[1]		
	Daytime	Night-time	Total 24-hour
Year 2040 design year			
Inland Rail Express	2	2	4
Inland Rail Superfreighter	7	4	11
Narrabri Export Containers	1	1	2
Queensland grain, Narrabri to Fisherman Island	1	2	3
Queensland cotton	0	1	1
Daily totals year 2040	**11**	**10**	**21**

Note 1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am.

7.3 Operational railway noise model inputs

7.3.1 Track gradient and locomotive notch settings

To control the speed of the trains, the locomotives have a series of throttle controls, known as notches. Most locomotives have up to eight notches and follow the operational principles below. The notch setting of a locomotive is related to the noise emission, with higher notch settings generally causing higher noise levels.

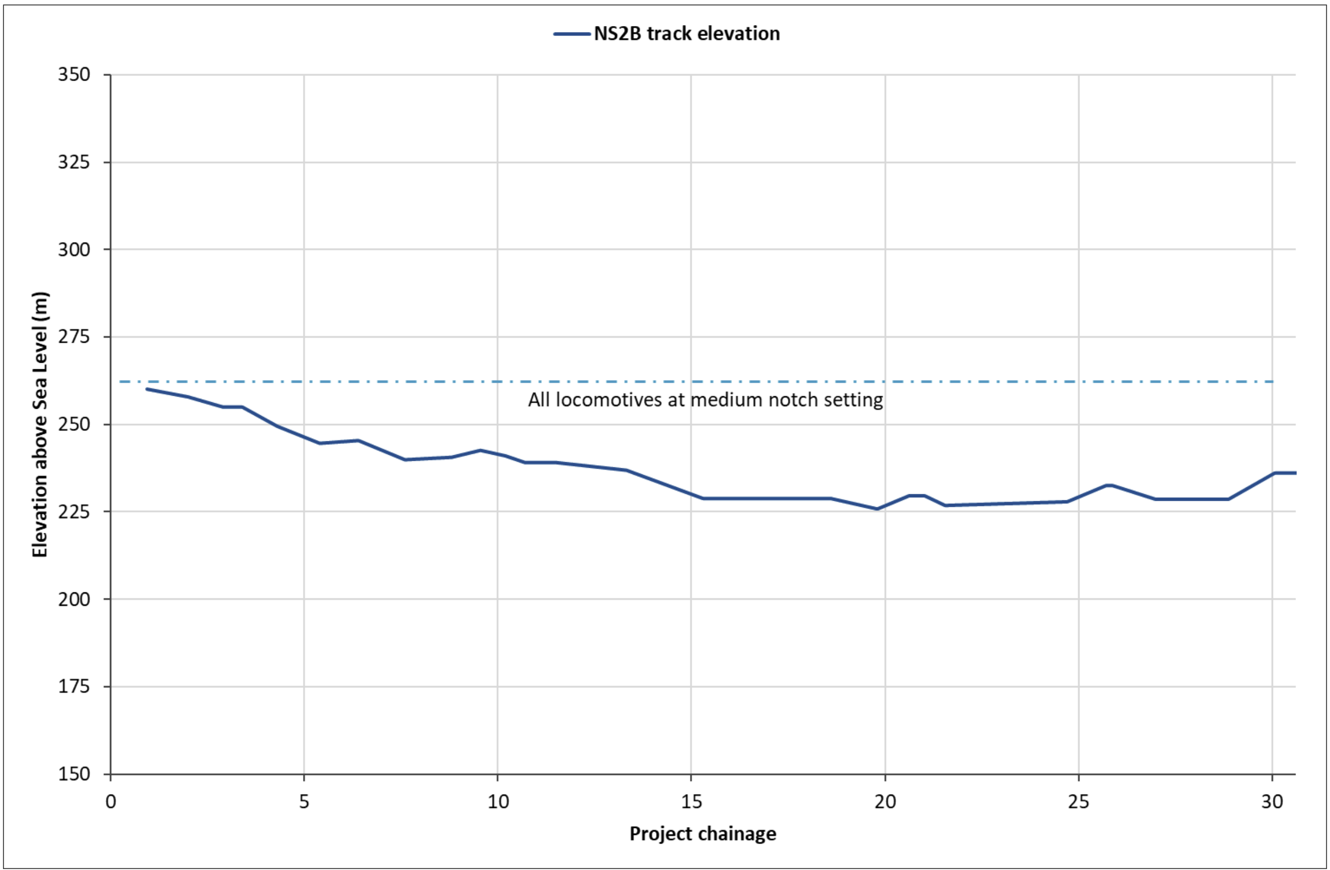
- When operating on relatively flat or moderate gradients the locomotive would generally be operated at a medium notch setting (notch settings 3, 4 or 5).
- On downhill gradient track trains are often in low notch setting or can use dynamic braking where the traction motors that drive each locomotive axle are used to slow the train. Dynamic braking can be a source of additional noise as the radiator cooling fans are used to dissipate heat energy.
- For uphill gradients the load is increased which requires high notch settings (notch setting 6, 7 or 8). Often on uphill sections the train can be operating at lower speeds but at a higher notch setting.

At this stage of the design, the specific notch operations of the locomotives as they traverse the alignment was not confirmed. For the purpose of assessment, a gradient of 1 in 100 or less was applied to identify areas where uphill and downhill sections may require a high notch setting or dynamic braking.

In practice, the selection of notch settings and dynamic braking will be determined by the driver and the 1 in 100 gradient was adopted to provide a conservative allowance for such events.

The track elevation for the Project and the notch settings and dynamic braking applied in the assessment of airborne noise are shown in **Figure 7**.

Figure 7 Track elevation of locomotive notch setting



7.3.2 Train speeds

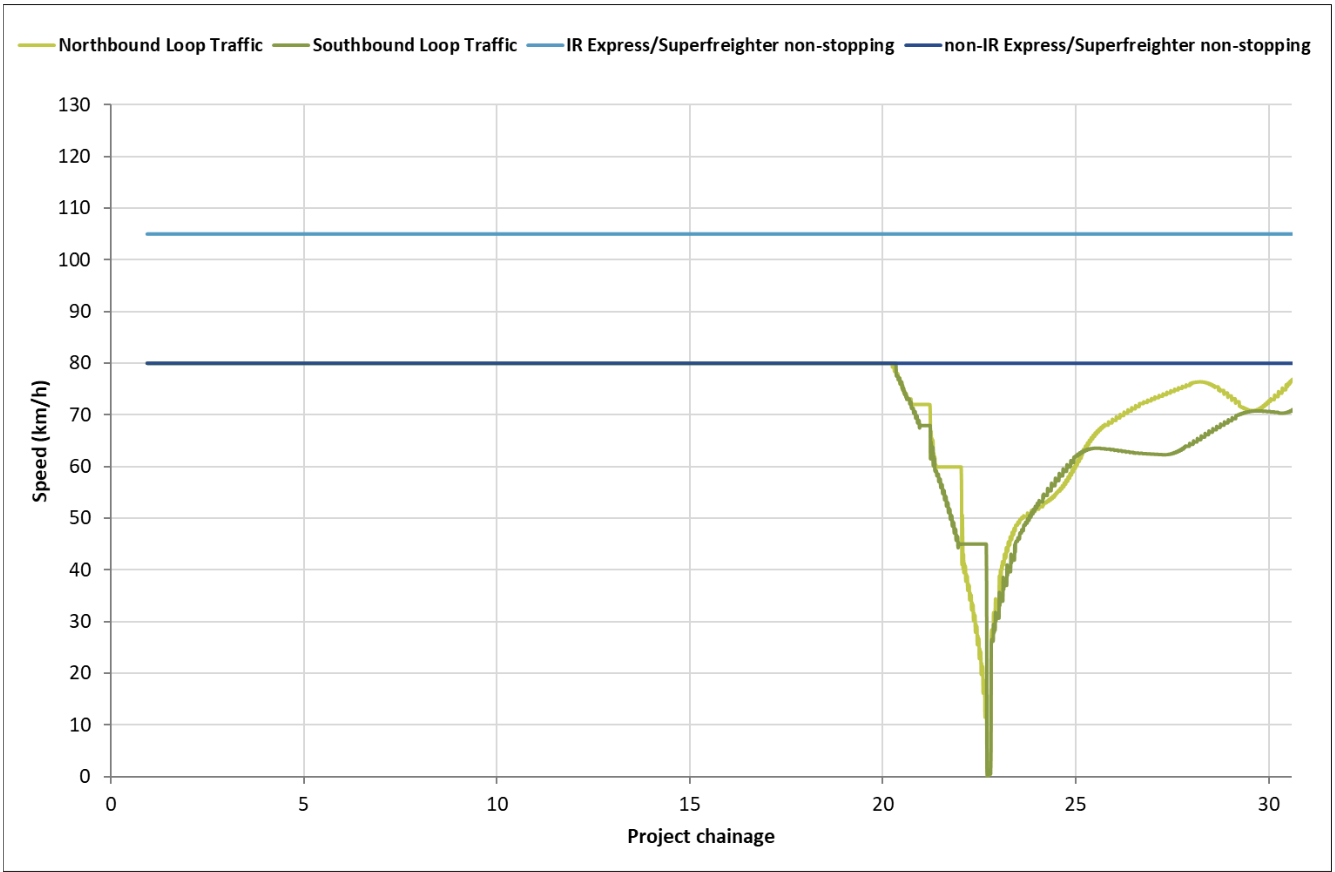
The trains on the Project are required to operate at their designated line speed of up to 105 km/h for the Inland Rail Express and Inland Rail Superfreighter services. The other rail services will operate at up to 80 km/h.

The train speeds supplied by ARTC, and presented below, included a modelled 8% reduction in the designated line speed to account for driver behaviour. The train speed will not be constant throughout the alignment, and the noise modelling applied speed profiles for each train type with the train speed detailed at 10 m intervals along the Project alignment.

To manage the railway operations, some trains will be required to slow down to access the crossing loop and then, on departure from the crossing loop, accelerate back up to the line speed.

Examples of the train speed profiles adopted in the noise modelling are presented in **Figure 8**. The acute changes in train speed are associated with entry to and exit from the crossing loop.

Figure 8 NS2B track speed profiles



7.3.3 Train lengths and locomotive classes

The length of each train type and the number of locomotives for the future railway operations with the Project is shown in **Table 17**. The train data was derived from ARTC's forecast daily train movements for the Inland Rail Program.

Table 17 Train lengths and locomotive class

Train service	No. locomotives	Total locomotive length	Length of wagons	Total train length
Inland Rail Express (NR class)	3	66 m	1,680 m	1,746 m
Inland Rail Superfreighter (SCT class)	2	44 m	1,700 m	1,744 m
Narrabri Export Containers (82 class)	2	44 m	580 m	624 m
Queensland grain, Narrabri to Fisherman Island (PR22L class)	3	54 m	800 m	854 m
Queensland cotton (PR22L class)	3	54 m	800 m	854 m

7.3.4 Source noise levels

Modelling of noise from railway operations requires defined source noise emission levels for the various classes of locomotives and rail wagons proposed to operate on the Project. The Transport for NSW (TfNSW) Asset Standards Authority (ASA) Stage III Rail Noise Database was referenced by this assessment to provide a source noise emission inventory for the locomotive classes proposed for Inland Rail. The TfNSW database defines reference noise levels for Australian rollingstock for use in commercial noise modelling software packages to conduct airborne noise predictions under a range of operating scenarios.

The database contains over 840 measurements of freight and passenger rail sources, including rail freight proposed on the Project. The noise levels were measured and analysed in line with procedures outlined in specific railway noise standards; International Standard ISO 3095[8] and Australian Standard AS 2377[9].

As part of the assessment, the rail source noise emission levels derived from the TfNSW ASA database were validated against the ARTC Pollution Reduction Programme Rail Noise Study, which was prepared by ARTC to evaluate locomotive noise as part of ARTC's pollution reduction program.

The Inland Rail Program is proposing to introduce the PR22L class locomotives on to the rail network. To address the information gap in the database, the referenced sound exposure levels (SEL) and L_{Amax} noise emission levels for the PR22L class locomotive were determined from measurement of train passbys where the locomotive class currently operates on the TasRail network in Tasmania.

The following principles were applied when determining the source noise emission levels for rollingstock:

- The SEL and maximum (L_{Amax}) noise emission levels are derived for each locomotive and set of wagons i.e. per unit.
- Noise emission levels are presented for a standardised train speed of 80 km/h at a distance of 15 m from the track centreline.
- The noise levels for freight wagons account for a variety of wagon classes. The freight wagon reference noise levels are representative of typical wagon operations, and do not include a correction for increased noise levels that can result from unique operational influences (such as heavy braking) or significant defects (such as major wheel flats or bearing failures).
- Locomotive noise is determined from the required power output (notch setting) and only the rolling (wheel-rail) noise emissions for the wagons have been normalised to a speed of 80 km/h.
- The SEL noise level for an individual locomotive or consist of wagons is the logarithmic average of the referenced noise emissions levels and the L_{Amax} emission level is the overall 95th percentile L_{Amax} value derived from the database of noise measurements for each locomotive class or wagons.
- The source noise levels assume the track is in good condition and that the running surface of the rail head is free of defects. Wheel tread condition is also assumed to be in good to fair condition.

Conservatively, locomotive noise emissions are considered to be dominated by engine, cooling fans and exhaust systems, and for this reason the locomotive noise source is set to 4.0 m above the top of rail height to broadly represent the actual emissions of those items.

[8] International Standards, 2013. ISO 3095 Railway applications – Acoustics – Measurement of noise emitted by railbound vehicles.

[9] Australian Standards, 2002. AS 2377 Acoustics – Methods for the measurement of railbound vehicle noise.

Noise emissions from wagons are considered to be dominated by 'rolling noise' generated equally by wheels and rail, so wagon noise emissions are set to the top of the rail height. On the basis that trains with defective wagons would not regularly be traversing the Project, the noise emission database does not account for local track defects, wheel flats or similar defects.

The referenced noise emission levels assume each train emits the same noise level and is therefore a typical worst-case noise generating event. Similarly, the method does not allow for deriving an arithmetic average of a range of maximum (L_{Amax}) noise levels for each train type as this could potentially result in lower daytime and night-time maximum noise level predictions.

Discussed in **Section 7.3.1**, the locomotive settings (notches) were assigned based on the gradient of track, which provided specific noise emissions based on the features of the railway infrastructure and its influence on the operation of the trains.

Table 18 Source rail noise emission levels

Rollingstock category	Rail source elevation	Train class	Reference length	Gradient	Reference noise level, dBA[1]	
					SEL	L_{Amax}
Diesel electric locomotives	4.0 m above the top of rail	NR	22 m	Flat	85	90
				Downhill	84	90
				Uphill	90	94
		GT46C[2]	21 m	Flat	84	88
				Downhill	84	91
				Uphill	89	92
		82	22 m	Flat	83	89
				Downhill	84	94
				Uphill	88	94
		PR22L	18 m	Flat	84	91
				Downhill	84	94
				Uphill	89	94
Wagons (all consist)	Top of rail	All	1,000 m	n/a	100	90

Note 1: Reference noise levels at 80 km/h, 15 m distance from track centreline, 1.5 m above top of rail, and ISO 3095 compliant track roughness.

Note 2: GT46C ACe model locomotive encompasses SCT, LDP, TT, WH, GWA, and SSR class designations.

7.3.5 Consideration of double-stack container freight

The Project will operate some trains with containers on wagons in a double-stacked configuration. Concerns were raised by stakeholders and the community that double stacking the containers could lead to significantly different wagon noise emissions. The potential noise emission levels from double-stacked containers were investigated as part of this assessment and the key outcomes are outlined below.

International Standard ISO 3095 provides general guidance on the difference in noise level resulting from changes in axle loads and notes that an approximate doubling of axle loads (increased weight) may result in a reduction in noise levels of around 1 dB in L_{Aeq} terms. A variance in noise emission of 1 dB is negligible in the context of other factors which can affect rolling noise and vibration emission levels, such as wheel and track condition, speed and unsprung mass.

To support the assessment of noise on the Project, a noise and vibration monitoring survey was undertaken to investigate the potential influence of single and double stacked containers on noise and vibration emissions from freight trains. The details of the survey are provided in **Appendix C** and the survey determined the following:

- Consistent with ISO 3095, individual wagons with double-stacked containers have L_{Aeq} noise levels approximately 1 to 2 dB less than the individual wagons with single-stacked containers.
- Overall train passby noise levels are not significantly reduced by wagons with double-stacked containers given the minimal change in rolling noise emissions from the wagons.
- The loading of individual trains can substantially vary both in terms of the number of wagons with single-stacked and double-stacked containers but also the weight of each container on the train will vary from empty to fully loaded (a typical range of 3 to 30 tonnes).
- The overall passby noise levels, particularly L_{Amax} noise levels, are more influenced by factors other than the configurations of the containers on individual wagons.

On the basis of the above, correction factors to account for the potential configuration of containers on the wagons were not applied to the source noise emission levels in **Table 18**.

7.3.6 Track feature corrections

Impact noise from rail discontinuities such as turnouts, expansion joints or rail defects can increase noise levels from trains and are heard as impulsive noise as each train wheel passes over the discontinuity. Noise modelling correction factors were applied at each turnout to account for potential impact noise during the train passbys.

The elevated structures on the Project are proposed to be ballasted concrete bridges and viaducts. Consistent with guidelines for noise prediction modelling, the rail noise emissions for the ballast track on the concrete bridges and viaducts were assumed to have noise emission levels and characteristics as the ballasted track at ground level.

The Project designs do not include tight radius curved track, so the noise modelling did not apply acoustic correction factors for curving noise.

The railway noise level corrections in **Table 19** were included in the railway noise prediction modelling to account for the potential influence of the rail infrastructure on the wheel-rail noise emissions.

Table 19 Noise model rail infrastructure corrections

Track feature and infrastructure	Modelling correction for wheel-rail contribution, dBA	
	SEL	LAmax[1]
Ballasted concrete rail bridges	0	0
Turnouts	+6	+6
At-grade active level crossings with the road network	+3	+3

Note The correction factors for tight-radius curved track are based on measurements and research from rail freight networks in Australia.

7.3.7 Level crossings

The noise assessment assumed all active level crossings included noise sources during each train passby for the crossing alarm bells and approaching train horns. The passive level crossings only included the train horns as noise sources.

At each active level crossing the noise sources included; a single alarm bell and two train horn source emissions, one located 100 m either side of the crossing to account for trains approaching from either direction. A source height of 2.0 m above ground level for the crossing alarm bells and 4.0 m above ground level was applied for the train horns.

The Nordic railway noise prediction methodology is specific to the rolling noise emissions. To calculate noise levels from the level crossing alarm bells and train horns at sensitive land uses, the International Standard ISO 9613-2[10] method for calculating the outdoor noise propagation was applied.

The ISO method calculates noise levels with default meteorological conditions favourable for downwind propagation of noise (wind speeds between approximately 1 m/s and 5 m/s) or under a moderate ground-based temperature inversion.

The noise modelling applied the source noise levels for alarm bells and train horn detailed in **Table 20**. The noise levels were referenced from SLR's measurement of train horn and alarm bell events on existing freight corridors.

Table 20 Level crossing and train horn source emission levels

Source	Noise emission level (LAeq) at 15 m, dBA										
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	16 kHz	Overall
Alarm bell	26	29	43	34	42	65	70	57	35	21	71
Train horn	38	52	68	81	93	98	95	92	82	62	101
Source	**Noise emission level (LAmax) at 15 m, dBA**										
	31.5 Hz	**63 Hz**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**	**8 kHz**	**16 kHz**	**Overall**
Alarm bell[1]	31	35	48	46	57	68	73	60	45	33	74
Train horn[2]	43	57	73	86	98	103	100	97	87	67	106

Note 1 LAeq noise level is for an alarm bell event 20-seconds in duration prior to the noise of the train becoming the dominant noise contribution and masking the alarm bell noise contribution.

Note 2 LAeq noise level for a train horn event 2-seconds in duration.

7.3.8 Train movements within the crossing loops

For the purpose of assessment, it has been assumed that approximately one in four trains per daytime or night-time period would access the crossing loop and each train could be held at the crossing loop for up to 1-hour.

The details of the loop operations used in the noise prediction modelling are shown in **Table 21**.

Table 21 Proposed crossing loop occupancy

Assessment scenario	Number of trains accessing the loop per period		Total hours occupancy time per period	
	Daytime	Night-time	Daytime	Night-time
Year 2025	2	2	2	2
Year 2040	3	3	3	3

[10] International Standards, 1996. ISO 9613-2:1996, Acoustics – attenuation of sound during propagation outdoors – Part 2: General method of calculation.

At a crossing loop the train will come to a complete stop from the main line track and idle until the train is signalled to return to the main line track. The assessment of airborne noise considered the noise emissions from the train locomotive engines idling whilst the train has stopped as well as short-lived noise events such as wagon bunching and stretching, which results in contact noise as the wagons come together.

For the purpose of assessing typical worst-case noise levels, the noise modelling included the faster and longer Inland Rail Express and Inland Rail Superfreighter on the main line track with the other general freight types held on the crossing loops.

The noise emission for an individual locomotive at idle was modelled as 70 dBA at a distance of 15 m. Because the idling of locomotive engines is a steady-state continuous noise emission, the emission level was referenced for the L_{Aeq} and L_{Amax} noise metrics. Acknowledging that trains can access each crossing loop from either direction, the noise modelling considered idling locomotives at both extents of each crossing loop.

The noise emission level was applied as a contribution to the L_{Amax} level as the short-lived nature of bunching noise (1 to 2 seconds per event) would not be sufficient to influence the overall daily L_{Aeq} noise levels.

The noise prediction modelling for the crossing loops applied the ISO prediction methodology and each idling locomotive and bunching noise event was modelled as individual point noise sources. The bunching sources were modelled at approximately 300 m intervals to anticipate the potential for such events along the length of the train.

The noise sources for the idling trains and wagons bunching referenced the source noise emission levels detailed in **Table 22**.

Table 22 Crossing loop source emission levels

Source	Noise emission level (L_{Aeq}/L_{Amax}) at 15 m, dBA										
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	16 kHz	Overall
Idling train	47	52	47	47	57	58	69	46	39	21	70
Source	**Noise emission level (L_{Amax}) at 15 m, dBA**										
	31.5 Hz	**63 Hz**	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**	**8 kHz**	**16 kHz**	**Overall**
Bunching	51	63	71	62	53	56	53	52	48	40	72

8 Airborne railway noise levels – Project opening 2025

8.1 Overview

The predicted daytime and night-time railway noise levels for the commencement of railway operations in Year 2025 are detailed in **Appendix D**. The railway noise levels are provided as tabulated noise level predictions at individual sensitive receptors and maps of railway noise contours for the Project alignment. The assessment of daytime, night-time and maximum railway noise levels is discussed in the following sections.

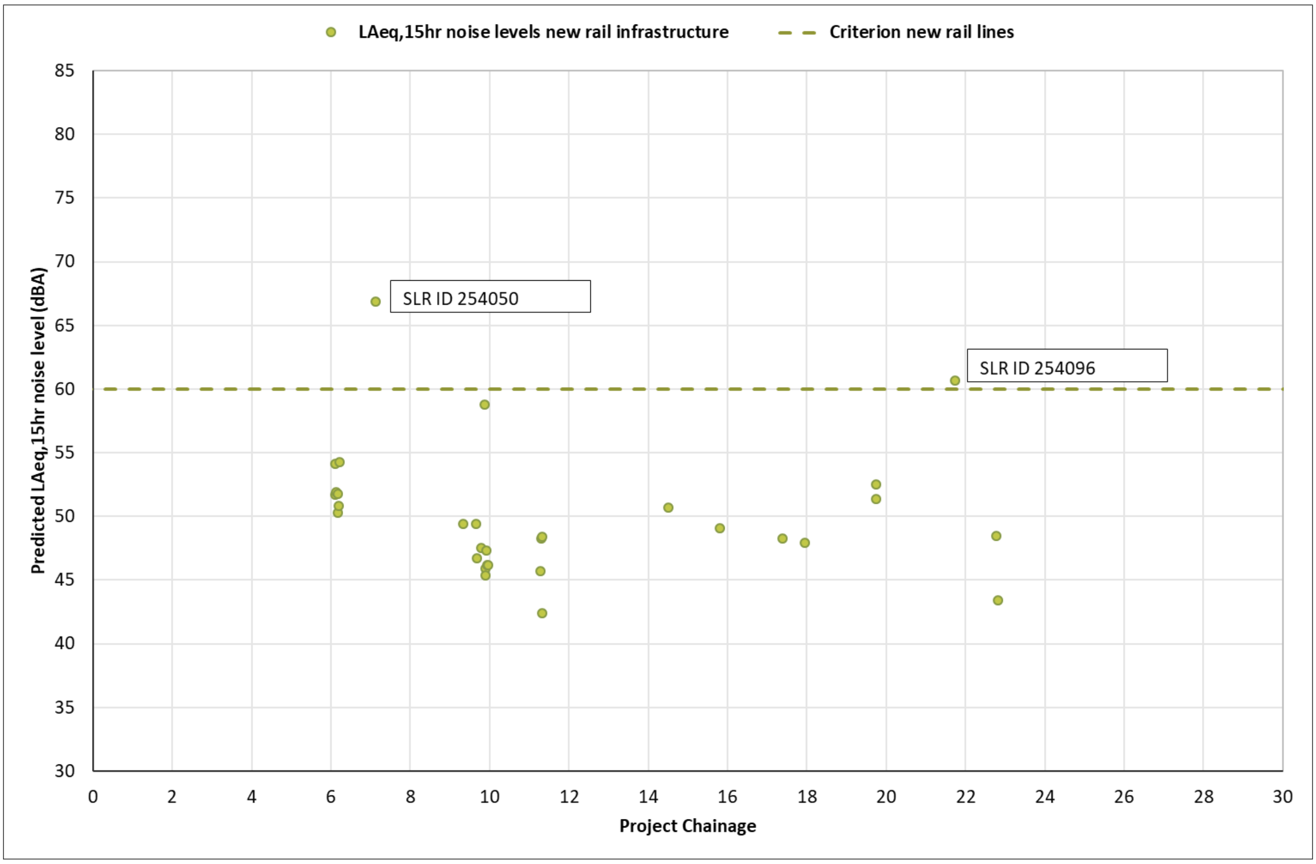
The railway noise levels are the combined noise levels from train passbys on the main tracks, train operations on the crossing loops and the alarm bells and train horn events at the level crossings. The predicted noise levels have been assessed against the adopted railway noise criteria to evaluate the potential noise impact of the Project and identify where noise mitigation options would need to be investigated.

8.2 Railway noise levels at sensitive receptors

8.2.1 Daytime railway noise levels

The predicted daytime $L_{Aeq(15hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 9**.

Figure 9 Predicted daytime $L_{Aeq(15hour)}$ railway noise levels (Year 2025)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

The predicted daytime railway noise levels achieve the $L_{Aeq(15hour)}$ 60 dBA noise criterion at the majority of sensitive receptors adjacent to the sections of new rail corridor. The predicted daytime $L_{Aeq(15hour)}$ railway noise levels are above the noise criterion at two sensitive receptors.

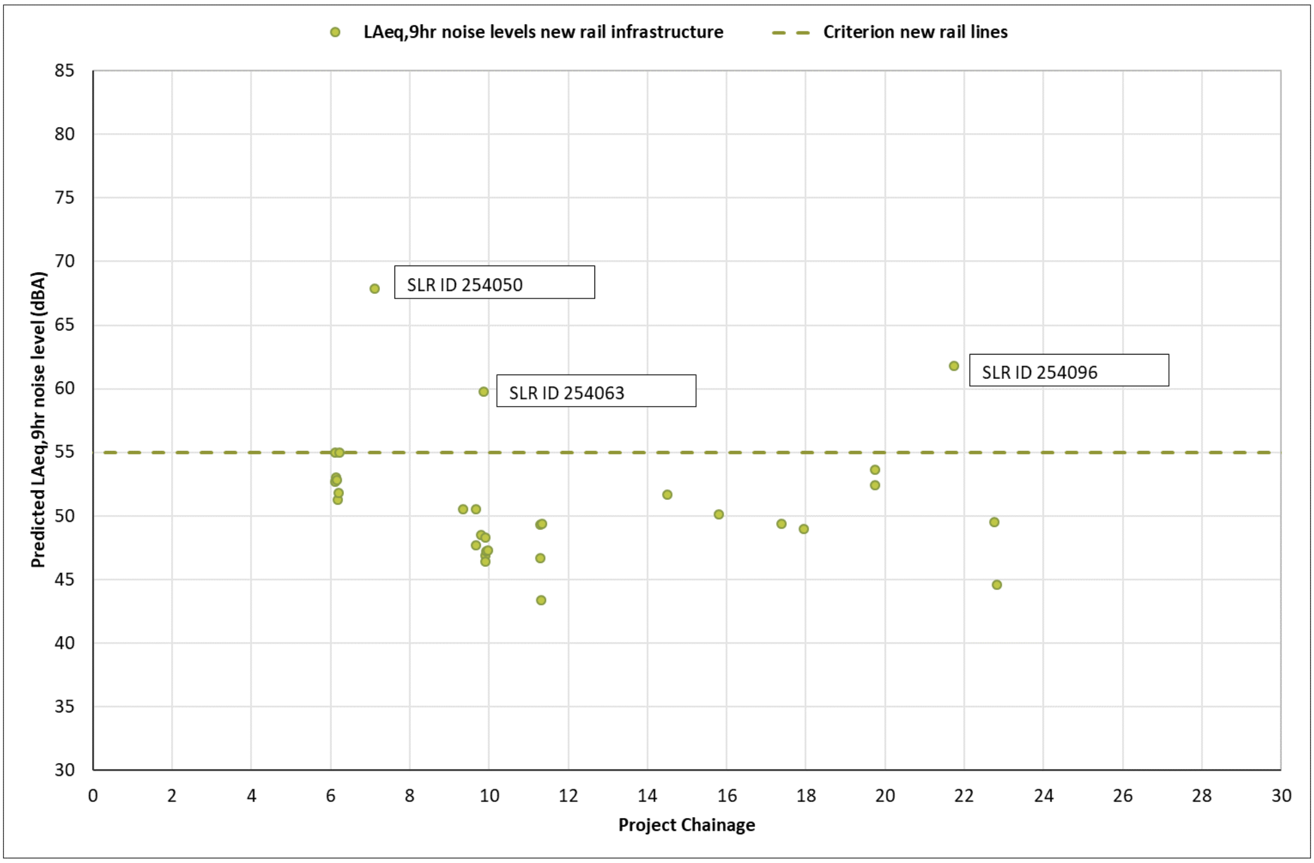
At receptor SLR ID 254050 the predicted noise levels are7 dBA above the noise criterion. A review of the predicted noise levels at this receptor determined the overall noise levels are a combination of train movements on the main line and the train horn and crossing alarms from the nearby level crossing at North Star Road.

At SLR ID 264096, the predicted noise levels are 1 dBA above the noise criterion, with the train movements on the adjacent main line the primary source of railway noise.

8.2.2 Night-time railway noise levels

The predicted night-time $L_{Aeq(9hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 10**.

Figure 10 Predicted night-time $L_{Aeq(9hour)}$ railway noise levels (Year 2025)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

The predicted night-time noise levels achieve the $L_{Aeq(9hour)}$ 55 dBA noise criterion at the majority of the sensitive receptors. At three residential receptors the predicted noise levels are above the night-time L_{Aeq} noise criterion.

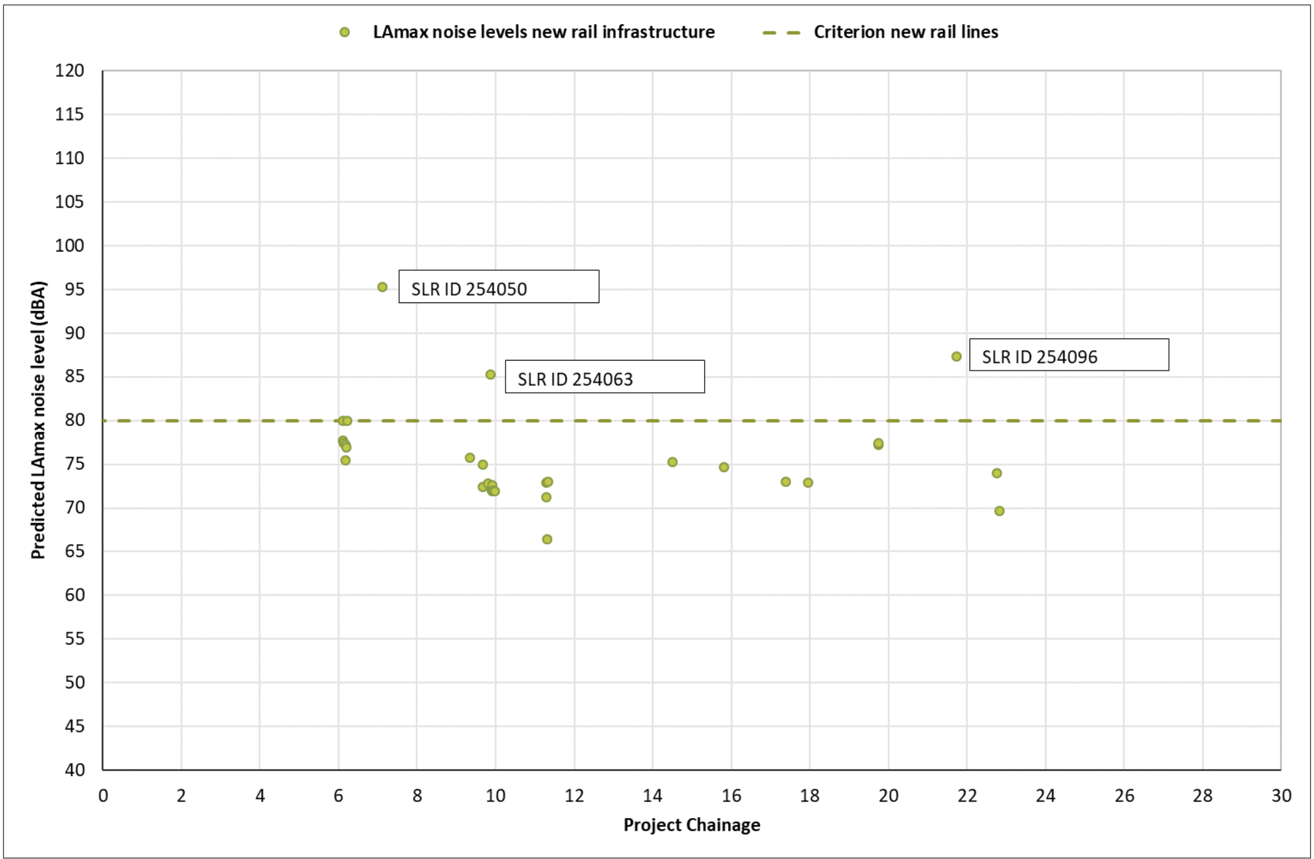
The predicted L_{Aeq} noise levels at SLR ID 254050 are up to 13 dBA above the $L_{Aeq(9hour)}$ 55 dBA noise criterion and result from both the main line train operations and the North Star Road level crossing. The noise levels at SLR ID 254063 and at SLR ID 254096 are 5 dBA and 7 dBA above the criterion respectively. At both of these sensitive receptors the train movements on the main line are the primary source of railway noise.

8.2.3 Daytime and night-time maximum railway noise levels

The maximum noise levels result from the highest discrete noise events from individual train passbys or the train operations on the level crossings or crossing loops. The predicted daytime and night-time LAmax noise levels were generally consistent at the sensitive receptors, with a variation of less than 1 dBA. Consequently, the higher predicted LAmax noise level was adopted to assess the maximum noise levels in both the daytime and night-time periods.

The predicted daytime and night-time maximum (LAmax) railway noise levels at the residential receptors are presented in **Figure 11**.

Figure 11 Predicted daytime and night-time maximum railway noise levels (Year 2025)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

The predicted railway noise levels achieve the LAmax 80 dBA noise criterion at the majority of the residential receptors adjacent to the sections of new rail corridor. At three residential receptors the predicted noise levels are above the LAmax noise criterion.

At receptor SLR ID 254050, the LAmax 95 dBA noise level is 15 dBA above the LAmax noise criterion. The LAmax noise event occurs from the potential train horn events at the nearby level crossing at North Star Road. The location of the level crossing may result in the train horn events occurring directly opposite to the property.

The LAmax noise levels at receptors SLR ID 254063 and SLR ID 254096 are 5 dBA and 7 dBA above the noise criterion respectively. The maximum noise levels result from the train passby events on the adjacent main line.

9 Airborne railway noise levels – Design year 2040

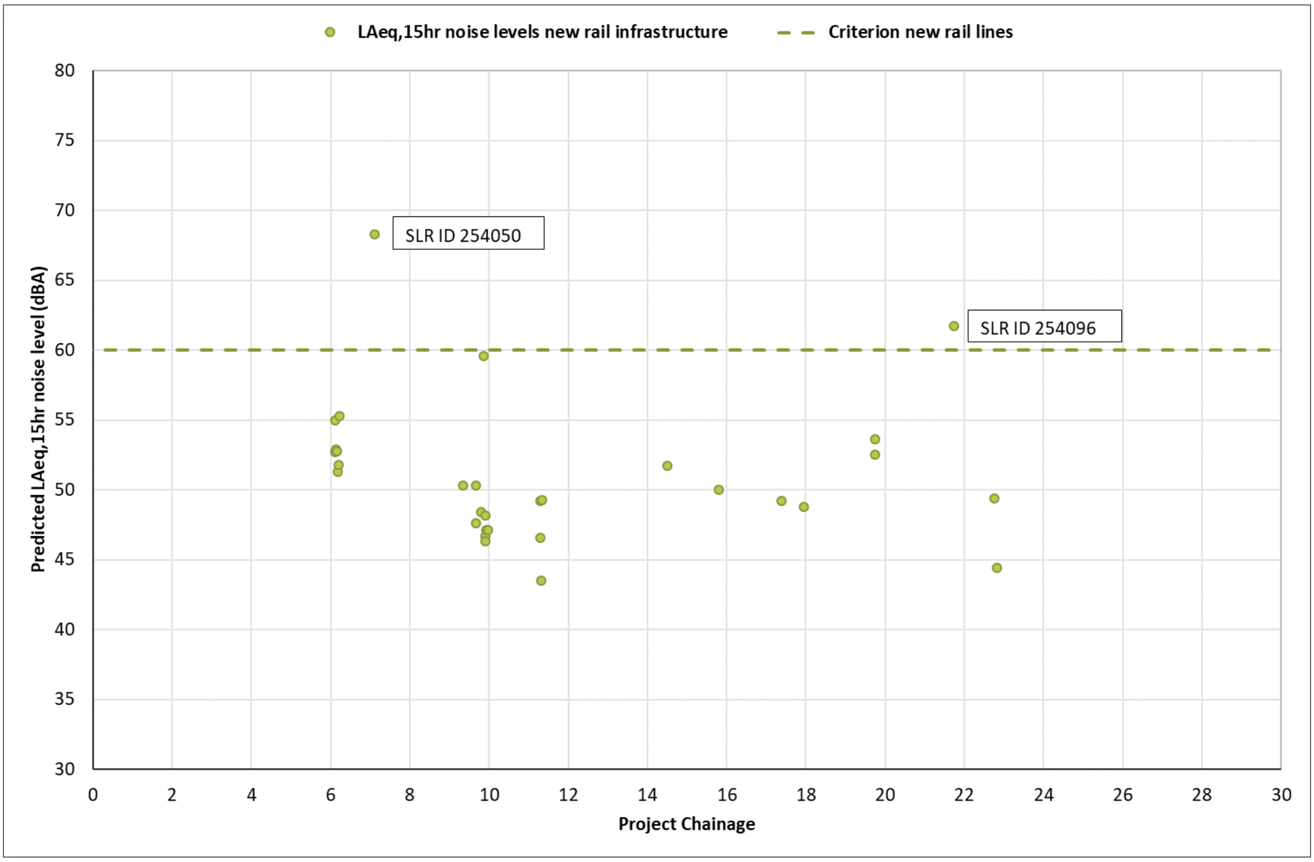
9.1 Overview

The predicted daytime and night-time railway noise levels for the railway operations in Year 2040 are detailed in **Appendix E**. The railway noise levels are provided as tabulated noise level predictions at individual sensitive receptors and maps of railway noise contours for the Project alignment. The assessment of daytime, night-time and maximum railway noise levels is discussed in the following sections.

9.1.1 Daytime railway noise levels

The predicted daytime $L_{Aeq(15hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 12**.

Figure 12 Predicted daytime $L_{Aeq(15hour)}$ railway noise levels (Year 2040)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

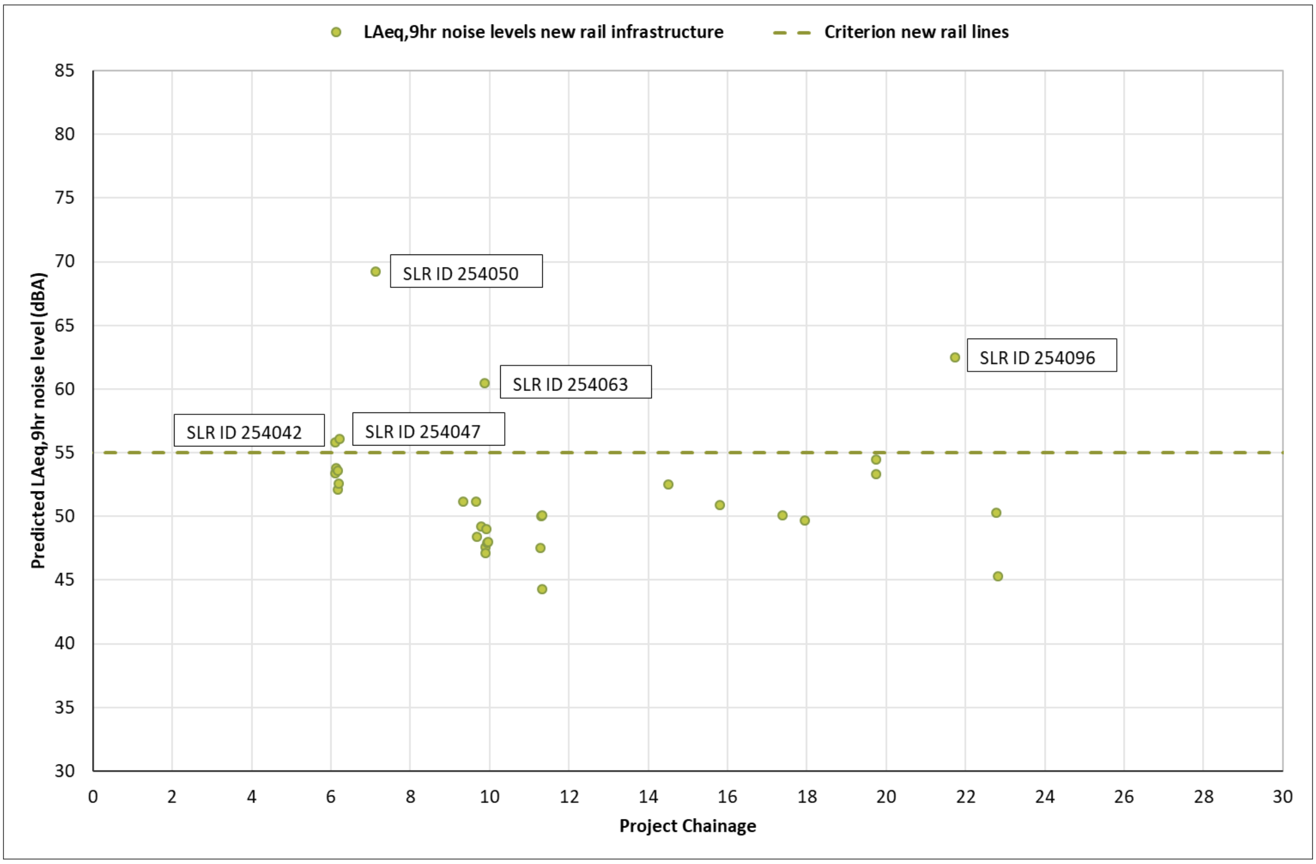
Consistent with the assessment of daytime L_{Aeq} noise levels at the Project opening in 2025, the predicted noise levels achieve the $L_{Aeq(15hour)}$ 60 dBA noise criterion at the majority of sensitive receptors.

The predicted noise levels are above the noise criterion at two receptors; SLR ID 254050 and SLR ID 254096. The noise levels are above the criterion by 8 dBA at SLR ID 254050 and 2 dBA above the criterion at SLR ID 254096.

9.1.2 Night-time railway noise levels

The predicted night-time $L_{Aeq(9hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 13**.

Figure 13 Predicted night-time $L_{Aeq(9hour)}$ railway noise levels (Year 2040)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

The predicted night-time noise levels achieve the $L_{Aeq(9hour)}$ 55 dBA noise criterion at the majority of the sensitive receptors. At five sensitive receptors the predicted noise levels are above the night-time L_{Aeq} noise criterion.

The predicted L_{Aeq} noise levels at SLR ID 254050 are up to 14 dBA above the $L_{Aeq(9hour)}$ 55 dBA noise criterion and result from both the main line train operations and the North Star Road level crossing. The noise levels at SLR ID 254063 and at SLR ID 254096 are 6 dBA and 8 dBA above the criterion respectively. At both of these sensitive receptors the train movements on the main line are the primary source of railway noise.

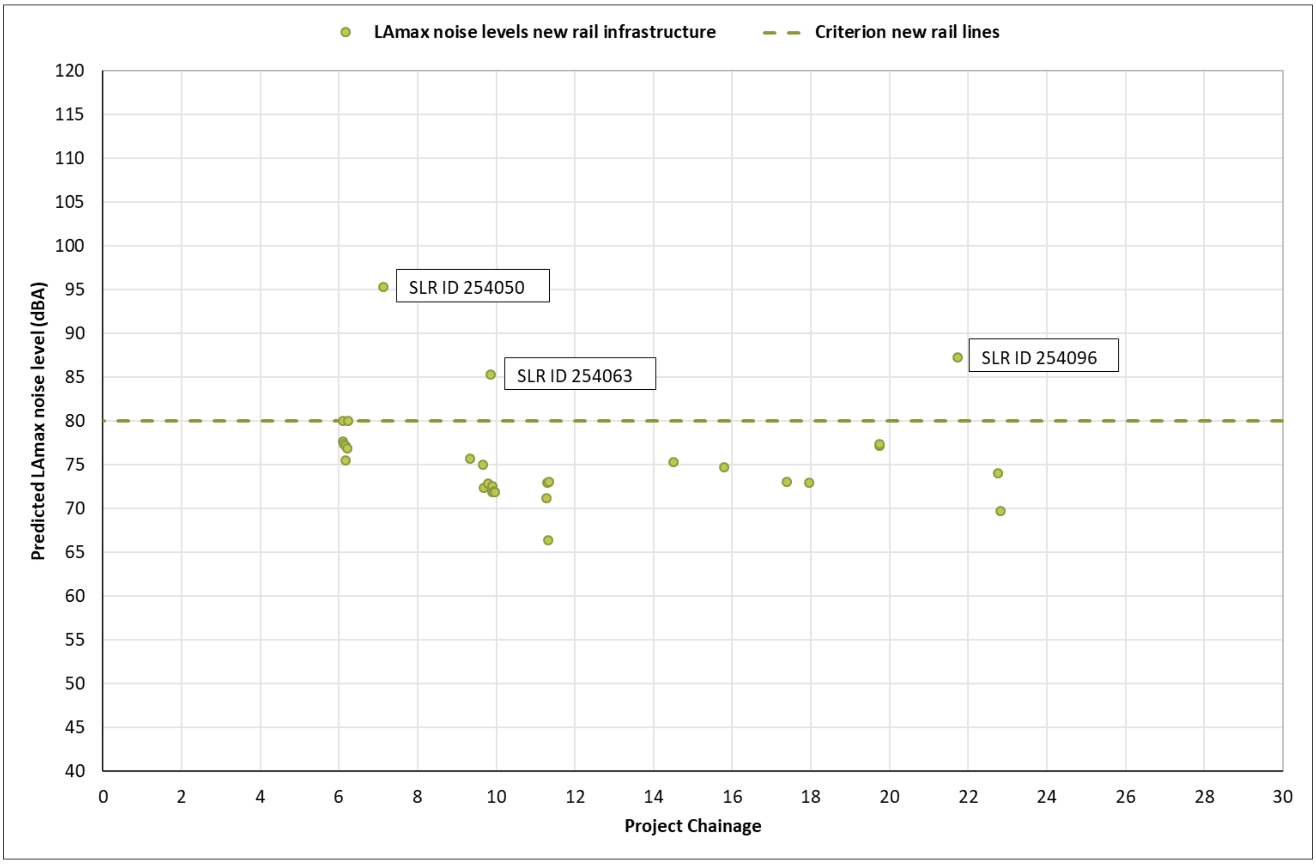
The sensitive receptors discussed above were identified to trigger the assessment criterion for the commencement of railway operations in 2025. For the design year railway operations in 2040, an additional two sensitive receptors are above the noise criterion. The predicted noise levels of $L_{Aeq(9hour)}$ 56 dBA at receptors SLR ID 254042 and SLR ID 254047 result from main line train movements and are a marginal 1 dBA above the criterion.

9.1.3 Daytime and night-time maximum railway noise levels

The predicted daytime and night-time L_{Amax} noise levels were generally consistent at the sensitive receptors, with a variation of less than 1 dBA. The higher predicted L_{Amax} noise level was adopted to assess the maximum noise levels in both the daytime and night-time periods.

The predicted daytime and night-time maximum (L_{Amax}) railway noise levels at the residential receptors are detailed in **Figure 14**.

Figure 14 Predicted daytime and night-time L_{Amax} railway noise levels (Year 2040)



Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

Consistent with the predicted L_{Amax} noise levels at Project opening (year 2025), the L_{Amax} noise levels are within the L_{Amax} 80 dBA noise trigger level at the majority of sensitive receptors. At three sensitive receptors, SLR ID 254050, SLR ID 254063 and SLR ID 254096, the predicted noise levels are above the L_{Amax} criterion.

At receptor SLR ID 254050, the L_{Amax} 95 dBA noise level is 15 dBA above the L_{Amax} noise criterion. The L_{Amax} noise event occurs from the potential train horn events from the nearby level crossing at North Star Road. The location of the level crossing may result in the train horn events occurring opposite to the property.

The L_{Amax} noise levels at receptors SLR ID 254063 and SLR ID 254096 are 5 dBA and 7 dBA above the noise criterion respectively. The maximum noise levels result from the train passby events on the adjacent main line.

10 Summary of the railway noise assessment

10.1 Receptors triggering the investigation of noise mitigation

Where predicted railway noise levels at sensitive receptors are above the noise criteria the Project will investigate reasonable and practicable mitigation measures to reduce noise levels with the objective of achieving the noise criteria.

The review of noise mitigation is triggered at up to three individual sensitive receptors for the commencement of railway operations 2025 and up to five individual sensitive receptors (two additional receptors) for the design year operations in year 2040.

The sensitive receptors where noise levels were predicted above the night-time noise criteria are detailed in **Table 23** for rail operations in 2040, with the individual criteria triggers highlighted in bold in the table. The predicted noise levels are provided for trains operating on the tracks of the main line and crossing loops and separately for the level crossings.

The location of the sensitive receptors where noise levels trigger the assessment criteria are presented in **Figure 15**.

The investigation of mitigation was most frequently triggered by the night-time L_{Aeq} rail noise levels, as the number of trains per hour is greater during the night-time and the noise criteria are 5 dBA more stringent than the daytime.

Table 23 Sensitive receptors triggering the investigation of noise mitigation

SLR ID	Rail noise levels – rail tracks, dBA		Rail noise – level crossings, dBA		Overall night-time noise levels, dBA	
	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax
254027	**56**	80	41	68	**56**	80
254042	**56**	80	43	71	**56**	80
254050	**66**	**91**	**66**	**95**	**69**	**95**
254063	**61**	**85**	<30	<50	**61**	**85**
254096	**63**	**87**	36	63	**63**	**87**

NORTH STAR TO BORDER

Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 15 - Map 1 of 4

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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Date: 23-Mar-2020
Author: JG

- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- Sensitive receptors triggering a review of mitigation

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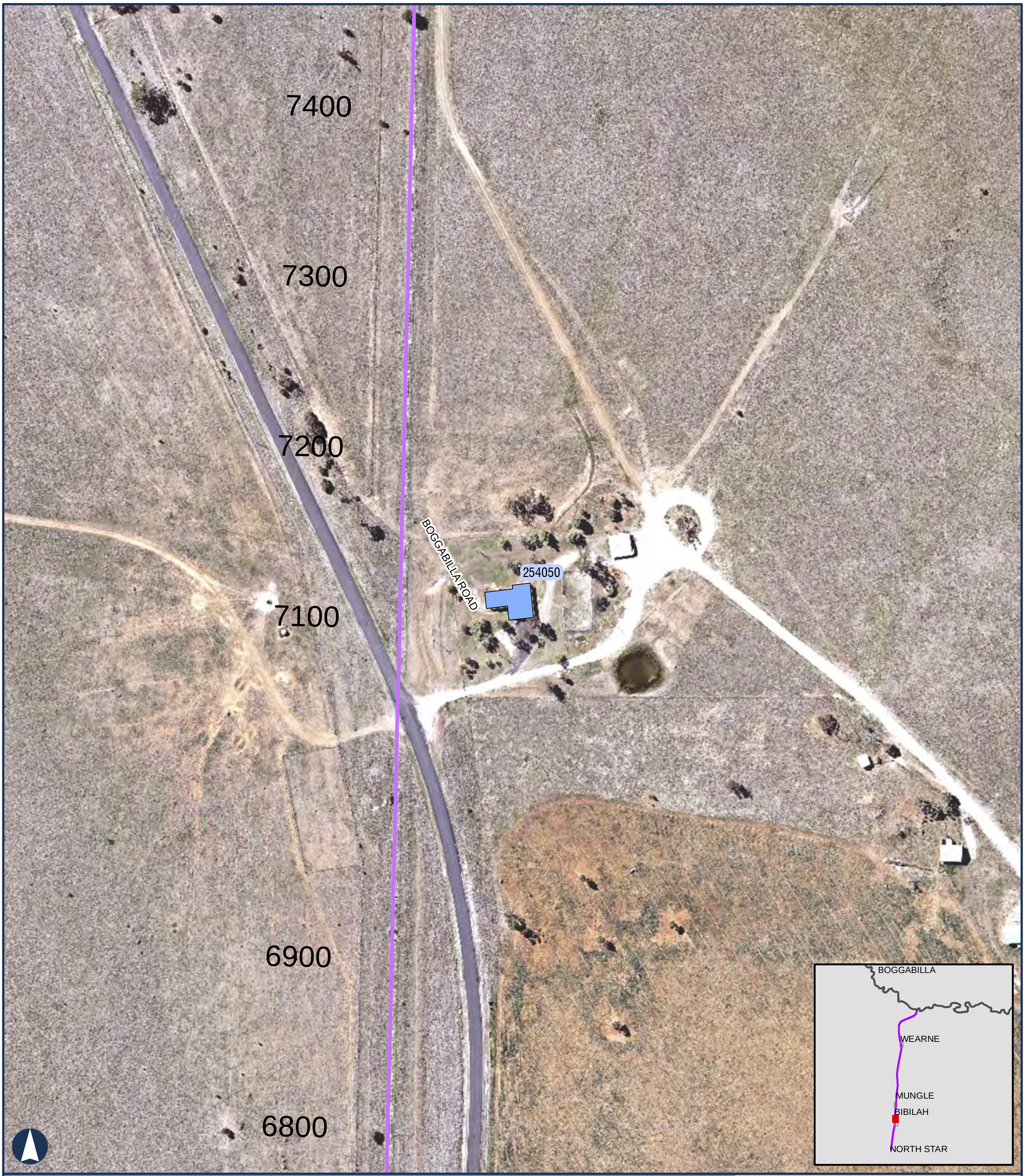
Service Layer Credits: Imagery ARTC 2015 and 2017



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Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 15 - Map 2 of 4

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
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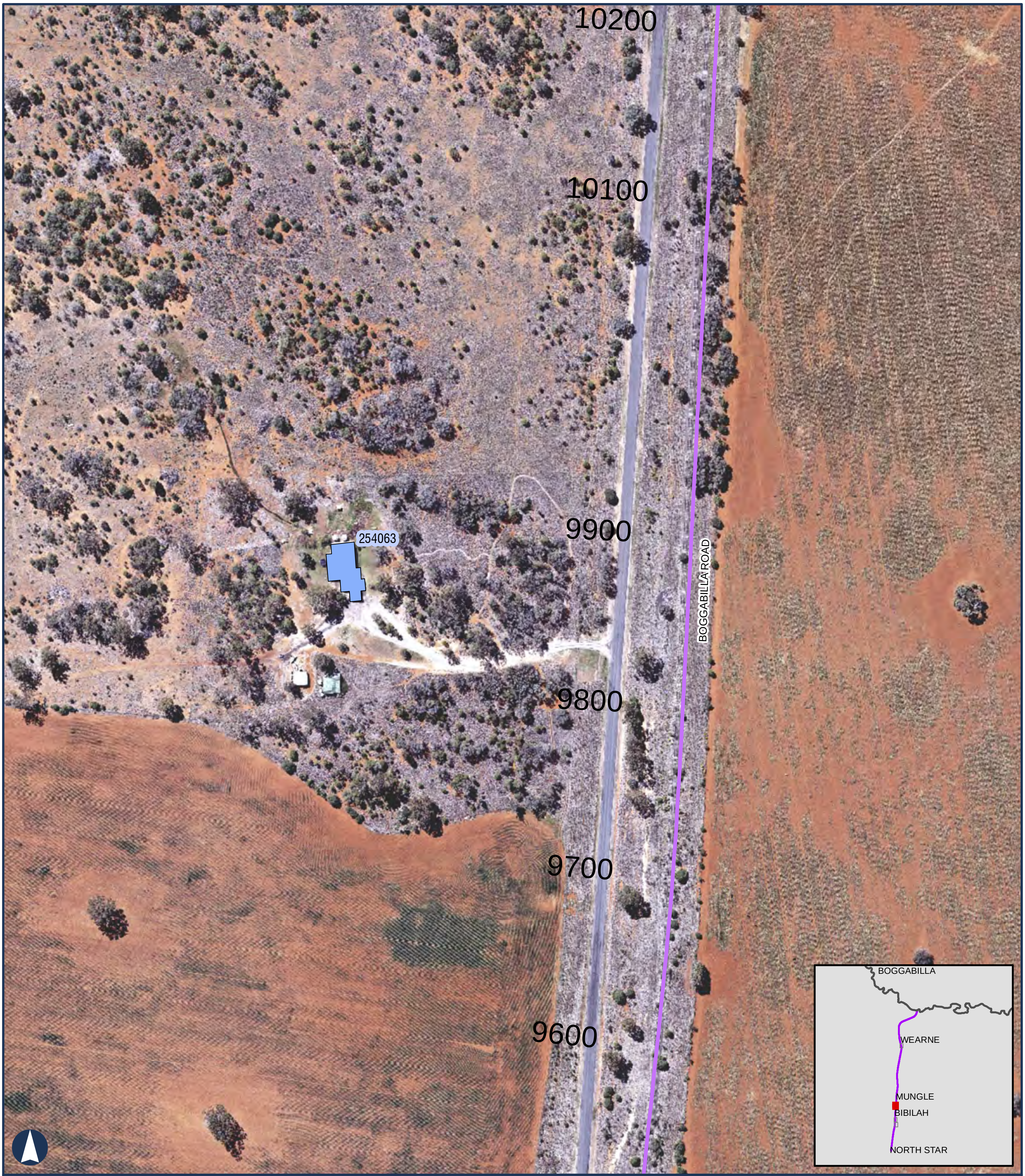

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Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 15 - Map 3 of 4

100 Metres

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NORTH STAR TO BORDER

Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 15 - Map 4 of 4

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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Service Layer Credits: Imagery ARTC 2015 and 2017

10.2 Trains accessing the crossing loops

The assessment of L_{Aeq} and L_{Amax} railway noise levels in the previous sections included the contribution of railway operations at the crossing loops. A review of the predicted noise levels at the sensitive receptors determined the noise level contribution from the crossing loops were up to $L_{Aeq(15hour)}$ 28 dBA daytime, $L_{Aeq(9hour)}$ 29 dBA night-time and L_{Amax} 31 dBA for both the daytime and night-time periods.

The predicted noise levels from the crossing loops were within the RING noise criteria and are lower than the railway noise levels from the daily train passby events on the main line. Because the crossing loop is within 4.5 m of the mainline tracks, it is not expected to be the primary influence on the overall daytime and night-time predicted noise levels at the sensitive receptors.

10.3 Operation of the level crossings

The predicted railway noise levels were reviewed to determine if the alarm bells and train horns at each level crossing were triggering the railway noise assessment criteria. In most cases, whilst the level crossings are a potential source of noise in the local environment, the predicted noise levels at the sensitive receptors was primarily influenced by the train passbys on the main line track.

Based on the analysis the active level crossing proposed for North Star Road is a potential source of noise that is predicted to trigger the noise assessment criteria at the nearby sensitive receptor (SLR ID 254040). The train horns are sounded on approach to the level crossing and the horns are the principal source of the noise associated with the level crossing.

10.4 Potential for sleep disturbance

The night-time L_{Amax} (maximum) rail noise management criteria adopted from the RING have been applied by ARTC to assess potential sleep disturbance impacts, such as; awakening, disrupted sleep or a general reduction to the quality of sleep over time. The L_{Amax} noise management criteria account for the highest level of noise during train passbys and the number of passby events in the night-time.

There are up to three sensitive receptors where the predicted noise levels are above the L_{Amax} noise assessment criteria by up to 15 dBA within the night-time period. The noise predictions identified the L_{Amax} noise management criteria was generally achieved where receptors were more than 400 m from the rail corridor.

Railway noise has the potential to be audible at sensitive land uses, both externally and internally, even where the noise management criteria are achieved. To further the evaluation of potential for noise related impacts, the assessment has referenced guidance on sleep disturbance from the World Health Organisation (WHO).

The WHO guideline Night Noise Guidelines for Europe[11] recommends that internal (indoor) noise levels are not above L_{Amax} 42 dBA to preserve sleep quality. The WHO guideline level corresponds to a conservative external (outdoor) level of L_{Amax} 49 dBA, allowing for a conservative 7 dBA difference between indoor and outdoor noise levels where windows at rural residential properties are open for ventilation.

[11] World Health Organisation, 2009. Night Noise Guidelines for Europe.

Based on the noise modelling, the noise levels from rolling stock could be above L_{Amax} 49 dBA within approximately 1 km from the rail corridor. The 1 km distance is a guide to where night-time noise levels may have the potential to result in sleep disturbance impacts. Individuals will respond to noise differently, and just because railway noise can be audible does not mean it will cause disturbance or annoyance.

Where sensitive residential land uses are proposed to be developed within 1 km of rail freight corridors, it would be expected that residential property, complying to Australian building codes and standards, would achieve façade noise reductions greater than the conservative 7 dBA assumption applied in this assessment.

10.5 Consideration of local weather on railway noise

The regional weather conditions have the potential to influence the propagation of noise within the local environment. Downwind from a noise source the wind conditions can enhance the propagation of noise and equally being upwind of a noise source, the wind conditions act to suppress noise propagation.

Temperature inversion conditions occur where the temperature of a layer of air in the atmosphere increases with height, rather than the typical conditions where air temperature decreases with height. This causes a layer of cool, still air being trapped below the warmer air. Temperature inversion conditions generally occur during the early morning and night-time periods during the winter months where little or no vertical air movement of the cool air layer can result in a refraction of sound waves and potentially enhance the propagation of noise.

The potential for railway noise at individual sensitive receptors to be influenced by the local weather conditions will be based on the complex interaction between the moving noise source (train passby), the varying frequency content of the received noise, the weather conditions in the region and the local environment.

Whilst there may be periods when the weather conditions influence the propagation of noise from train passby events, the railway operation are forecast to be 1 to 2 train movements per hour with audible passby events likely to be 2 to 5 minutes in duration. The combination of the duration and intermittency of the train passbys would diminish the influence of weather conditions on the railway noise levels assessed over the 15-hour daytime and 9-hour night-time periods.

The daily noise levels from the steady state noise emissions from idling trains at the crossing loops can be more readily influenced by local weather conditions than noise from the transient train passbys. In this regard, the ISO methodology applied for the calculation of noise levels from the crossing loops and level crossings included an allowance for downwind noise enhancing weather conditions and/or moderate temperature inversions.

10.6 Characteristics of railway noise

The potential impacts of noise from railway operations can be influenced by the characteristics of the noise from the train passbys and rail operation at the crossing loops. A noise spectrum for a typical freight train passby events is detailed in **Figure 16**.

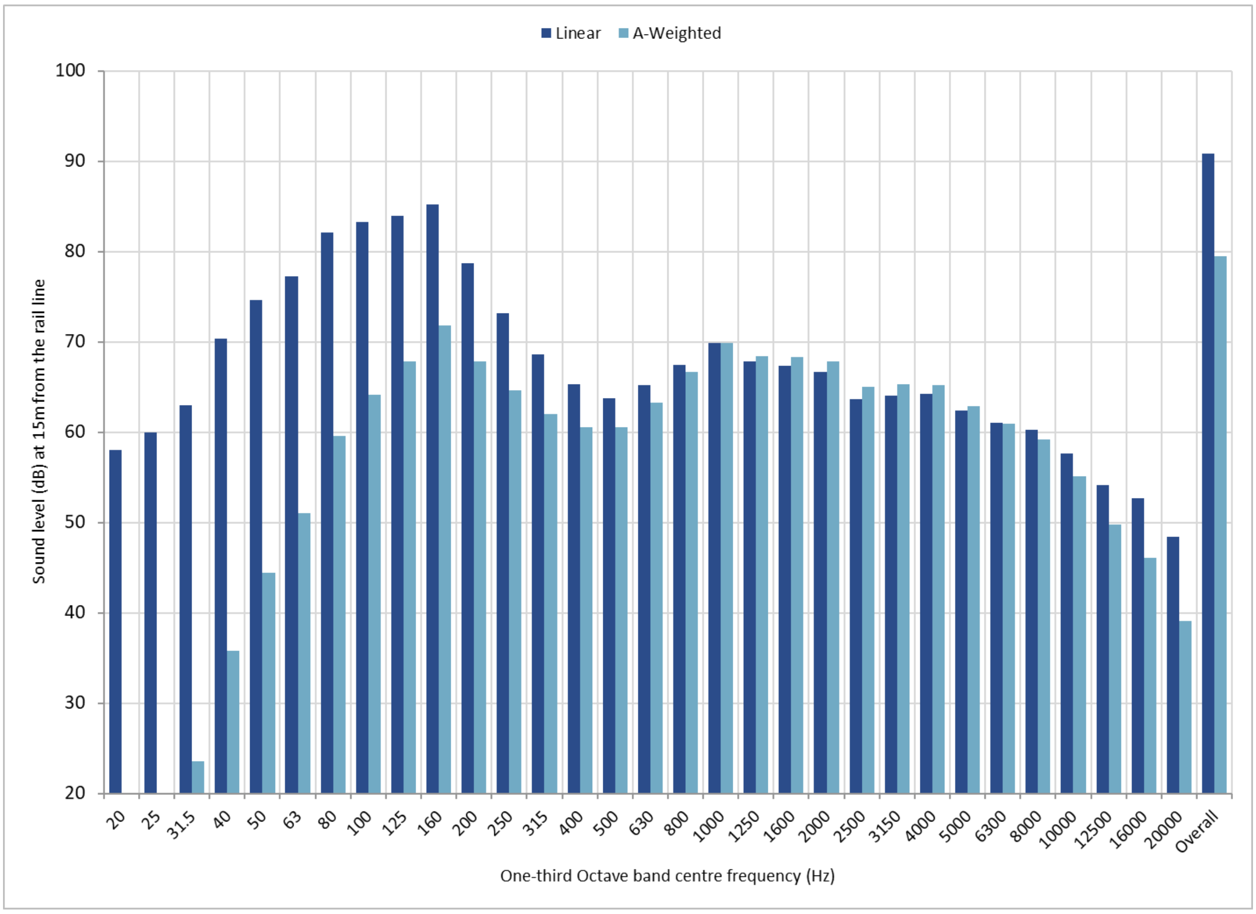
The noise spectrum was derived from measurement of noise levels from 149 rail freight and coal train movements at an existing rail corridor on the Inland Rail Program in Queensland in March 2019. The noise levels were measured at 15 m from the rail line where trains were operating at approximately 60 km/h.

The typical train passby spectra identifies there is a prominent contribution of noise in the low frequency range between 80 Hz and 250 Hz at 15 m from the rail line. The diesel-electric locomotive engines and exhaust systems are the primary source of the low frequency noise content during the train passby events.

It is important to note that where the noise emission of the locomotives have a low frequency noise content in close proximity to the rail line it does not mean that low frequency noise characteristics will necessarily be experienced at sensitive land uses.

The ability to detect features, such as low frequency noise, will also depend on the contribution of the other sources of noise in the local environment, which may influence an individual's perception of the loudness and character of the rollingstock noise.

Figure 16 Example noise emission spectra for rail freight



Note Noise spectra determined as the logarithmic average of daily coal and freight train passbys as measured at 15 m from the rail centreline.

The Nordic noise modelling methodology provides the overall A-weighted level of railway noise, it does not provide the frequency spectra for rollingstock noise at individual sensitive receptors. Notwithstanding, based on the typical frequency content of diesel electric locomotives, it would be reasonable to assume that where railway noise would be clearly audible above the ambient noise environment, such as within 300 m of the rail corridor, there could be low frequency noise content in the passby noise emission.

Analysis of the noise spectrum did not identify prominent tones at specific frequencies, and the noise emission from the rollingstock operations is not expected to include tonal noise characteristics.

Other general characteristics of railway noise are summarised below and are usually specific to individual items of rollingstock and track features:

- Bunching or stretching can occur when the couplings on a train are subject to sudden changes in force during acceleration and deceleration, this can cause short-lived 'squeaks' and 'bangs'. Events of this nature may have subjective impulsive noise emission characteristics, although not necessarily quantified as impulsive noise at nearest sensitive receptors. Noise events from bunching or stretching have been assessed at the crossing loop proposed on the Project.
- Short-lived 'booming' noise with potential low frequency characteristics can be caused by empty containers and wagons resonating.
- Curving noise, such as wheel-squeal, can result in prominent tonal noise emissions. The Project does not include tight-radius curves, and this limits the potential for curving noise.
- The condition of the track can be a primary influence on the rolling noise from the locomotives and the wagons. Features such as corrugation (deformation of the track) increase the roughness of the rails which can cause increased noise levels on both straight track and curves. The Project will be newly constructed rail that shall be specifically designed for freight rail operations and subject to periodic maintenance.
- Features such as jointed track can increase rolling noise. The track for Inland Rail will be continuously welded rail which reduces the likelihood of 'clickety-clack' sounds from the wheel-rail interface.

11 Assessment of ground-borne vibration

11.1 Approach

To inform the assessment of potential ground-borne vibration from the railway operations, guidance was referenced from International Standard ISO 14837[12] on the typical assessment requirements for new rail systems, including definitions of:

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

For this assessment, a combined Scoping Model with elements of an Environmental Assessment Model was adopted. In accordance with the ISO standard, modelling for ground-borne noise and ground-borne vibration considers key parameters that are critical in determining the likely range levels of ground-borne noise and vibration and the benefits (or otherwise) of different design and mitigation options.

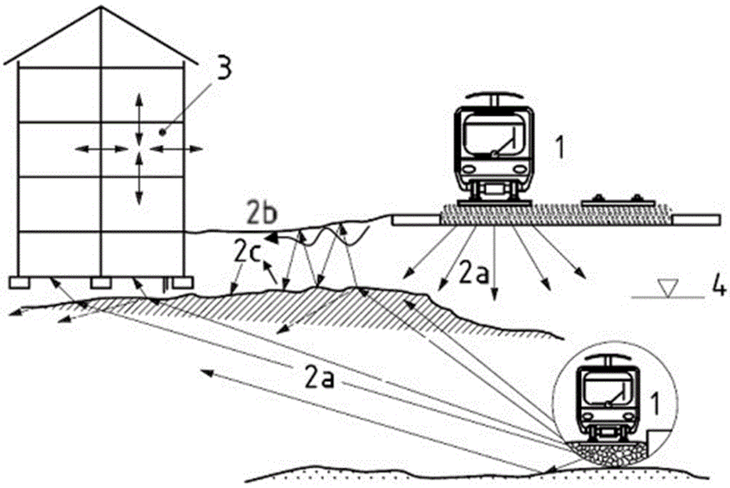
An overview of the modelling approach is illustrated in **Figure 17**. The approach considers the source vibration levels, the vibration propagation between the surrounding environment and nearby building foundations, and the propagation of vibration within the building elements.

[12] ISO 14837-1 2005 "*Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General guidance*

The modelling has been carried out using a combination of theoretical and empirical relationships to determine the attenuation and/or amplification of ground-borne vibration levels with assumptions that include:

- Single frequency overall values vs distance;
- No adjustment for buildings of substantially greater mass or size than those used to inform published data (conservative); and
- a crest factor[13] of 4.

Figure 17 Example of rail vibration source, propagation and receptor system



Key

1 source

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

3 receiver (vibration, re-radiated noise)

4 water table

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

Previous measurement and assessment of ground-borne vibration from existing rail freight corridors indicates that potential for ground-borne vibration impacts would be limited to sensitive receptors located within 100 m of the proposed rails. Forecast levels at properties beyond this distance are routinely expected to be within assessment criteria and the integrity of building structures is unlikely to be compromised by passing trains.

The calculation of ground-borne vibration from above ground rail operations refrained from applying estimated adjustments, such as loss of vibration energy as it is transferred to buildings (coupling loss), where adjustments could infer there would be no risk of impacts from ground-borne vibration outside of the rail corridor.

Railway traffic over bridges and viaducts on the Project can also be sources of vibration. The bridge and viaduct structures are expected to be constructed from reinforced concrete and a ballasted track system is expected to include resilient matting for ballast retention (and also some vibration isolation).

13 Ratio of peak to root mean square (RMS) velocity level.

By inspection of the nearest sensitive locations and the modelled source vibration spectrum, the ground-borne vibration criteria are therefore expected to be met at ground level assessment positions near bridges and viaducts. On this basis, further assessment of rail induced vibration at the bridges and viaducts is not considered to be required.

11.2 Source vibration levels

The Project alignment is a greenfield rail corridor with no existing comparable rail freight operations or speeds as that proposed. Consequently, it is not possible to measure local vibration levels directly and a model is used to estimate results at each location.

To determine a reference ground vibration level, detailed measurement surveys were completed on existing rail corridors between Wagga Wagga and Albury in NSW and Euroa and Wallan in Victoria. The locations are associated with the Inland Rail Program in NSW and Victoria where there are comparable existing rail freight operations, with single-stacked freight wagons, on ballasted track form.

The rail corridor in these regions is mainly used for rail freight and had an average of 20 or more freight train movements per day operating at 60 km/h to 80 km/h. Ground-borne vibration levels were measured at three locations in each region, with measurements made at-grade (ground level) at distances of 15 m to 45 m from the outer rail line.

The train vibration measurements were referenced to calculate the W_b-weighted VDVs at 15 m from the outer rail varied at all sites from 0.01 $m/s^{1.75}$ to 0.04 $m/s^{1.75}$ for a single train passby event. The variation is representative of differences in rollingstock, wheel conditions and consists.

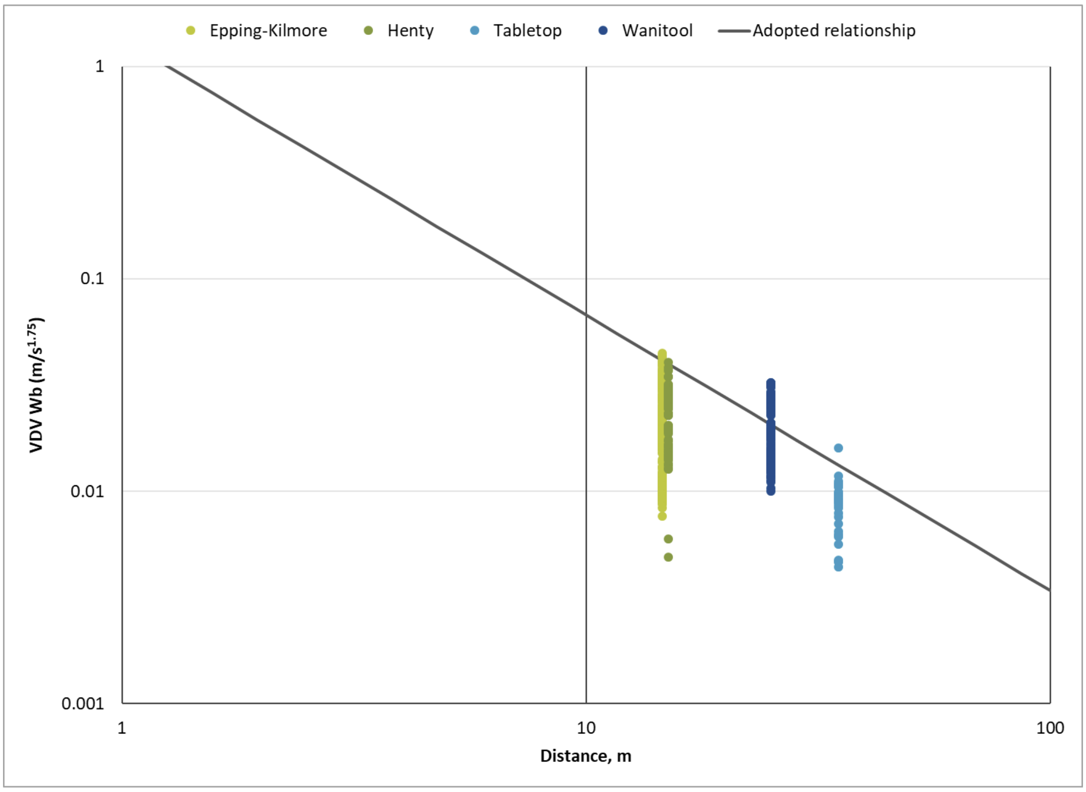
The adopted VDV (W_b weighted) of 0.04 $m/s^{1.75}$ at a setback of 15 m for a single train passby was based on the maximum derived VDVs. Accordingly, the assessment inherently assumes that each train is a worst-case vibration generating event and is therefore conservative.

The change in VDV for a single train passby event with distance from the track is shown in **Figure 18**. The figure presents the monitored vibration levels at the four sites and the adopted relationship between rail vibration and distance from the outer rail. The figure shows the reduction of VDV with increasing distance from the track based on geometric spreading of the vibration energy only (ignoring site specific dampening).

The results obtained using this process had similar vibration spectra and relationships between overall levels and distance from the rail track. The modelled vibration spectrum in **Figure 19** is provided as one-third octave bands based on the logarithmic averages of the measurement in order to bias sites with the highest ground-borne vibration levels during train passby events.

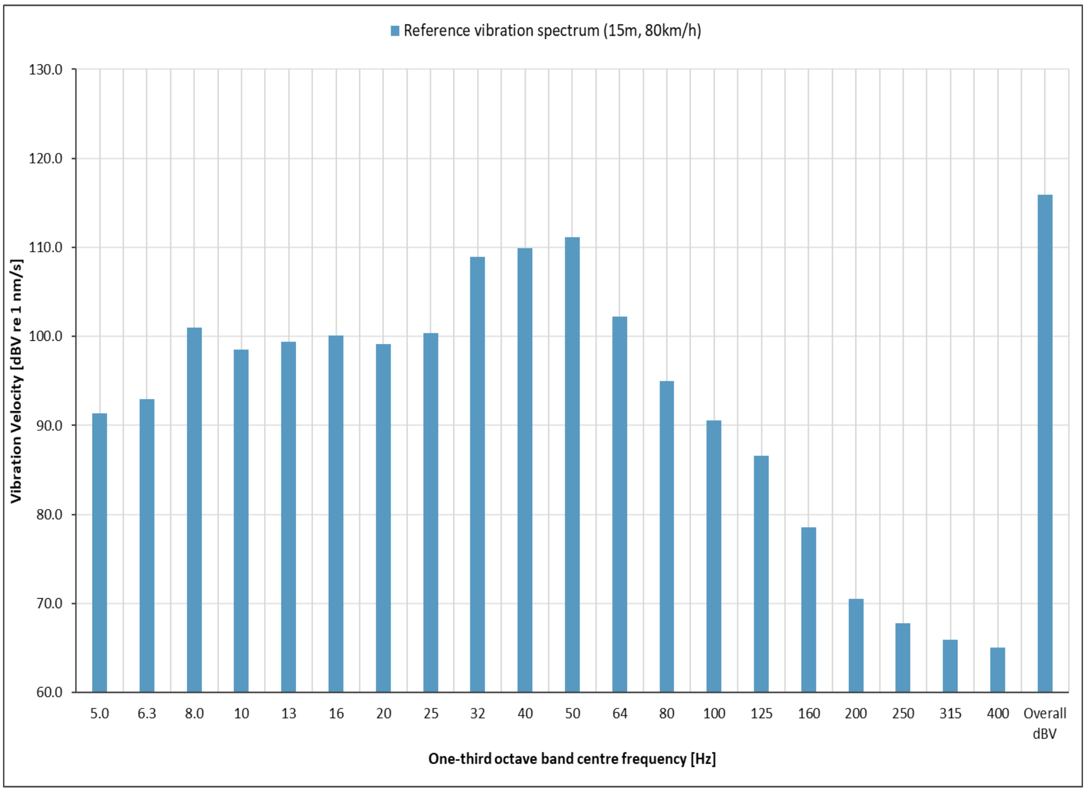
As ground-borne vibration propagates away from the track, the amplitude of the vibration wave attenuates with increasing distance. The reference vibration spectrum was adjusted to account for this reduction in amplitude.

Figure 18 Logarithmic relationship between VDV and distance



Note Reference VDV for a single freight train passby.

Figure 19 Vibration velocity spectrum at 15 m from the outer rail



Note Reference vibration velocity spectrum for a single freight train passby.

11.3 Ground-borne vibration from ground-level train passbys

The effects of vibration in buildings can be divided into two broad categories which are considered further in the following sections.

- Where the occupants or users of the building are inconvenienced or possibly disturbed either from tactile vibration or audible noise generated from the building vibration ('comfort risk'); and
- Where the building contents or internal linings may be noticeably affected or where the integrity of the building or the structure itself may be prejudiced ('cosmetic damage risk').

11.3.1 Residential and other occupied buildings

The VDV results were estimated based on daily train movements at the project opening in 2025 and the 2040 design year and the forecast train speeds. Estimated VDV levels for trains at 105 km/h were applied to determine the minimum off-set distance from the outer rail of the Project where the ground-borne vibration criteria would be expected to be achieved.

Suggested off-set distances to achieve the daytime and night-time rail vibration criteria are shown in **Table 24**.

Table 24 Screening assessment of ground-borne vibration levels

Year of operation	Estimated off-set to meet vibration criteria, subject to detailed review		Receptors within the off-set distance
	Daytime (0.2 $m/s^{1.75}$)	Night-time (0.13 $m/s^{1.75}$)	
2025 opening year	10 m (9 trains)	13 m (8 trains)	None
2040 design year	10 m (11 trains)	13 m (10 trains)	None

Note The estimated off-set distances are based on the VDV reference, actual vibration levels at individual receptors can vary from the calculated levels due to the rail infrastructure and geological conditions.

VDV levels calculated applying the W_b-weighted vibration levels as per the 2008 version of BS 6472.

Based on the highest estimated off-set distance for the night-time railway operations for the design year 2040, an estimated off-set distance of 13 m from the outer rail would be required to achieve ground-borne vibration criteria.

A review of the Project alignment identified that all sensitive receptors would be outside of the 13 m off-set distance from the outer rail of the Inland Rail track. On this basis, the railway operations on the Project rail tracks would achieve the ground-borne vibration assessment criteria at all sensitive receptors.

Where ground-borne vibration from railway operations are within the assessment criteria, there can still be potential for rail operations to generate perceptible levels of ground-borne vibration at sensitive receptors. The ground-borne vibration levels would achieve the criteria for managing vibration disturbance, consequently the less stringent vibration criteria for managing risk of cosmetic damage to buildings would also be achieved.

11.3.2 Heritage sites

The assessment has considered the potential for ground-borne vibration from railway operations to impact sites along the Project alignment that were identified as possessing historical or cultural values in the Non-Indigenous Cultural Heritage Survey report undertaken for the EIS.

As this study is not informed as to the structural condition of each heritage site, SLR has considered that heritage structures are not structurally unsound, on the understanding that the Project will require:

- Condition surveys of buildings and structures in the vicinity of the alignment and any excavations would be carried out prior to final design.
- Where ground-borne vibration levels are predicted to exceed the screening criteria, a more detailed assessment of the structure and vibration monitoring would be carried out to confirm vibration levels remain below appropriate limits for that structure.
- For heritage items, any detailed assessment would determine any specific sensitivities in consultation with relevant specialists to ensure risks are adequately managed.
- If a heritage building or structure is found to be structurally unsound (following inspection), a more conservative cosmetic damage objective (for example 2.5 mm/s peak component particle velocity for long term vibration from DIN 4150.3) would be considered.

Based on the reference ground-borne vibration velocity for a freight train passby (**Figure 19**), the PPV levels would be within the vibration targets for minimising potential impacts at 15 m or more from the nearest rail, allowing for local factors such as turnouts. Within this distance it is to be acknowledged that ground-borne vibration levels may still be within the guidelines given the conservative assumptions and the dominant frequencies of rail vibration.

Excluding the heritage sites identified to be either within the future rail corridor or the disturbance footprint of the Project, the remaining heritage sites are further than 15 m from the outer rail. On this basis none of the heritage sites are considered to be potentially at-risk from railway induced ground-borne vibration.

12 Assessment of ground-borne noise

The ground-borne vibration scoping model and the referenced source rail vibration levels were applied to assess the potential ground-borne noise from railway operations at the ground-level track.

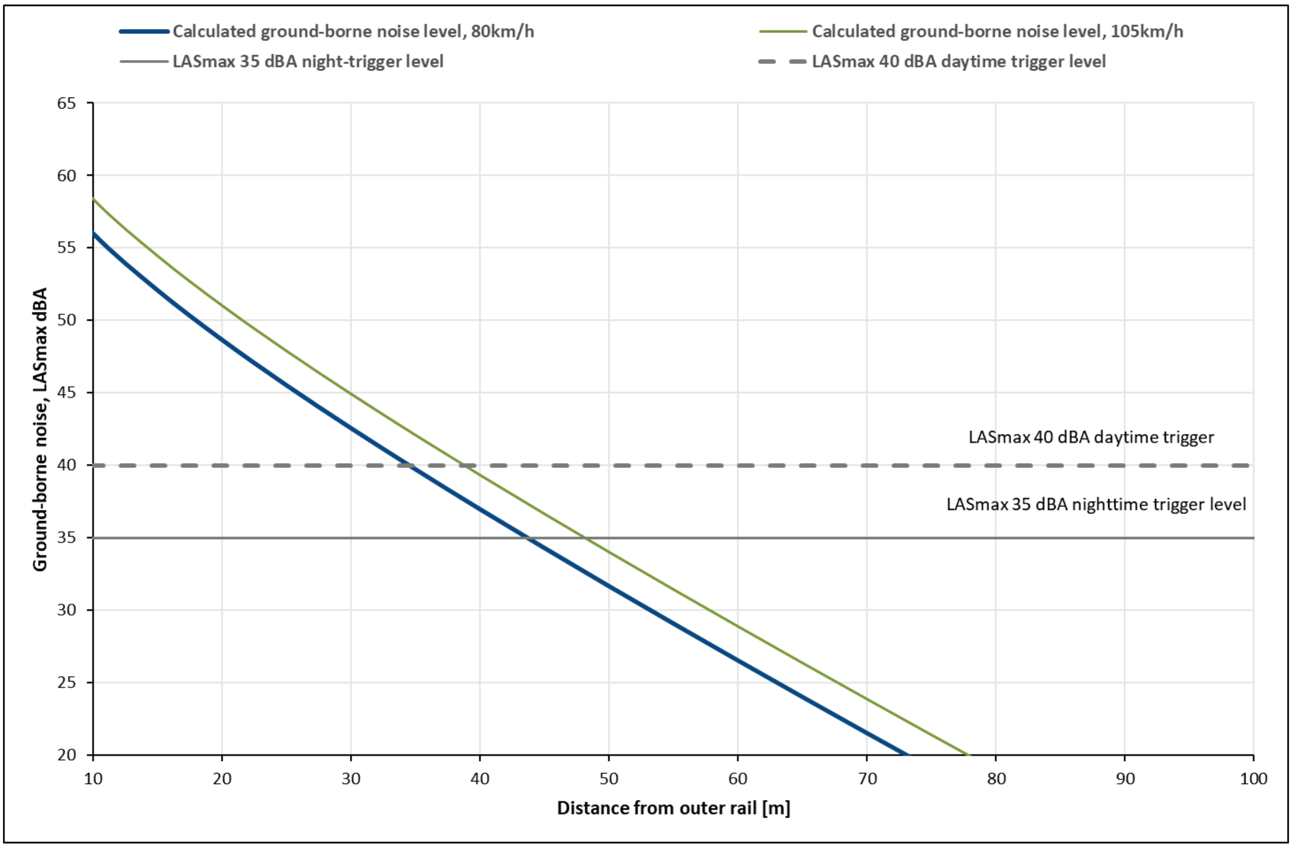
The building types and construction details of the sensitive receptors are not known and could have substantial variations in rural areas. To conservatively estimate the ground-borne noise levels at sensitive receptors, the calculations applied the following key assumptions:

- No coupling loss between the ground and the receptor building structures to account for loss of energy as vibration enters the building footings.
- No floor amplification effects or floor-to-floor losses within the receptor structures.
- Use of a vibration to sound pressure (noise) conversion factor of -32 dB[14].
- Application of a 0.05 per metre damping loss estimated from the rail vibration measures described in **Section 11**.

The calculated ground-borne noise levels in decibels, at increasing distance from the outer rail, of the Project is detailed in **Figure 20**. The ground-borne noise levels are presented for a train speed of up to 105 km/h.

[14] Acoustics and Noise Consultants, Guideline "Measurement & Assessment of Groundborne Noise & Vibration", 2nd Edition 2012.

Figure 20 Calculated ground-borne noise levels from train passbys



The calculated ground-borne noise levels identified that at a distance of greater than 50 m from the outer rail the L_{ASmax} 40 dBA daytime and L_{ASmax} 35 dBA night-time ground-borne noise assessment criteria would be achieved.

There was one sensitive receptor (SLR ID 254050) identified to be approximately within 50 m of the outer rail of the Project alignment. The nearest facades of the receptor building are located where the outdoor noise environment would be dominated by the airborne railway noise, which can mask the potential ground-borne noise content at the nearest habitable rooms facing the rail corridor.

Within other habitable rooms, where the airborne noise component can be lower, there is potential for the airborne noise to not fully mask potential ground-borne noise and perceptible ground-borne noise impacts may be experienced.

All the other sensitive receptors were determined to be greater than 50 m from the outer rail and on this basis the ground-borne noise criteria would likely be achieved. Whilst ground-borne noise levels calculated at the majority sensitive receptors were within the assessment criteria, and do not trigger investigation of mitigation, there can still be a risk of minor perceptible ground-borne noise at sensitive receptors. Ground-borne noise can be perceptible even where the ground-borne vibration assessment criteria are comfortably achieved.

At this stage of the design, because the building construction of the sensitive receptors is not known, it is not possible to forecast with certainty the indoor ground-borne noise levels that could eventuate during railway operations. It is recommended that ground-borne noise levels are reviewed through further assessment during the detail design of the Project to confirm the assessment outcomes.

13 Cumulative impacts

The Project directly links to the south with the adjoining N2NS project section and links directly to the B2G project section to the west. At the sensitive receptors within the NS2B project area, the primary source of rail noise will be the Inland Rail trains as they travel on the NS2B alignment.

Rail noise from the arrival and departure of the trains from the adjacent N2NS and B2G project sections will occur further from the NS2B project infrastructure. Consequently, adjacent rail operations are not expected to result in a cumulative increase in daily railway noise levels at the sensitive receptors within the Project area.

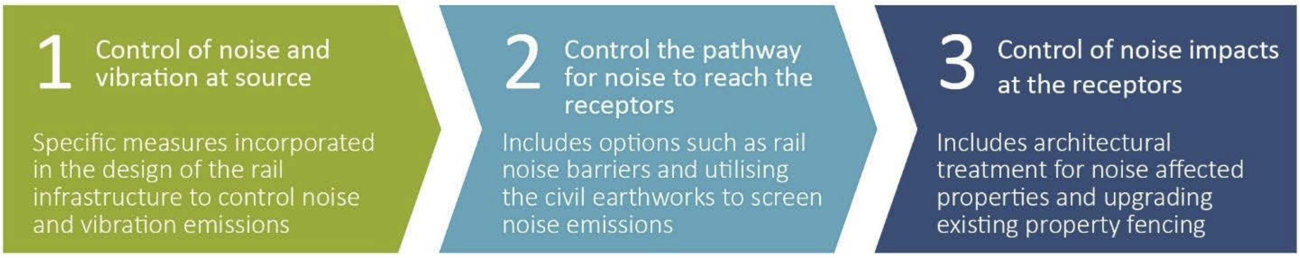
Whilst the Inland Rail Program is being delivered as separate project sections, once in operation the source of railway noise and vibration would be unlikely to be defined by sensitive receptors as being within the extent of a specific project section. In this regard, subjective cumulative noise or vibration impacts from trains operating within individual project sections on Inland Rail is not anticipated to occur.

14 Recommendations

14.1 Feasible and reasonable mitigation measures

Mitigation measures shall be investigated where the predicted or monitored railway noise, ground-borne noise or ground-borne vibration levels are determined to be above the criteria. The investigation of noise and vibration mitigation for the Project follows a hierarchy of control options, as summarised in **Figure 21**.

Figure 21 Hierarchy of noise and vibration mitigation measures



On the Inland Rail Program, ARTC is applying the following strategy as the basis for selecting feasible and reasonable noise mitigation:

- Noise barriers are generally only considered where groups of triggered sensitive receptors are apparent. For isolated sensitive receptors, such as single dwellings in rural areas, noise barriers would generally not be considered.
- The noise mitigation for isolated sensitive receptors is expected to include:
  - At-property architectural treatments to the building (such as increased glazing or facade constructions) to control rail noise inside building; and/or,
  - Upgrades to the receptor property boundary fencing to improve screening of rail noise.
- For two sensitive receptors on the same side of the track, the potential for a noise barrier or architectural treatment of the building will be considered on a case by case basis.
- For three or more sensitive receptors in close proximity on the same side of the track noise barriers will be considered as a primary noise mitigation option.

Further to the above strategy, the selection and specification of as-required noise mitigation also requires the consideration of a of range of safety, community, visual amenity, engineering, environmental and cost factors. These factors are considered in determining whether a mitigation option is reasonable to implement.

The terms 'feasible' and 'reasonable', with respect to noise mitigation, are outlined below in **Table 25**.

Table 25 Evaluation of feasible and reasonable for noise mitigation

Term	Description	
Feasible (practicable)	The noise mitigation should be a conventional and available noise mitigation approach. Ideally the option is consistent with industry best practice and does not introduce novel or untried technology. The mitigation should be practical to build with consideration to the constructability, engineering, maintenance and reliability of the option.	
Reasonable	When determining if mitigation is reasonable, the following factors should be considered:	
	Safety	The mitigation should not adversely impact the safety of the public or the safety of implications of rail operations within the rail corridor. For example, pedestrians should be able to audibly and visually detect trains at pedestrian crossings.
	Noise impacts	The effect of the noise mitigation to change aspects such as the overall noise levels, the amenity of the ambient noise environment and how frequently the rail noise levels could trigger mitigation are all considered.
	Noise mitigation benefits	The noise reduction performance achieved by the mitigation is reviewed, along with the perceptible change in noise level that could be experienced.
	Community views	The views of landowners and the community should be consulted and options that have the majority support from the affected community should be considered.
	State government requirements	Consider any State specific requirements for what constitutes reasonable or practicable.
	Cost	The costs should be reasonable in context of the overall project cost and spending on other similarly affected residents. The cost should consider the overall project costs including maintenance costs. Any residual costs to the community, such as running air-conditioning, should also be reviewed.

14.2 Noise and vibration mitigation options

A review of potential feasible and reasonable mitigation options to reduce and control noise and/ or vibration levels, and related impacts at sensitive receptors, is discussed below in **Table 26**.

The options demonstrate the range of mitigation measures that can be implemented on the Project. The final decision on noise mitigation measures will be determined during the detail design and construction of the Project. This is expected to include further noise and vibration prediction modelling to verify the outcomes of this assessment.

The detail design may determine a combination of options would be implemented to provide the feasible and reasonable control of the noise and vibration, targeted to achieving the assessment criteria and minimising potential impacts.

Table 26 Review of potential noise mitigation measures

Noise source	Aspect	Commentary
Rolling noise	Noise walls or barriers at the rail corridor boundary	Rail noise barriers can be an effective noise mitigation option to control the noise emissions from both the wheel-rail interface and from the locomotives. Appropriately designed noise walls and barriers can typically reduce the overall noise levels between 5 dBA to 15 dBA, where the line of sight between the sensitive receptor and the source(s) is fully impeded by the barrier structure. The Project would only consider noise walls or barriers where the mitigation can effectively control noise at groups of sensitive land uses and receptor buildings and where noise level reductions of generally 5 dBA or more are required at sensitive receptors.
		The key considerations with rail noise walls or barriers, include: • The proximity of key infrastructure such as local roads, waterways and drainage culverts can constrain the location and extent of noise walls or barriers. These factors can prevent noise walls and barriers from being a reasonable or practicable noise mitigation option. • There would be little or no reduction in the noise emissions from the locomotive exhaust and train horns unless the wall or barrier structures are constructed to a height of at least 4 m and located within the rail corridor. • Availability of land between the rail line and sensitive receptors may constrain the construction of the base/ foundations of the noise wall or barrier. • The location, extent and height of noise walls or barriers would need to be designed to achieve a minimum noise reduction performance, control reflected sound and meet specifications for earthworks, flooding, surface water run-off, stabilisation, wind loading and erosion. • Social and environmental factors considered include; loss of open aspect and breezes, potential for vandalism and a need for graffiti removal, reduction in visual amenity of the landscape, loss of views and vistas and the removal of vegetation.
	Low height noise barriers	In situations where the primary noise source is from the wheel-rail interface, low height barriers (for example ≤ 2 m in height) can be constructed close to the outer rail track. Such barriers can achieve similar noise reductions to noise walls or barriers at the rail corridor boundary. Typically, this mitigation option only suits single tracks and where only the rolling noise needs to be controlled. Given the overall noise levels from rail freight are a combination of rolling noise and locomotive noise emissions the low height noise barriers could have a negligible influence on the compliance to the noise criteria. In some cases, the use of low height barriers could be considered to achieve a perceptible change in railway noise. Reductions in noise levels by at least 3 dBA could result in a perceptible improvement to the loudness of train passby events.

Noise source	Aspect	Commentary
Rolling noise	Earth mounds at the rail corridor boundary	Earth mounds at the rail corridor boundary can be an alternative to or complement noise walls and barriers. The earth mounds can mitigate noise by impeding the direct line of sight between the noise source and receptor. To reduce noise levels between 5 dBA to 10 dBA, potential earth mounds would need to be a comparable height and length to potential rail noise walls or barriers. A review of conceptual earth mounding identified that outside of the main townships earth mounds up to 3 m in height could reduce the LAeq noise levels by at least 3 dBA.
		The required height of noise walls or barriers can be achieved where the structure is constructed on an earth mound base. This approach provides the required screening of noise and can reduce the associated costs of the noise wall or barrier. When reviewing the practical application of earth mounds, the following should be considered: • The construction of earth bunds can be constrained by the available space between the rail corridor and neighbouring infrastructure. • Earth mounds require considerably more space than the footprint of a rail noise barrier. A 2 m height earth mound could require an 8 m wide base. • Earth mounds could provide a benefit to control perceptible rail noise impacts. Reductions in noise levels by at least 3 dBA could result in a perceptible improvement to the loudness of train passby events. • Whilst earth mounds may not achieve specific noise reduction performance as can be achieved with noise walls or barriers, they can assist in reducing the overall noise levels to be closer to the assessment criteria. • In addition to the potential constraints associated with noise walls and barriers, the earth mound would also need to be designed to meet contamination, dust, health and ecological requirements. • The implications to water through flow and flooding will need careful consideration to ensure the earth mounding does not adversely impede the movement of surface water. • The required extent and height of the earth mounds to achieve reduction in noise levels may exceed the availability of re-usable spoil material.
	Rail dampers	Rail dampers may provide localised benefit for the control of rolling noise where the contribution from the rail is a primary factor. Typical international experience is a reduction in rolling noise of 3 dBA and there is limited evidence that suggests rail dampers can provide some benefit in controlling curving noise. The effectiveness of rail dampers may be limited by the stiffness of the ballasted track and concrete sleepers, the forces exerted by the heavy rail freight and the long-term durability and maintenance of such measures. Sections of generally straight track would not be highly susceptible to prominent or regular wear and would be most suited for the consideration of rail dampers.

Noise source	Aspect	Commentary
Rolling noise	Maintaining defective rollingstock	Defects with the wagons, such as wheel flats or misaligned axles/ bogies, can cause discrete and potentially annoying high noise events. ARTC currently implements Wayside Monitoring Systems across the rail network to identify individual rollingstock and the specific sources of noise for the targeted mitigation of railway noise. The Wayside Monitoring Systems include: • Wheel impact and load detector, bearing acoustic monitoring (RailBAM) and Squeal acoustic detector (RailSQAD), • Angle of attack, hunting detector and wheel profile monitoring. A similar monitoring program could be implemented to identify sources of high noise events. Once identified, defective rollingstock can be temporarily removed from service and defects repaired to address factors contributing to higher noise levels or discrete annoying noise characteristics. It is likely the overall reduction to L_{Aeq} and average L_{Amax} noise levels would be minor (probably less than 1 dBA) but would assist in managing noise events that could cause disturbance.
Locomotives	Exhaust mufflers	The exhaust outlets of the locomotives can be a primary source of low frequency and overall noise emissions from the train passbys. The exhaust systems of new and existing locomotives can be modified with exhaust mufflers to improve attenuation of noise emissions, including low frequency noise. Because such measures require specifications for the rollingstock they will not be readily implementable by ARTC without appropriate commitments from rail operators.
Safety warning devices	Safety requirements	The operation of devices such as train horns and level crossing alarms are exempt from compliance to airborne noise criteria due to public safety obligations. The following mitigation options are proposed as part of ARTC's commitment to managing potential noise impacts.
	Wayside horns	A wayside horn is an automated audible warning located at the level crossing. Instead of the train sounding its horn on approach to a level crossing the wayside horn automatically sounds to provide a targeted audible noise event for vehicles and pedestrians at the level crossing. The objectives are to remove the need for the train to sound its horn adjacent to sensitive receptors and to implement a horn event that has a noise emission level and sound directivity focused to the users of the level crossing. It is expected that respite from train horns could reduce L_{Amax} noise levels by more than 10 dBA at sensitive receptors and provide a notable improvement in loudness and potential risk for annoyance, particularly where there can be more than two train horn events every hour with the Project.
	Soft tone alarm bells	The design of level crossing alarm (warning) bells will be required to confirm to specific design standards. Typically, loud tone alarm bells operate at L_{Amax} noise levels between 85 dBA to 105 dBA at 3 m. A soft tone bell design, which has a lower L_{Amax} noise emission level between 75 dBA to 85 dBA at 3 m can be applied, where practicable, to reduce maximum noise levels from the alarm bells by approximately 10 dBA. The L_{Aeq} noise level would have a more marginal improvement as the noise environment surrounding level crossings is primarily influenced by the train passby events.

Noise source	Aspect	Commentary
Property controls	Architectural treatment of property	Where external rail noise levels are validated, through measurement, to exceed the assessment criteria a potential option is to mitigate the intrusion of rail noise within the affected property. The provision of architectural treatment would depend on a number of factors and is expected to only apply to habitable rooms or acoustically significant rooms/uses of sensitive buildings. Typically, measures such as upgraded acoustic glazing, acoustic window and door seals, acoustic insulation for the roof are considered to mitigate noise intrusion. The provision of upgrades to ventilation, such as fresh air ventilation (acoustic ducting) or air-conditioning will allow windows to be kept closed as a mitigation option whilst maintaining air flow.
		Appropriately designed measures, where windows are closed, can mitigate the intrusion of noise by more than 10 dBA. However, these measures can be more effective to control the intrusion of rolling noise as it is more broadband in nature and often does not have prominent tonal or low frequency components. All consideration of architectural property treatment would be subject to an inspection of each individual property to confirm its suitability for the implementation of noise control treatments.
	Property construction	In rural locations, the age and construction of residential properties can influence the practical implementation of modern architectural treatments. The review of architectural treatments will require a detailed survey of the eligible properties and advice from engineers, architects and acousticians.
	Consideration of low frequency noise content	Noise which is considered to have low frequency and/or tonal content can be increasingly annoying. Where the control of low frequency noise is required at properties, the architectural acoustic treatments would need to consider the control of low frequency noise intrusion to achieve an overall improvement to the internal rail noise levels and potential characteristics that could cause annoyance. The control of low frequency noise within a property is challenging and care needs to be taken to manage residual impacts such as the architectural treatments controlling the mid and high frequencies which may cause the low frequency noise to become more perceptible. The United Kingdom Department of Environment, Food and Rural Affairs has published a reference curve for assessing low frequency noise indoors[15]. This curve should be adopted as a design target for architectural treatments where measured external rail noise levels at sensitive receptors are above the assessment criteria and identify prominent low frequency noise content.

[15] UK Department of Environment, Food and Rural Affairs, 2005. Proposed Criteria for the Assessment of Low Frequency Noise Disturbance, University of Salford, February 2005.

Noise source	Aspect	Commentary
Property controls	Upgrades to existing property fencing	Existing fencing at the boundary of individual receptors can be upgraded by replacing part or all of the existing fencing with an 'acoustic' fence design. Compared to standard residential property fencing, an acoustic fence, such as aerated concrete (solid masonry), has an improved acoustic transmission loss performance. Whilst the noise reduction performance will be specific to individual properties, upgrades to existing property fencing are likely to be suitable only where noise reductions of less than 10 dBA are required. The potential for upgrading existing property fencing can be limited by the line of sight between the railway and the receptor, the available land and the requirements of local Councils and regulatory authorities with respect to the height and materials permitted for property boundary fencing. Agreement between the landowner and ARTC would be required for ARTC to undertake works on private property.
	Property relocation	In rural locations, individual residential property can be located on large land holdings. It may be possible to relocate the residential property within the same land so that it is further from the rail corridor and noise levels would be lower. The relocation of property would be assessed on a case by case basis and ensure there would be a notable improvement to the noise environment at the relocation site. As a general rule, where the distance between the dwelling and the rail line is doubled the rail noise levels can 3 dBA less.
	Negotiated agreements	The implementation of architectural treatments and other measures to private property would likely be subject to the agreement of commercial and legal terms between ARTC and the property owner.

14.3 Summary of noise mitigation

The airborne noise assessment identified railway noise levels triggered the review of noise mitigation at three sensitive receptors for rail operations at project opening (2025), with an additional two sensitive receptors triggering the criteria, for a total of five sensitive receptors triggering investigation of noise mitigation at the design year 2040).

The sensitive receptors triggering the review of noise mitigation were identified from geospatial information and surveys of aerial imagery to be properties for residential activities. A review of the noise mitigation triggers, based on the margin the rail noise levels are above the criteria, is provided in **Table 27**.

Table 27 Summary of noise mitigation triggers

Assessment criteria margin	Sensitive receptors triggering the assessment criteria
Year 2025 – project opening	
1 dBA to 3 dBA	0
>3 dBA to 5 dBA	1
>5 dBA to 10 dBA	1
>10 dBA	1
Total receptors triggering noise mitigation - project opening	**3**

Assessment criteria margin	Sensitive receptors triggering the assessment criteria
Year 2040 – design year	
1 dBA to 3 dBA	2
>3 dBA to 5 dBA	0
>5 dBA to 10 dBA	2
>10 dBA	1
Total receptors triggering noise mitigation - design year[1]	**5**

Note 1 The total receptors triggering noise mitigation includes the three receptors triggering the criteria in 2025 and the additional two receptors identified by the year 2040.

A review of the location of these sensitive receptors determined the properties are isolated properties dispersed along both sides of the Project alignment. In addition to evaluating the location of the sensitive receptors, rail noise barriers may not be the feasible and reasonable mitigation option where noise levels are within 5 dBA of the assessment criteria.

Based on both the location of the sensitive receptors and the margin by which the noise criteria is triggered; the feasible and reasonable noise mitigation options, in addition to at-source controls, are expected to be:

- Architectural acoustic treatments to the buildings triggering the assessment criteria to control rail noise within the internal environment of the building; and/or,
- Upgrades to any existing property boundary fencing to improve screening of rail noise levels.
- Review operation of the North Star Road level crossing to reduce source noise emissions from the level crossing alarm bell and the train horns.

During the detail design phase, the sensitive receptors shall be surveyed to exclude rooms and buildings that are not noise sensitive from the consideration of at property treatments, such as storage areas, bathrooms, hallways and corridors. The surveys would need to investigate the noise attenuation performance of the existing property facades and, as-required, revise the assessment of potential internal rail noise levels.

14.4 Further noise prediction modelling

The noise prediction modelling for this assessment adopted the Nordic method (Kilde 130) for calculating rail noise emissions and the propagation of rail noise within the environment. Whilst the Nordic methodology is accepted to provide reliable predictions, and can be inherently conservative, it does not allow for more advanced prediction and analysis of railway noise.

It is recommended that during the detail design of the Project, when aspects such as noise mitigation will be confirmed, the rail noise prediction modelling is updated for the detail designs. The modelling should include the potential for assessing the frequency content of the railway noise emissions and the influence of regional meteorological conditions.

The consideration of the frequency content from the rollingstock is important where predicted external rail noise levels are applied to determine the appropriate architectural property treatments or the design of mitigation such as rail noise barriers.

14.5 Validation of noise and vibration levels during operation

A programme of noise and vibration monitoring is recommended to be undertaken within six months of the commencement of railway operations on the Project. The purpose of the monitoring surveys shall be to:

- Quantify the rail noise and vibration levels from the daytime and night-time rail operations and determine the $L_{Aeq(15hour)}$ daytime, $L_{Aeq(9hour)}$ night-time and L_{Amax} rail noise levels at the most affected sensitive receptors.
- Assess the Project's compliance with any relevant conditions of approval relating to noise and vibration emissions from the operation of the Project.
- Provide an assessment of the effectiveness of any noise and vibration management and mitigation measures implemented on the Project.
- Identify, if required, further noise and vibration mitigation measures to meet the ARTC's noise and vibration management criteria and relevant conditions of approval.

The recommendations below are provided to assist the development of a noise and vibration monitoring plan:

- Provide a monitoring strategy consistent with the requirements of relevant acoustic standards and guidelines for monitoring environmental and transport noise and vibration.
- Plan and schedule the monitoring surveys with consideration to:
  - The rail movements during each daytime and night-time period. The survey period shall include the days during which the highest number of train movements would be expected.
  - At locations free from localised buildings and structures (other than noise barriers) that may screen or reflect noise.
  - The condition of the rails and other rail infrastructure.
  - Weather conditions during the monitoring periods.
- Monitoring should be conducted at the sensitive receptors with the potential for the highest received noise and vibration levels from rail operations.
- Where feasible, noise levels should be assessed 1 m in front of the most affected building façade. Where noise levels are monitored in the free-field a +2.5 dBA correction should be considered to adjust the free-field level for a noise level at the building façade.
- Should monitoring be required within a property, the noise monitoring would be conducted at the centre of the habitable room that is most exposed to noise from rail operations.
- Vibration shall be monitored in the three axes representing horizontal, vertical and axial direction of displacement (movement). Vibration shall be monitored as the Peak Particle Velocity (mm/s) and vibration acceleration (m/s^2).
- If required, reference the monitored noise levels to update the predicted rail noise levels and re-assess rail noise and vibration levels at the sensitive receptors aligning the Project.
- If the noise and/or vibration levels are above the applicable criteria at any sensitive receptors, allowing for any monitoring and compliance tolerances, the key sources of rail noise and contributing factors (e.g. rail defects, excessive rail roughness levels, turnouts, locomotive engine exhausts) shall be identified to inform the investigation of feasible and reasonable mitigation measures.

The results of the monitoring surveys are to be applied, as-required, to revise and update the rail noise and vibration predictions for the rail operations. In this regard, the validated noise and vibration levels can be applied to continually refine the conservatism and uncertainty in the predictions and support the selection of feasible and reasonable mitigation measures.

15 Residual impacts

The rail noise and vibration assessment criteria are designed to manage aspects such as environmental harm and nuisance. The intent of the criteria is to identify where feasible and reasonable noise mitigations should be implemented to manage the potential for impacts consistent with best practice for environmental management.

The criteria do not require noise from railway operations, including where noise mitigation is implemented, to not be audible at sensitive receptors. The potential for annoyance or disturbance from rail noise is subjective and can remain a potential impact even where noise mitigation is implemented, and noise levels are well within the noise criteria.

The feasible and reasonable noise mitigation for the Project is expected to primarily be at-property treatments, such as upgrading existing glazing or the provision of air-conditioning, to manage the intrusion of rail noise and maintain internal (indoor) noise amenity within habitable rooms. These treatments do not address the source emission of rollingstock noise or the external (outdoor) rail noise levels within the environment surrounding the rail corridor.

On this basis, the rail noise levels can remain above the external rail noise assessment criteria, and be perceptible, at the sensitive receptors with the implementation of at-property noise mitigation measures. Notwithstanding, the at-property treatments would be implemented to reduce to internal railway noise levels to achieve targeted improvements to the indoor acoustic environment of habitable rooms.

In lieu of the known building construction of the sensitive receptors and the acoustic performance specification of individual at-property treatments, the noise reduction performance is not able to be quantified at this stage. Referencing conventional building construction treatments and acoustic glazing specifications, it is reasonable to assume the internal railway noise could be reduced by at least 5 dBA. Reducing noise levels by this margin would be a perceptible improvement to building occupants, where noise characteristics such as low frequency are also suitably controlled.

There is potential for ground-borne noise and vibration to be perceptible even where the assessment criteria are achieved within sensitive receptors. However, disturbance or annoyance impacts would not necessarily be experienced based on the relatively low levels of ground-borne noise and vibration predicted at the receptors.

16 Conclusion

The operation of the NS2B project section of the Inland Rail Program has the potential to be a source of airborne noise, ground-borne noise and ground-borne vibration within the environment surrounding the Project. This report has identified where the predicted levels of noise and vibration from the railway operations would achieve assessment criteria and where the levels trigger an investigation of feasible and reasonable mitigation options.

Based on the assessment of potential noise levels from the daily train movements on the Project, the noise criteria for the daytime and night-time periods are achieved at the majority of the identified sensitive receptors. There are up to five sensitive receptors where noise levels trigger a review of mitigation.

The location of the five sensitive receptors, the predicted noise levels at each receptor and the principles of ARTC's management of noise on the Inland Rail Program were reviewed to identify the appropriate noise mitigation options.

In addition to source noise controls implemented in the design and construction of the Project, the reasonable and practicable noise mitigation is expected to include at-property treatment for the sensitive receptors.

At-property mitigations can include architectural treatments to control railway noise within the building and upgrades to property fencing. Whether at-property controls or other alternative mitigation options are required will ultimately be determined through the detail design of the Project. This will include consultation with the property owners, further railway noise modelling, analysis of engineering and environmental constraints and the verification of noise levels once railway operations commence on the Project.

The assessment of vibration from railway operations determined that predicted levels would achieve the criteria for ground-borne noise and ground-borne vibration at all but one of the identified sensitive receptors. The airborne railway noise levels are expected to dominant the noise environment at these receptors. On this basis, the assessment did not identify a need for specific vibration treatments beyond the resilient matting for retention of ballast on bridge and viaduct structures.

Where the Project achieves the noise and vibration criteria there can still be potential for noise and vibration from railway operations to be audible/ perceptible within the environment. It is not unreasonable for outdoor noise from railway operations to be audible and perceptible at least 1 km from the Project alignment.

The airborne noise, ground-borne noise and ground-borne vibration levels will continue to be assessed during the detail design and construction of the Project. It is recommended that the predicted noise and vibration levels and assessment outcomes presented in this report are verified as part of the on-going assessments.

INLAND RAIL

APPENDIX K

Operational Railway Noise and Vibration Assessment

Appendix A Sensitive Receptors

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 1 of 10

300 m

Coordinate System: GDA 1994 MGA Zone 56

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Scale: 1:15,000
Date: 24-Mar-2020
Author: JG

- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
- Bridges & Viaducts
- Sensitive Receptors (Residential)
- State Boundary

ARTC InlandRail

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 2 of 10

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 4 of 10

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 5 of 10

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 6 of 10

300 m

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- Rail Alignment/Centreline
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- State Boundary

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 7 of 10

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 8 of 10

300 m

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 9 of 10

300 m

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Paper: A4 Scale: 1:15,000
Date: 24-Mar-2020
Author: JG

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NORTH STAR TO BORDER

Sensitive Receptors

APPENDIX A - Map 10 of 10

300 m

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APPENDIX

K

Operational Railway Noise and Vibration Assessment

Appendix B Noise Prediction Model Verification (NSW)

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

Overview

The level and character of railway noise within the local environment is specific to the rollingstock operations, condition of the rails and the daily rail traffic. Because of the wide range in variability of these factors, noise prediction models for railway infrastructure are commonly developed from a database of verified source noise emission levels for the rollingstock.

Organisations such as TfNSW have available train noise emission databases for the use in noise modelling and railway noise impact assessments. A similar verified noise emission database has been adopted for the Inland Rail project (refer **Table 18** of this report).

The methodology to predict railway noise within the environment adjacent to the Inland Rail project has also been verified with reference to existing railway noise levels monitored by SLR at sections of existing railway operations that shall become part of the Inland Rail project NSW. The details of the railway noise monitoring and noise model verification at three locations in NSW are provided in the following sections.

Noise monitoring locations and methodology

The noise monitoring locations were selected based on the following criteria, designed to provide a consistent across the noise monitoring locations:

- At monitoring sites adjacent to the rail line(s) that could be safely and regularly accessed without requiring entry to the rail corridor.
- Generally, be approximately 15 m from the rail line to be representative of the nearest sensitive receptors that align the Inland Rail project and to be close enough to limit the potential influence of local weather conditions.
- Where the track was generally straight and observed to be in relatively good condition. This requirement limited the potential influence of unique factors such as curving noise or prominent track wear which can substantially increase localised rail noise levels.
- Where daily rail traffic was comparable to the proposed rail movements with the Inland Rail project.
- Railway operations were predominately heavy rail traffic (general freight and intermodal trains) and the locomotives were expected to generally be at a constant speed to minimise potential for discrete events such as braking or acceleration (high notch).

Railway noise levels for the daily existing trains movements were monitored at three nearby to Table Top, Henty and Wanitool, as summarised in **Table B1**.

Table B1 Noise monitoring locations in NSW

SLR ID	Location	Monitoring dates	Equipment[1,2]
1	331 Perryman Lane, Table Top NSW. 15 m from the outer rail	14 to 22 November 2018	NGARA noise logger (s/n 878000)
2	262 Henty-Walla Road, Henty NSW. 15 m from the outer rail.	14 to 22 November 2018	NGARA noise logger (s/n 8780C7)
3	731 Ballengoarrah Lane, Wanitool NSW. 13 m from the southbound outer rail and 17 m from the northbound outer rail	29 November to 7 December 2018	NGARA noise logger (s/n 878042)

Note 1 All monitoring equipment complies with the requirements of Australian Standard AS1259-1990 (part 1 and 2) and IEC 61672.

Note 2 All equipment was calibrated before and after the monitoring period with any drift in signal less than 1 dB.

To avoid the influence of surrounding buildings and structures on the railway noise levels, the railway noise levels were monitored in the free-field environment at 1.5 m above ground level for a period of seven consecutive days at each location.

The noise levels were measured at intervals of 1/10th of a second in order to isolate the discrete noise contribution from the train passby events.

The noise monitoring data was analysed to determine the noise emission level and duration of each clearly discernible train passby event. Applying principles from ISO 3095, the noise levels were analysed to define each train passby event. The analytical process for each location adopted the following approach:

- Identifying all noise level events above an initial threshold and sustained for a defined period of time; this was site specific and provided a first pass filter to identify likely train passby events.
- The length of each event was identified from the start and end points where the noise levels reached 10 dB above the background noise level at the time of each event.
- Each event was visually inspected to identify statistically valid train profiles i.e. a train passby signature that can be used to refine the processing of identifying each passby event.
- The audio data for each identified noise event was reviewed to confirm it was a train passby and not other, erroneous, activity nearby to the monitoring location.

Monitored rail passbys

The sound exposure level (L_{AE}) for each individually processed train passby was calculated as part of the analysis process. The discrete L_{AE} of each identified Freight and XPT train are plotted in **Figure B1** and **Figure B2** below for the three monitoring locations.

The average L_{AE} is plotted with comparison to the modelled value representative of a 1,000 m freight train with NR class locomotive, as per **Table 18**. The relevant existing train speeds at the monitoring locations were estimated from posted track speeds and site observations. Based on the distribution of data, both sides of the double-track at Wanitool are in use, while the other two monitoring locations represent single track conditions.

Figure B1 Monitored freight train passby sound exposure levels

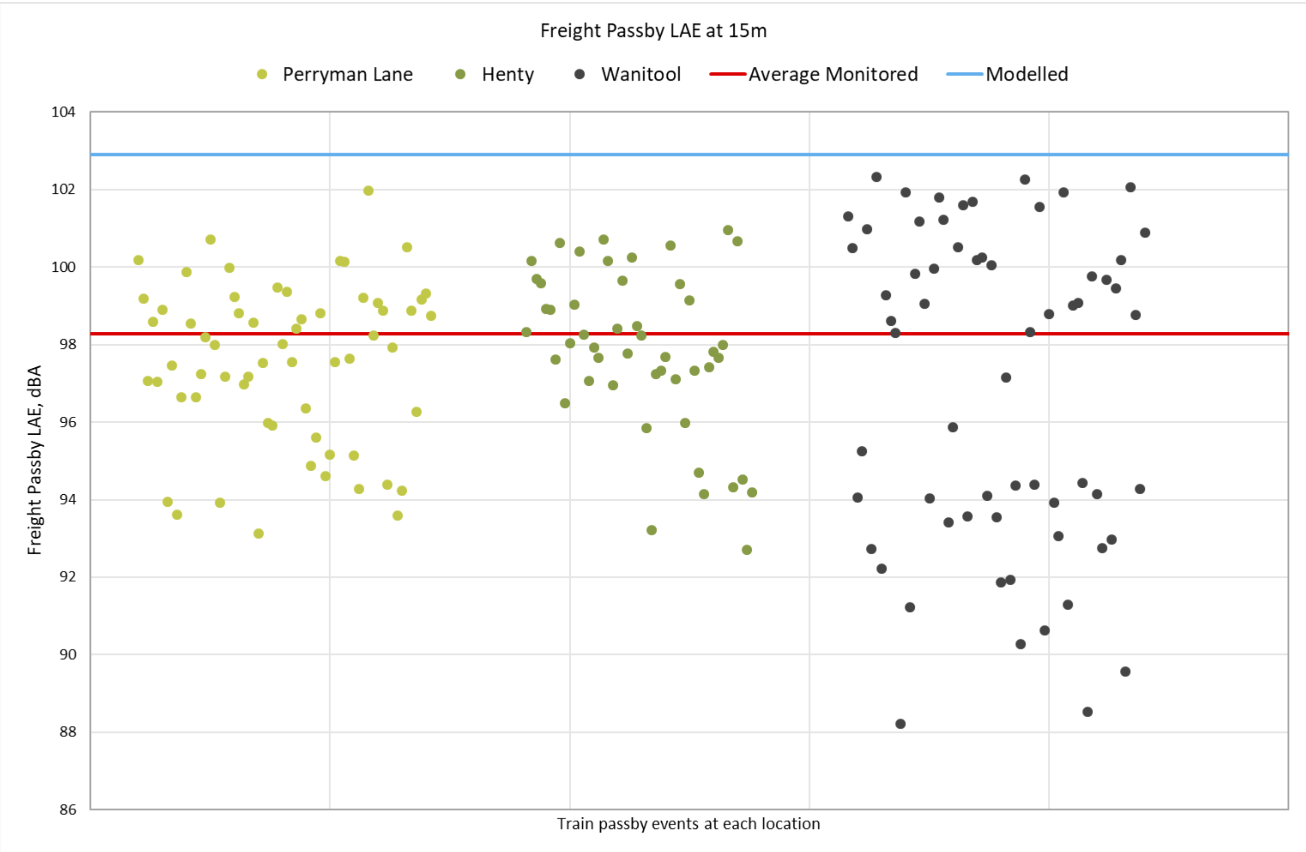
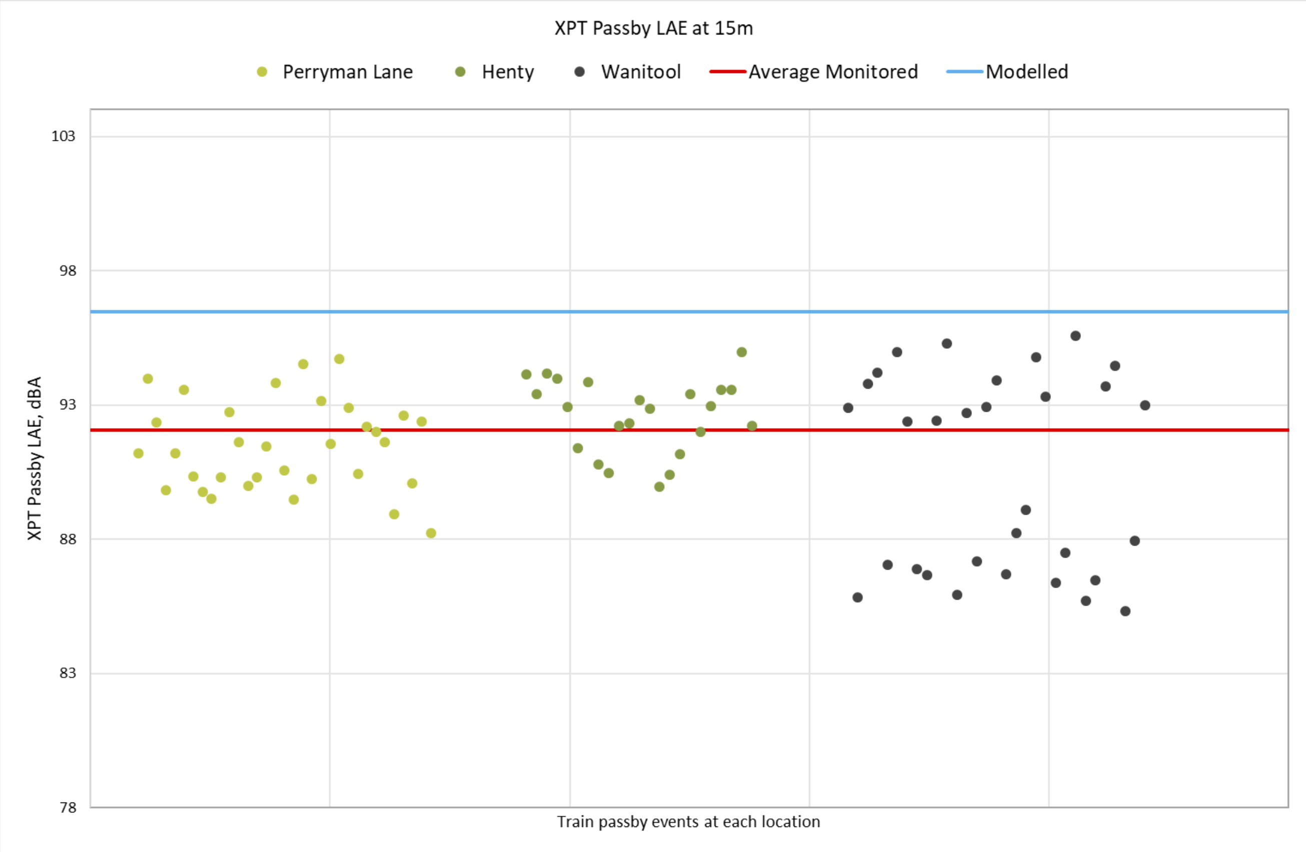


Figure B2 Monitored XPT train passby sound exposure levels



Monitored daily rail noise levels

The monitored daily LAeq railway noise levels at each monitoring location are detailed in the following table. The daily LAeq noise levels for validation are calculated from the noise level of each train passby, averaged over each day monitored and applied to the modelled number of trains on this section.

Weather data was referenced from the nearest Bureau of Meteorology weather stations to the monitoring locations. The local weather conditions, principally wind speed and precipitation, were found to not have influenced the monitoring noise levels for the train passby events. This was also, in part, due to the proximity of the monitoring locations to the rail lines. The daily railway noise levels, based on monitored data, at the locations at the monitoring locations are detailed in **Table B2**.

Table B2 Monitored daily railway noise levels

Monitoring location	Monitored railway noise levels, dBA	
	Daytime	Night-time
	LAeq(15hour)	LAeq(9hour)
Perryman Lane	61.5	64.3
Henty	60.6	63.6
Wanitool	62.7	65.4

The analysis of the monitored noise levels and audio recordings for the train passbys, along with on-site observations, identified the following:

- The daytime and night-time L_{Aeq} noise levels correlate quite closely between sites, with a total variability of approximately 2 dB. This reaffirms that the same rail traffic is dominant across all monitoring locations.
- The night-time L_{Aeq} noise levels are generally louder than the daytime, due to a similar volume of train passbys occurring over a smaller period of time.
- The noise statistics are lower at Henty when compared with the other two monitoring locations. Given that no obscuring geometry or other notable features were observed at this location it is assumed that existing train speeds a relatively lower on this section.

Noise modelling

To enable verification of the monitored noise levels, the SoundPLAN noise modelling method, as discussed in **Section 77** of this report, was applied to calculate railway noise levels at each noise monitoring location. A summary of the key noise modelling data is provided in **Table B3**.

Table B3 Noise modelling inputs

Noise model attribute	Source data/ modelling approach
Daily train movements	As per the existing A2I sections (volumes are consistent for day and night periods): 3 x Intermodal, 1 x Steel, 1 x General Freight, 1 x Grain – 1 and 2x XPT.
Rail line speeds	Referencing the posted speed data and monitoring observations the freight train speeds were estimated as 110 km/h at Perryman Ln, 90 km/h in Henty and 115 km/h at Wanitool. The XPT speeds were estimated as 150 km/h for all monitoring locations.
Railway acoustic corrections	Nil, all track was straight with no tight-radius curves, turnouts etc. within 100 m of each monitoring location.
Track strings	The alignment of the existing rail tracks was referenced from publicly available datasets and rail corridor designs supplied by ARTC.
Consist information	All trains modelled as per the existing consists, detailed in **Table 17**.
Passenger rail traffic	Two XPT passenger train movements are included for both the day and night-time periods at all monitoring locations.
Local environment	3-dimensonal digital terrain models were developed for the environment at each monitoring location. Ground conditions were modelled as soft ground (ground absorption co-efficient of 0.6).

Noise model verification

The predicted and monitored L_{Aeq} railway noise levels at each location were compared as part of the noise model verification, as detailed in **Table B4**. The model was determined to be verified to a suitable accuracy where the predicted L_{Aeq} noise levels were within ±2 dBA of the measured railway noise levels.

Table B4 Modelled railway noise levels

Monitoring location	Monitored railway noise levels, dBA	
	Daytime	Night-time
	$L_{Aeq,15hr}$	$L_{Aeq,9hr}$
Perryman Lane	63.2	65.2
Henty	62.3	64.2
Wanitool	64.1	66.0

The monitored and modelled L_{Aeq} noise levels at each location were compared, as detailed in **Table B5**. The noise model validation was determined for all three noise monitoring locations. Overall, the L_{Aeq} noise levels verify within 2 dBA of the monitored L_{Aeq} noise levels during the daytime and night-time periods and achieves NSW guidelines on transport noise model validation.

At the EIS stage it is satisfactory to slightly over-predict the railway noise levels to provide conservatism in both the assessment of potential noise impacts and the recommendations for potential noise mitigations.

Table B5 Noise model verification

Monitoring location	Monitored railway noise levels, dBA	
	Daytime	Night-time
	$L_{Aeq,15hr}$	$L_{Aeq,9hr}$
Perryman Lane	1.6	-0.1
Henty	1.8	0.6
Wanitool	1.3	0.6

INLAND RAIL

APPENDIX K

Operational Railway Noise and Vibration Assessment

Appendix C Noise and Vibration from Double-Stacked Freight Wagons

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

ARTC

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

The load on the axles from freight wagons has the potential to influence the noise and vibration emission levels during the train passby event. The load will vary depending on the configuration of single stacked and double stacked containers and the contents of the containers which can vary from empty to the capacity weight.

To investigate the noise and vibration emission levels, SLR conducted a noise and vibration monitoring survey in January 2019 at a section of straight track near to Merriton, approximately 170 km north of Adelaide. The freight trains in the area were known to have both single stacked and double stacked containers on the wagons.

Based on site observations from outside the rail corridor area, the following features of the track were identified:

- The track was single line, on a ballasted track with concrete sleepers with train movements in both directions.
- The depth of the ballast was estimated at 700 mm on clay and sandy topsoil.
- Based on site observations the train speeds ranged from 80 km/h to 100 km/h.

During train passby events, noise and vibration levels were monitored simultaneously at six locations along the track section. A comparison of the noise and vibration level across the whole train passby was made for the trains that had only single stacked containers on the wagons and those trains with a combination of double stacked and single stacked containers. It was noted that no trains had all wagons loaded with double stacked containers and the analysis did not isolate those wagons that were empty or stacked with empty containers.

The noise level over the duration of the train passby events are presented for the three noise monitoring locations (Channel 4, Channel 5 and Channel 6) in **Figure C1**. Spot 2D acoustic intensity measurements confirmed the rail and wheel are key noise sources (and not say radiated vibration of containers).

The locomotives at the front of the train are the initial elevated noise levels with the sections of known single stacked and double stacked containers identified thereafter. It can be seen that the noise levels at the three monitoring locations were approximately 2 dBA or less during the passby of the double stacked wagons.

As shown in **Figure C2**, consistent with the measured noise levels, albeit a more marginal difference, the vibration velocity levels (in dB) are higher with the single stacked container wagons.

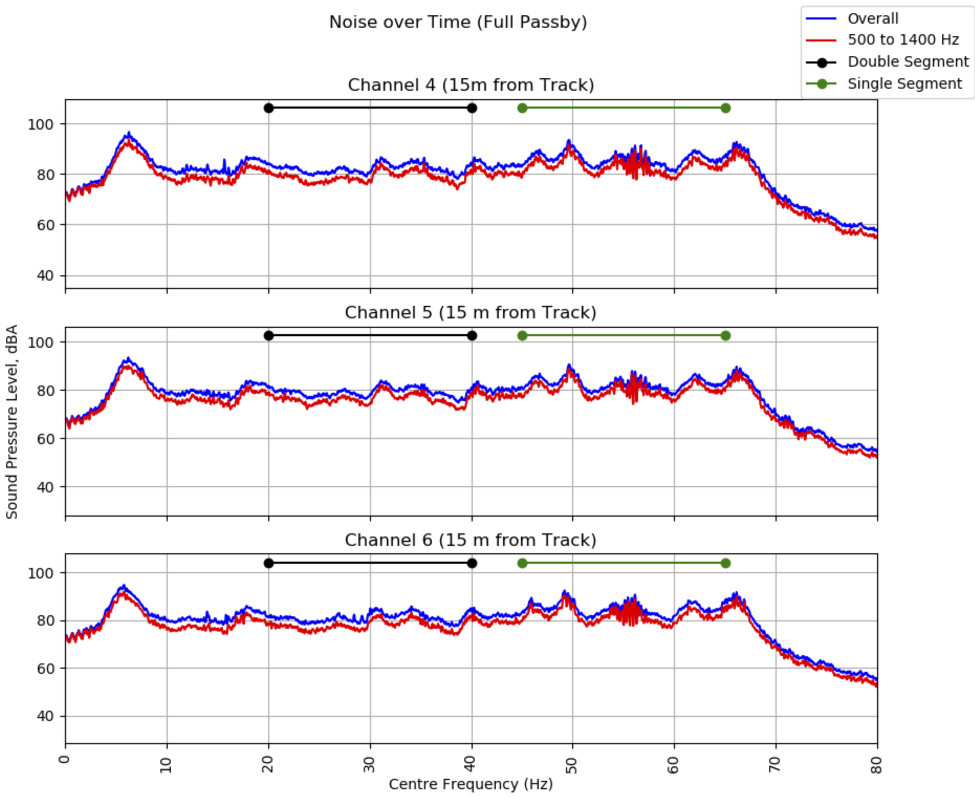
It is considered that if a noise emission correction factor were to be applied to the stacking configuration, this would be complicated by many factors in practice, particularly:

- the proportion of wagons with single and double stacked containers and where they are located,
- the number and position of empty wagons (no containers), and;
- the load of the individual wagons, which can vary from empty to the maximum load capacity.

Consequently, whilst the loading of the freight consist can vary considerably depending on the mix of empty or fully loaded containers, the measurements to date find it insignificant with respect to rolling noise and vibration emissions compared to other factors such as individual wheel and track condition.

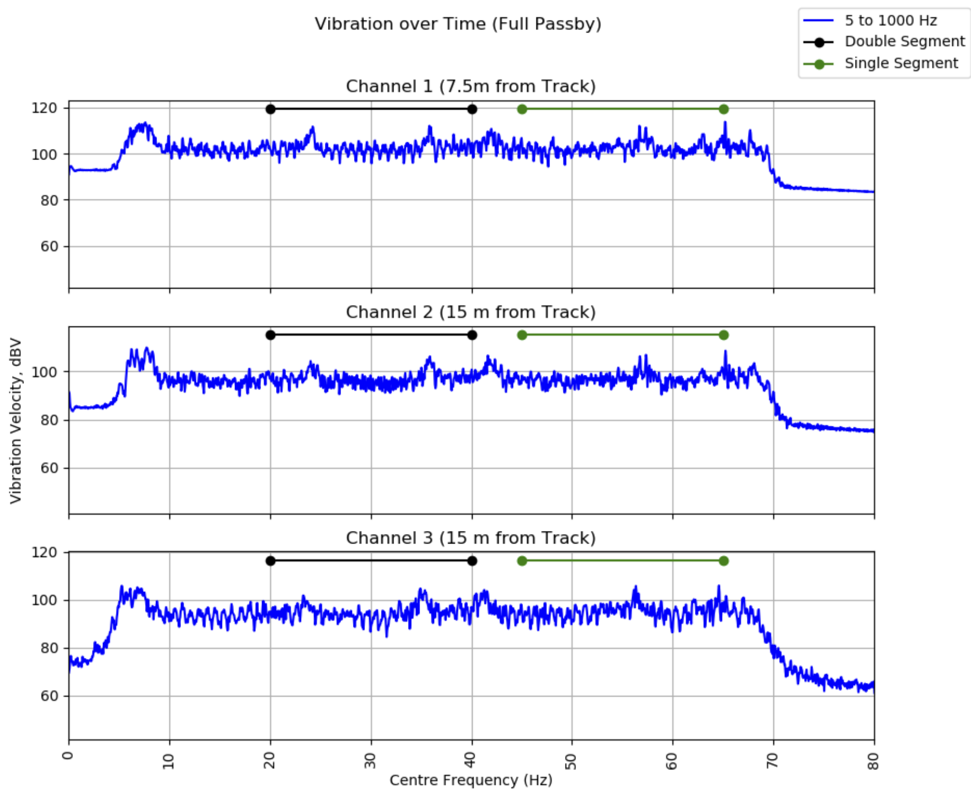
On the basis of the above analysis, correction factors to the noise and/or vibration emissions from double stacked wagons should not be considered in the Inland Rail operational rail noise and vibration assessments.

Figure C1 A-weighted noise levels for the entire train passby



The ground vibration levels at three locations (Channel 1, Channel 2 and Channel 3) for the same train passby event is presented in **Figure C2**.

Figure C2 Vibration velocity levels for the entire train passby



APPENDIX

K

Operational Railway Noise and Vibration Assessment

Appendix D Predicted Airborne Railway Noise Levels—Year 2025 Project Opening

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The predicted railway noise levels at the commencement of railway operations in year 2025 are detailed in the following table and noise contour maps.

The predicted noise levels are provided for the identified sensitive receptors within the 2 km study area. This includes all sensitive receptors where the predicted noise levels triggered an investigation of noise mitigation.

The symbol (-) in the table denotes there was not a prediction of future rail noise as the sensitive receptor was located more than 2 km from the source of noise or, for existing rail noise, the receptors were outside the assessment area where the Project tied into the existing rail corridors.

Following the tabulated results are the predicted noise contour maps for the daytime and night-time railway operations at the project opening in year 2025. The noise contours have been presented as the daytime and night-time assessment criteria applied by ARTC on the Project. All noise contours are predicted at 2.4 m above ground level.

The noise contours are calculated from the interpolation of thousands of calculation points and provide an overview of the railway noise levels to assist the interpretation of the assessment and its outcomes. The tabulated noise levels at the individual sensitive receptors should be referenced when assessing railway noise levels against the criteria.

Receptor ID	New rail corridor	Rail noise criteria			Project rail noise levels dBA		
		LAeq Day	LAeq Night	Lamax	LAeq,15hr	LAeq,9hr	LAmax
254027	New	60	55	80	54	55	80
254028	New	60	55	80	52	53	78
254031	New	60	55	80	52	53	77
254035	New	60	55	80	52	53	77
254037	New	60	55	80	50	51	76
254041	New	60	55	80	51	52	77
254042	New	60	55	80	54	55	80
254050	New	60	55	80	67	68	95
254056	New	60	55	80	49	51	76
254059	New	60	55	80	49	51	75
254060	New	60	55	80	47	48	72
254063	New	60	55	80	59	60	85
254064	New	60	55	80	48	49	73
254065	New	60	55	80	46	47	72
254067	New	60	55	80	45	46	72
254068	New	60	55	80	47	48	73
254070	New	60	55	80	46	47	72
254071	New	60	55	80	46	47	72
254072	New	60	55	80	46	47	71
254074	New	60	55	80	48	49	73
254075	New	60	55	80	42	43	66
254076	New	60	55	80	48	49	73
254078	New	60	55	80	51	52	75
254082	New	60	55	80	49	50	75
254085	New	60	55	80	48	49	73
254087	New	60	55	80	48	49	73
254088	New	60	55	80	51	52	77
254089	New	60	55	80	53	54	77
254096	New	60	55	80	61	62	87
254100	New	60	55	80	49	50	74
254103	New	60	55	80	43	45	70

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 1 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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Author: JG

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- Level Crossings
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- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- State Boundary
- Daytime noise criteria LAeq15hr 60dBA New rail corridor
- Daytime noise criteria LA max 80dBA New rail corridor
- Receptors

Noise contours are based on a set distance above the local terrain level of 2.4m.

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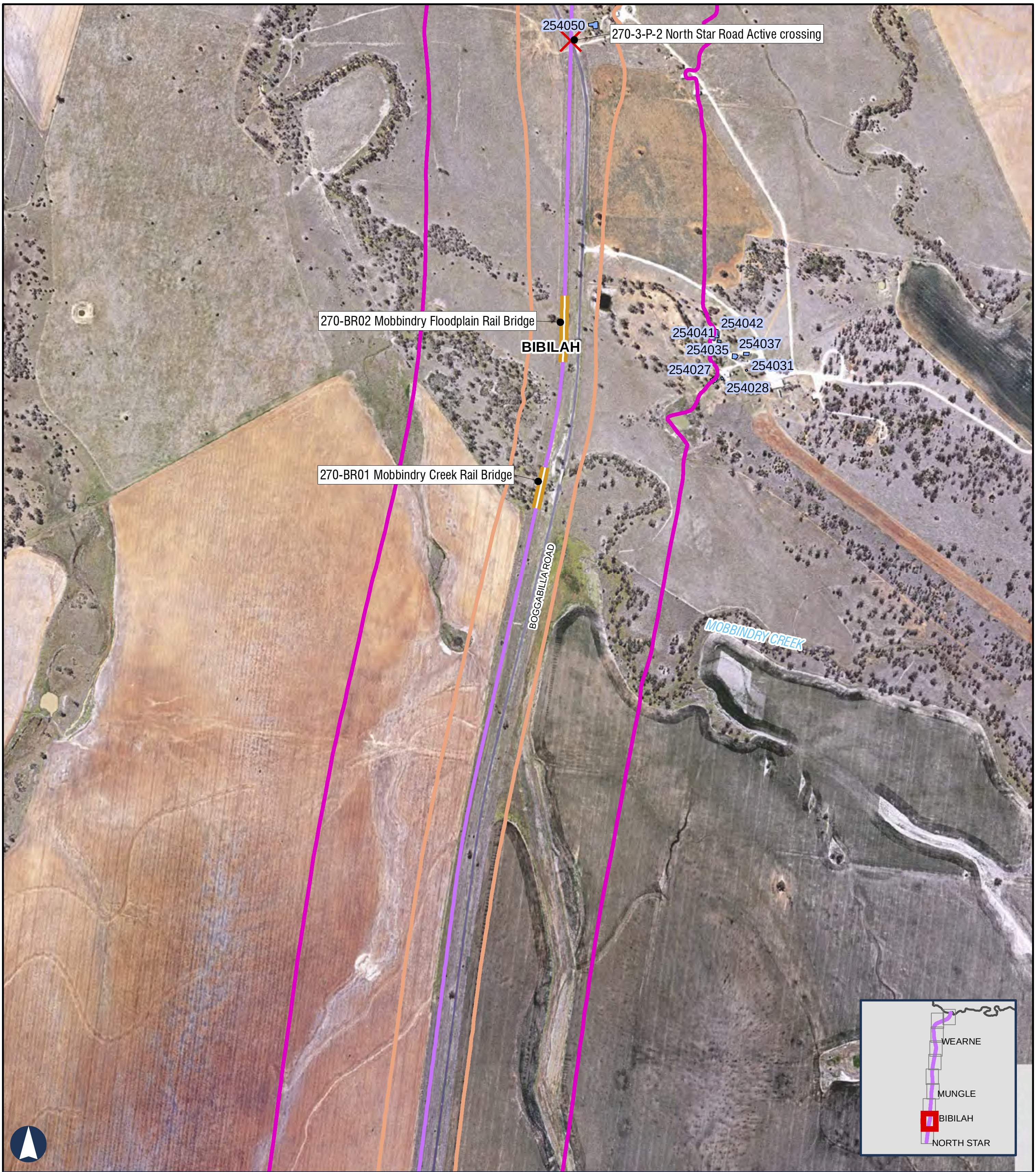

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 2 of 10

410 m

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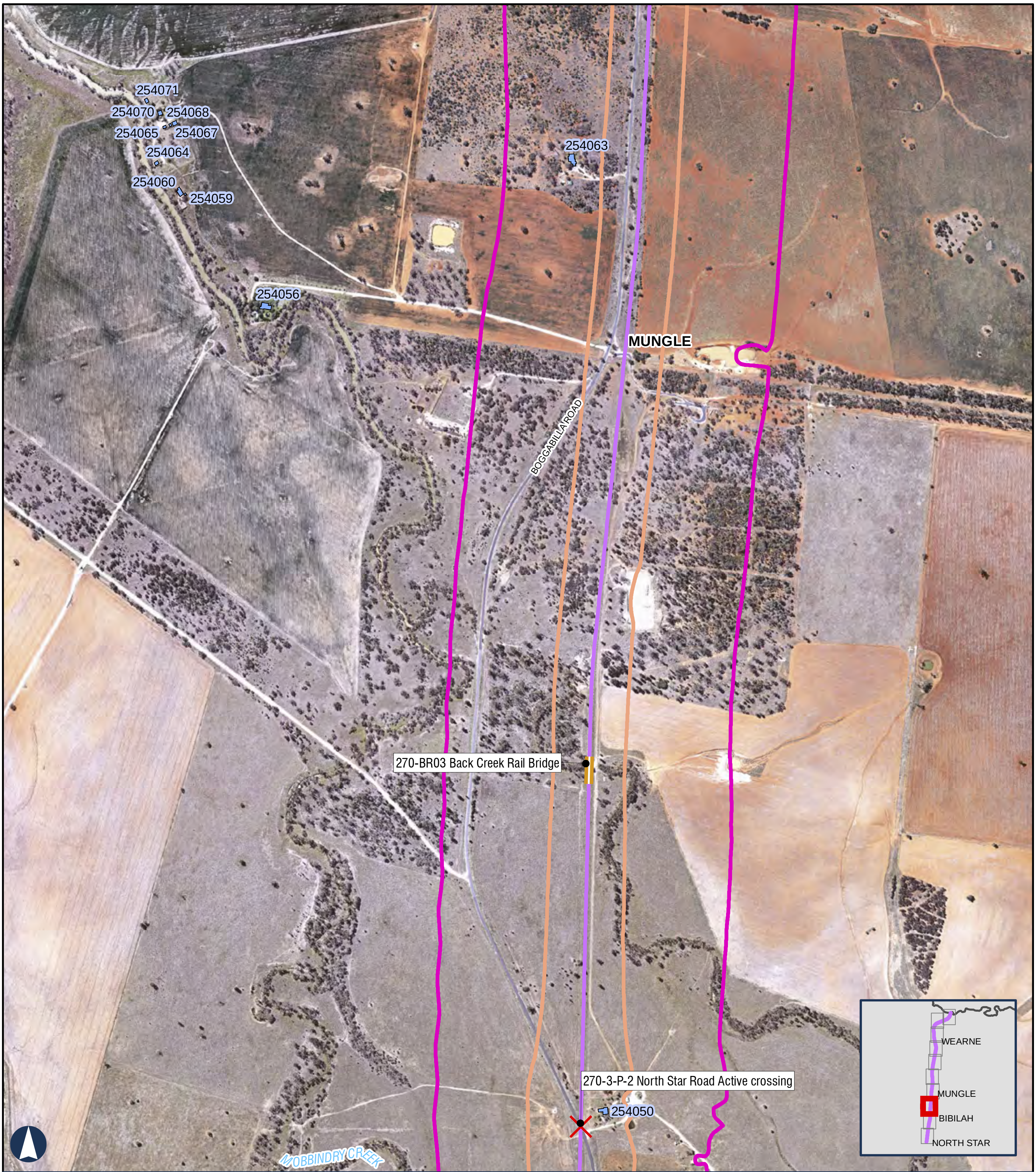

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 3 of 10

410 m

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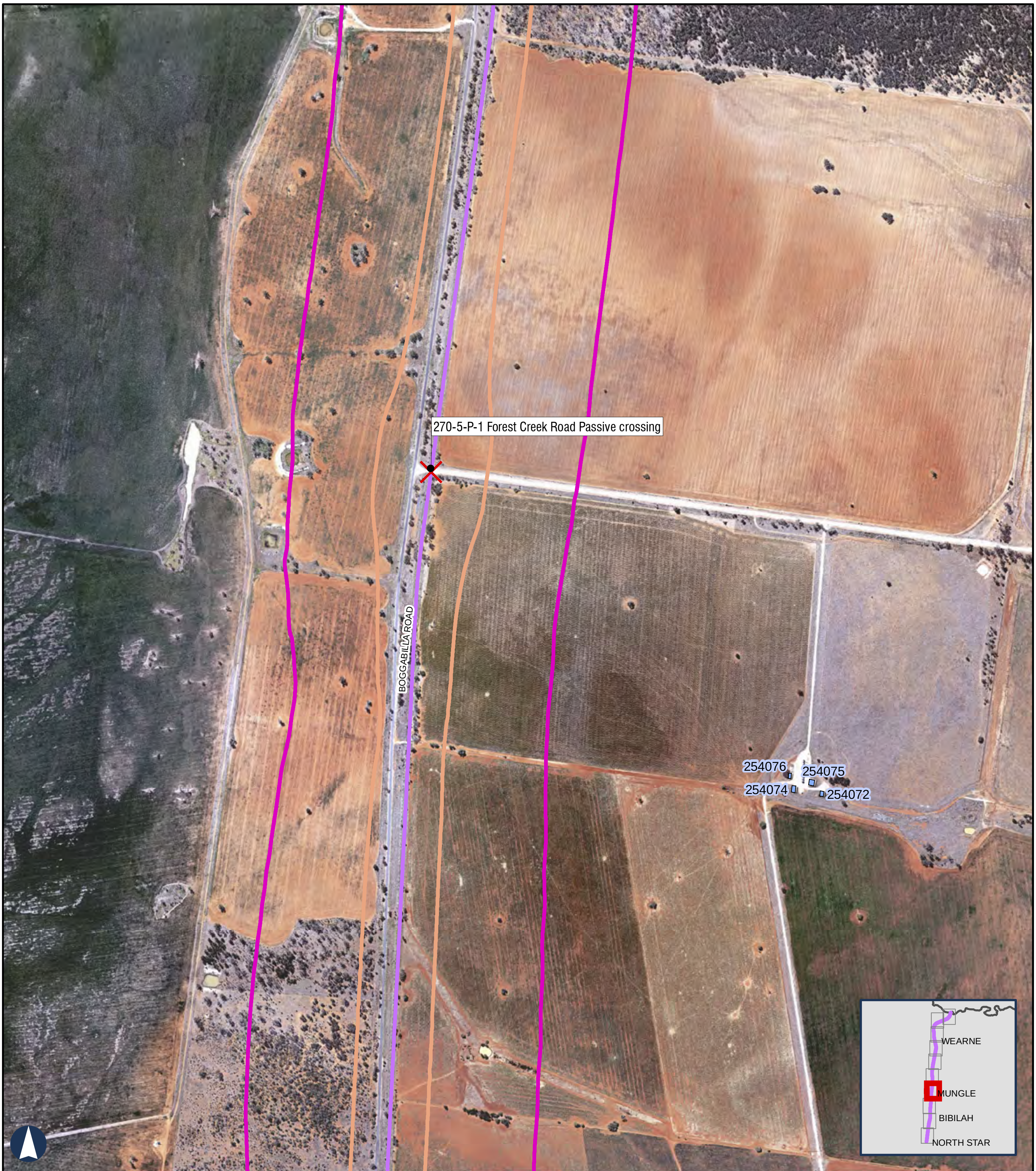

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 4 of 10

410 m

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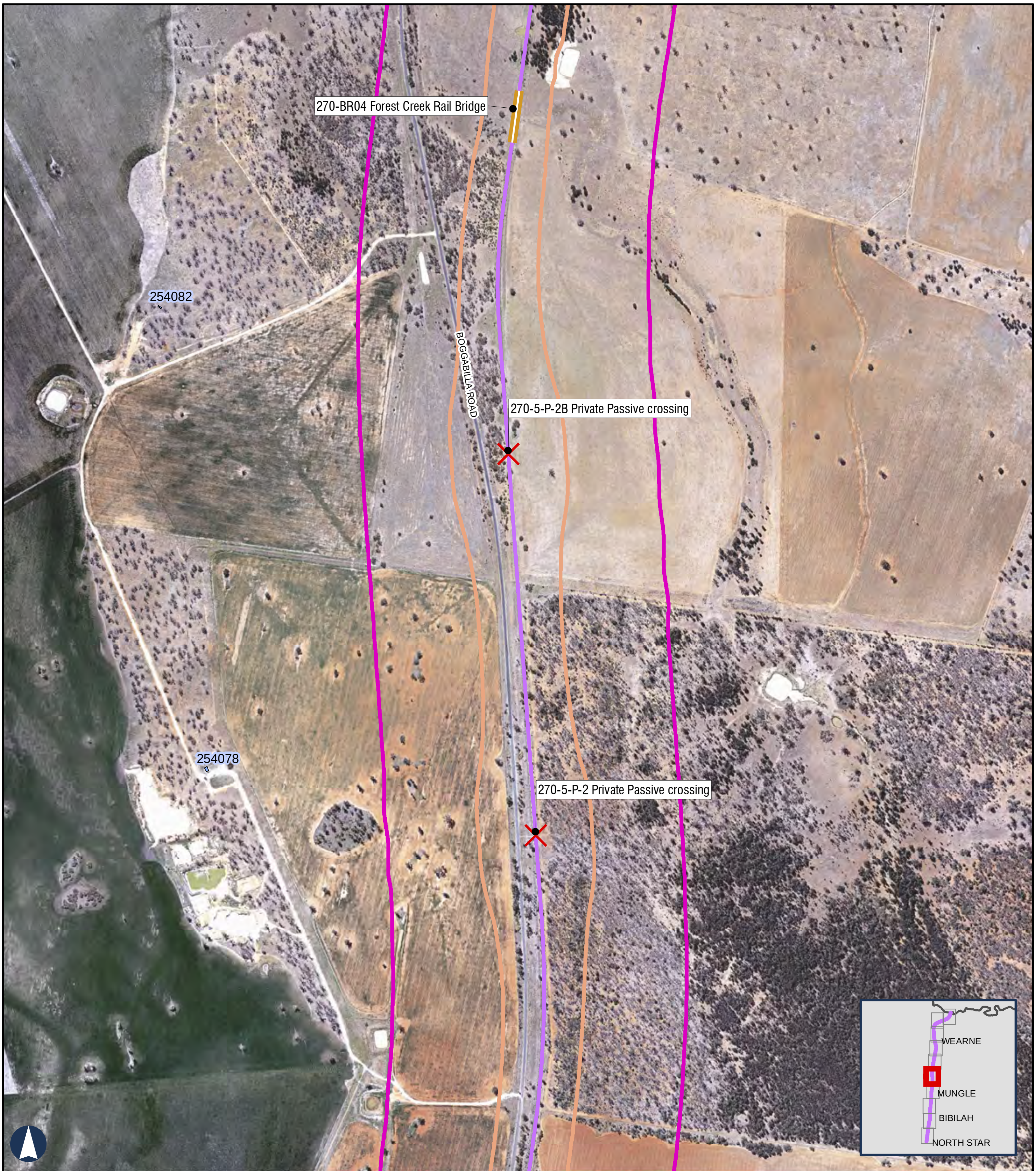

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 5 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 6 of 10

410 m

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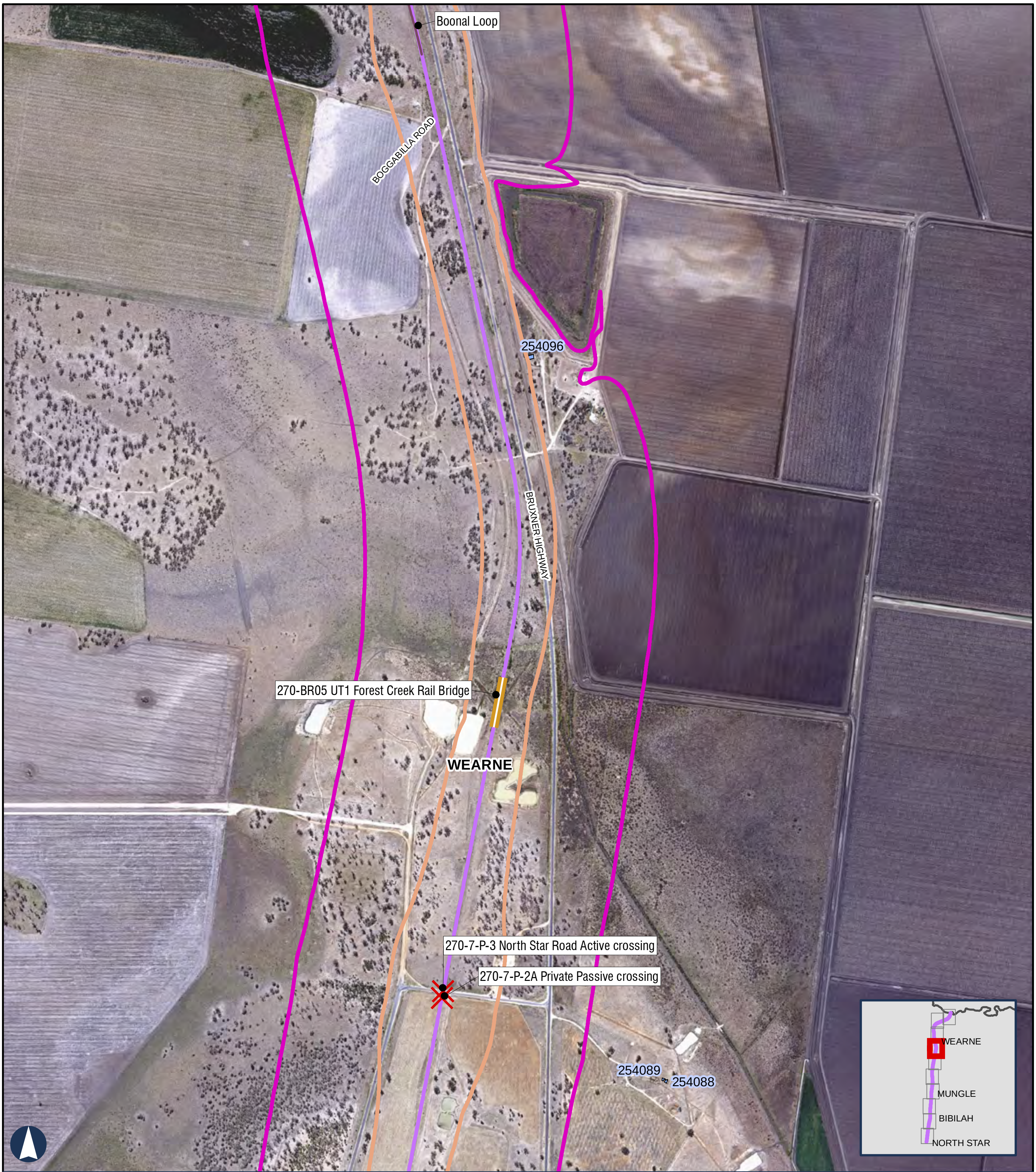

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 7 of 10

410 m

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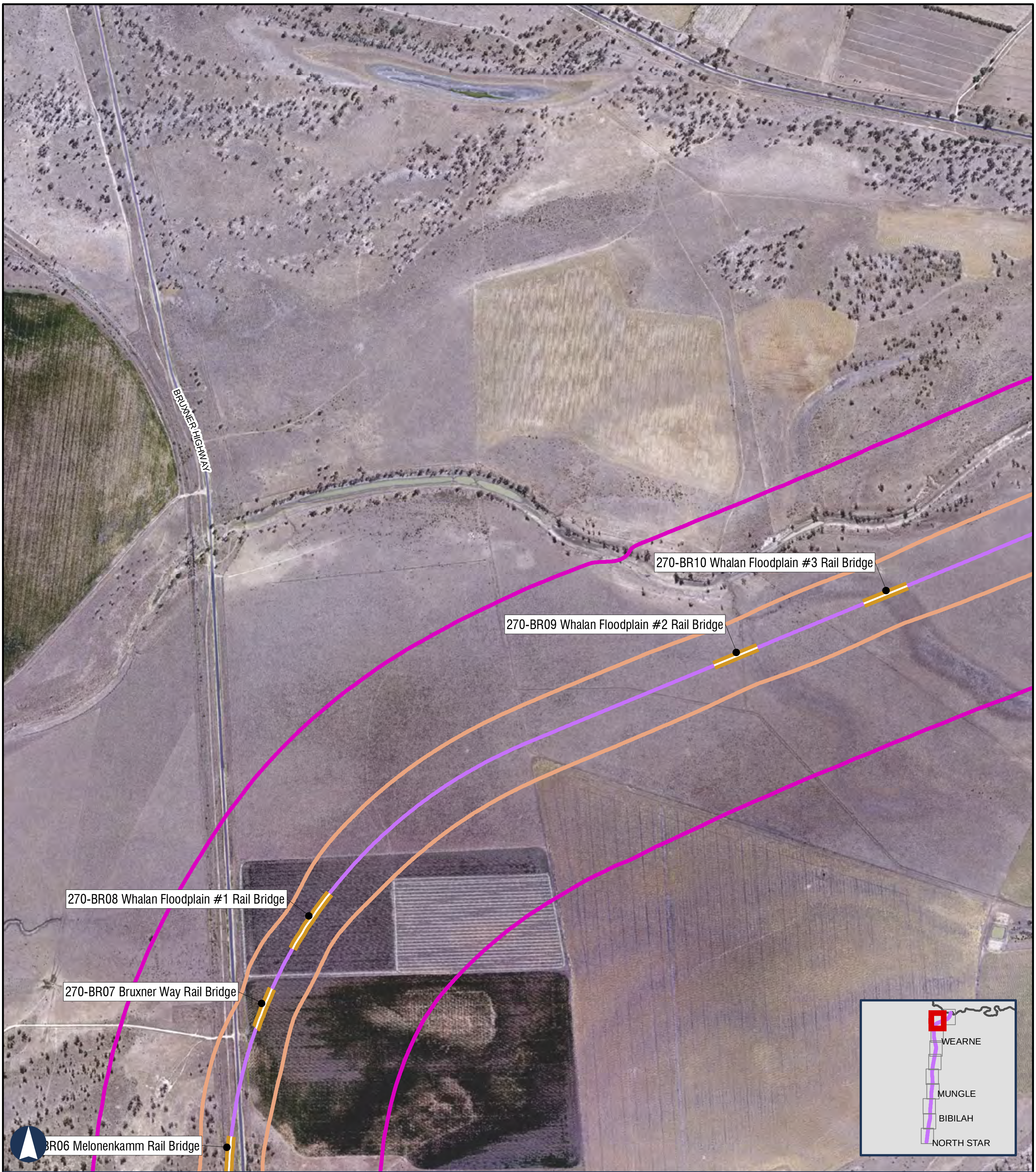

NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 8 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 9 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Daytime rail noise levels

APENDIX D - Map 10 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 1 of 10

410 m

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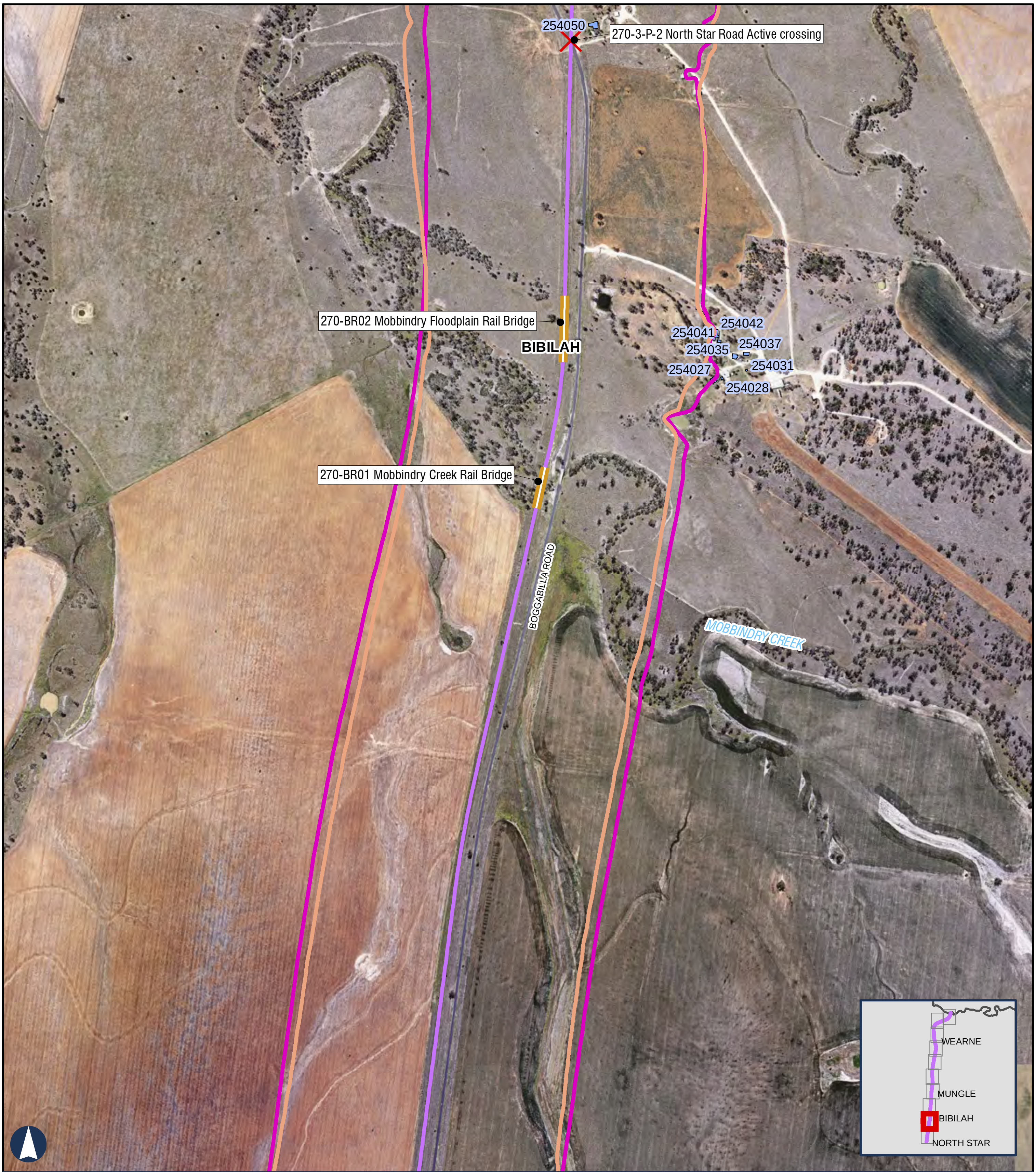

NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 2 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 3 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 4 of 10

410 m

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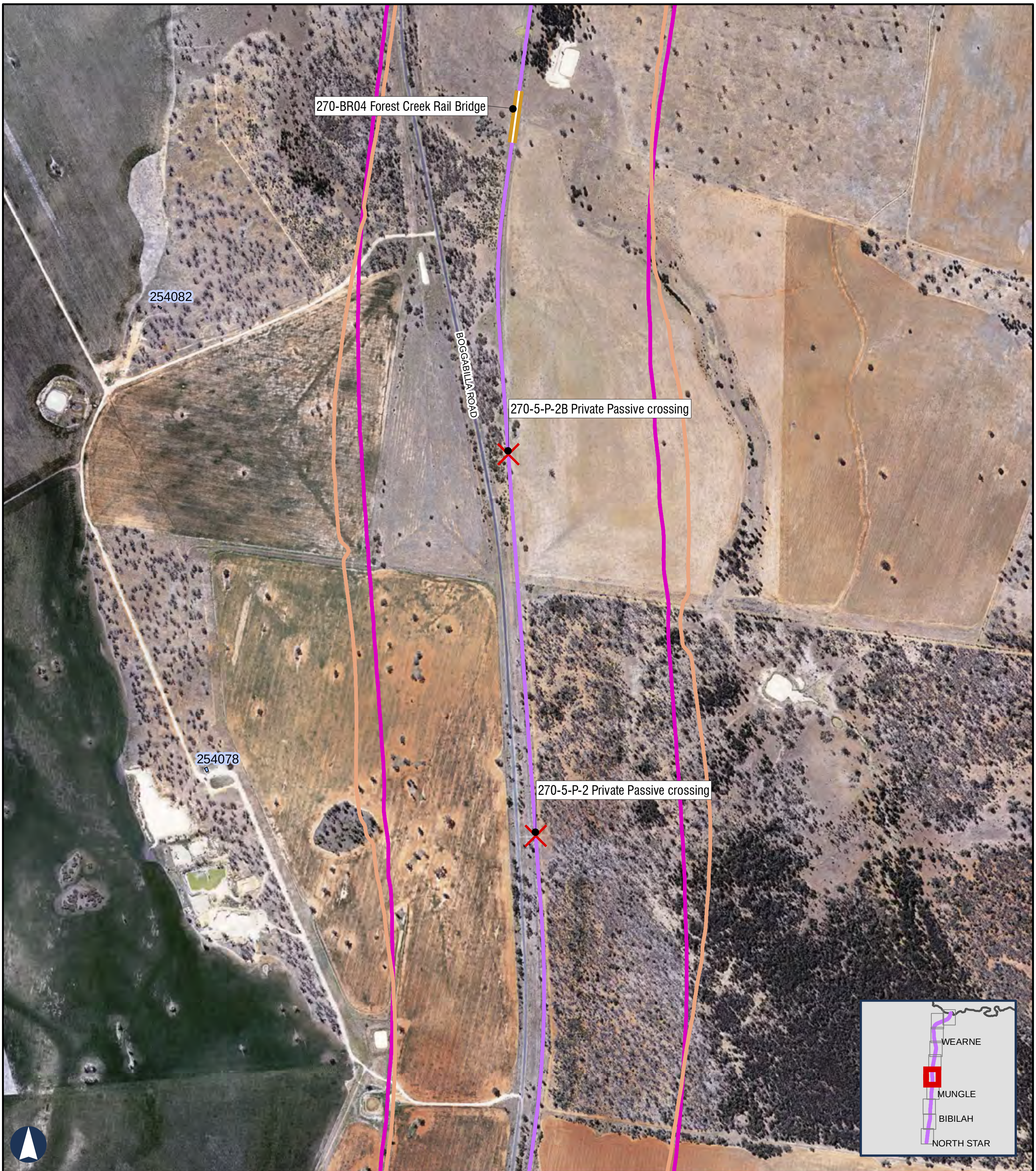

NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 5 of 10

410 m

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NORTH STAR TO BORDER Year 2025 Night-time rail noise levels

APENDIX D - Map 6 of 10

410 m

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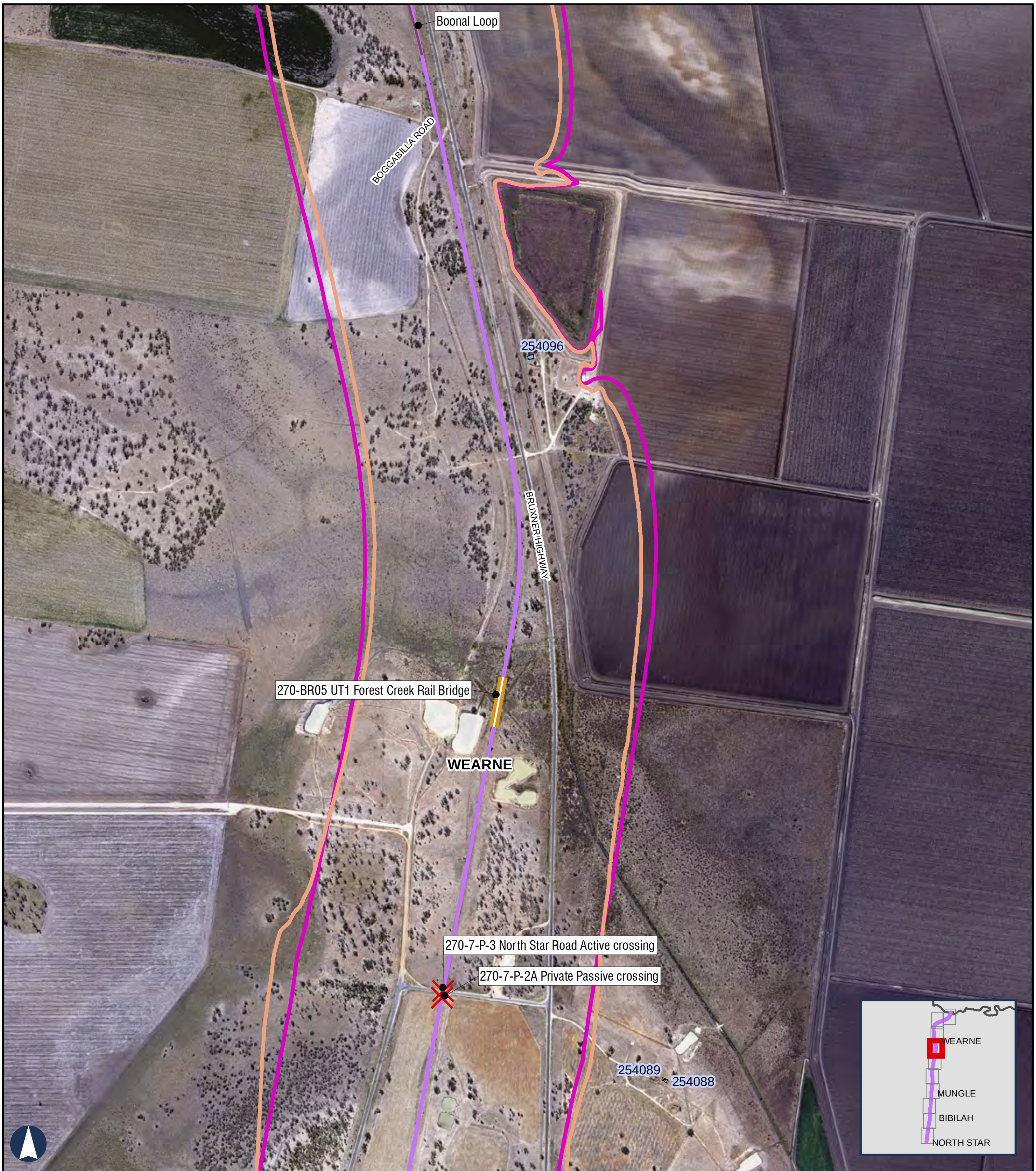

NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 7 of 10

410 m

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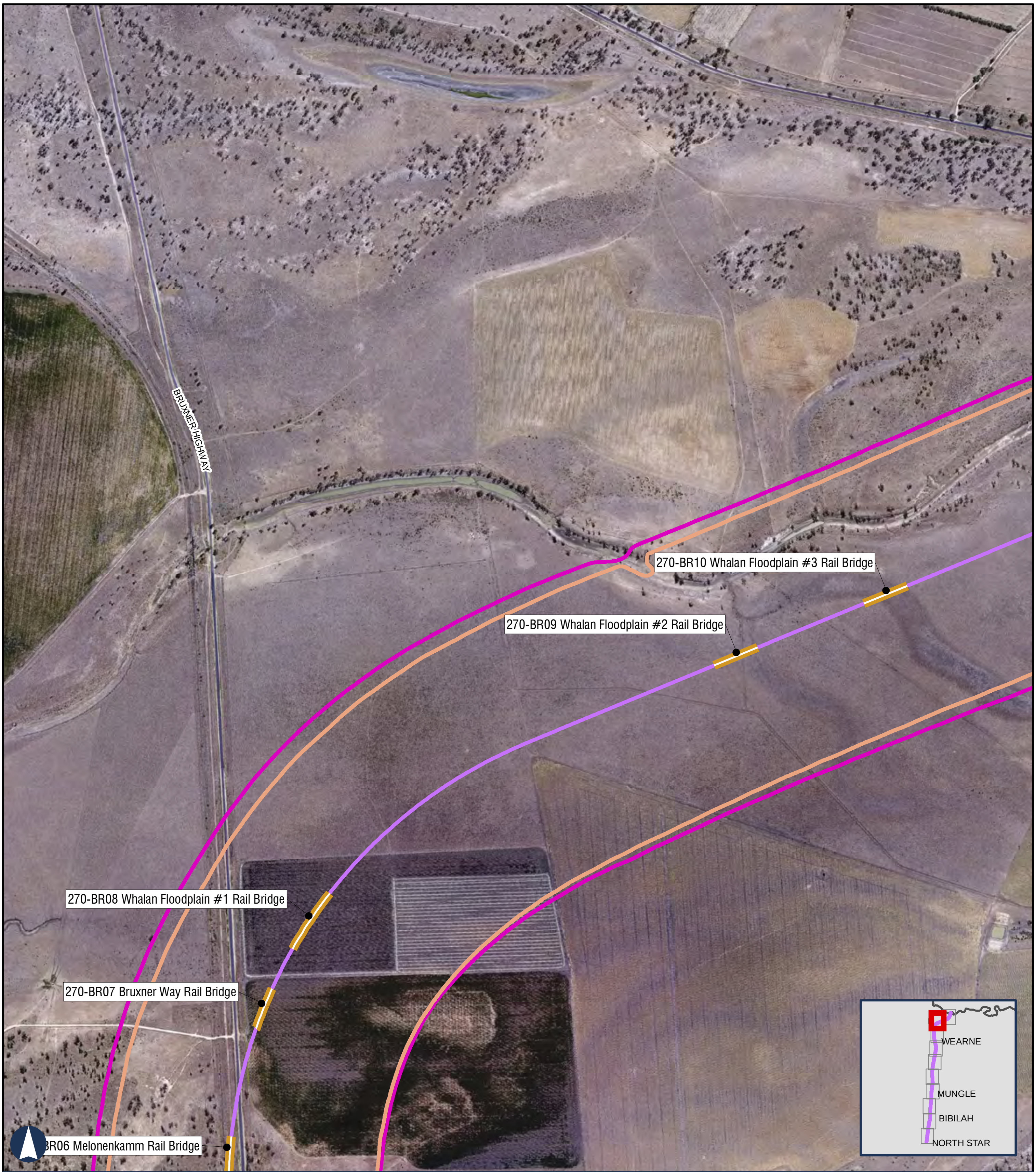

NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 8 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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Author: JG

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NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 9 of 10

410 m

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NORTH STAR TO BORDER

Year 2025 Night-time rail noise levels

APENDIX D - Map 10 of 10

410 m

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APPENDIX

K

Operational Railway Noise and Vibration Assessment

Appendix E Predicted Airborne Railway Noise Levels—Year 2040 Design Year

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation (ARTC), in partnership with the private sector.

The predicted railway noise levels for the future railway operations in 2040 are detailed in the following table and noise contour maps.

The predicted noise levels are provided for the identified sensitive receptors within the 2 km study area. This includes all sensitive receptors where the predicted noise levels triggered an investigation of noise mitigation.

The symbol (-) in the table denotes there was not a prediction of future rail noise as the sensitive receptor was located more than 2 km from the source of noise or, for existing rail noise, the receptors were outside the assessment area where the Project tied into the existing rail corridors.

Following the tabulated results are the predicted noise contour maps for the daytime and night-time railway operations at the project design year 2040. The noise contours have been presented as the daytime and night-time assessment criteria applied by ARTC on the Project. All noise contours are predicted at 2.4 m above ground level.

The noise contours are calculated from the interpolation of thousands of calculation points and provide an overview of the railway noise levels to assist the interpretation of the assessment and its outcomes. The tabulated noise levels at the individual sensitive receptors should be referenced when assessing railway noise levels against the criteria.

Receptor ID	New rail corridor	Rail noise criteria			Project rail noise levels dBA		
		LAeq Day	LAeq Night	Lamax	LAeq,15hr	LAeq,9hr	LAmax
254027	New	60	55	80	55	56	80
254028	New	60	55	80	53	53	78
254031	New	60	55	80	53	54	77
254035	New	60	55	80	53	54	77
254037	New	60	55	80	51	52	76
254041	New	60	55	80	52	53	77
254042	New	60	55	80	55	56	80
254050	New	60	55	80	68	69	95
254056	New	60	55	80	50	51	76
254059	New	60	55	80	50	51	75
254060	New	60	55	80	48	48	72
254063	New	60	55	80	60	61	85
254064	New	60	55	80	48	49	73
254065	New	60	55	80	47	48	72
254067	New	60	55	80	46	47	72
254068	New	60	55	80	48	49	73
254070	New	60	55	80	47	48	72
254071	New	60	55	80	47	48	72
254072	New	60	55	80	47	48	71
254074	New	60	55	80	49	50	73
254075	New	60	55	80	44	44	66
254076	New	60	55	80	49	50	73
254078	New	60	55	80	52	53	75
254082	New	60	55	80	50	51	75
254085	New	60	55	80	49	50	73
254087	New	60	55	80	49	50	73
254088	New	60	55	80	53	53	77
254089	New	60	55	80	54	55	77
254096	New	60	55	80	62	63	87
254100	New	60	55	80	49	50	74
254103	New	60	55	80	44	45	70

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 1 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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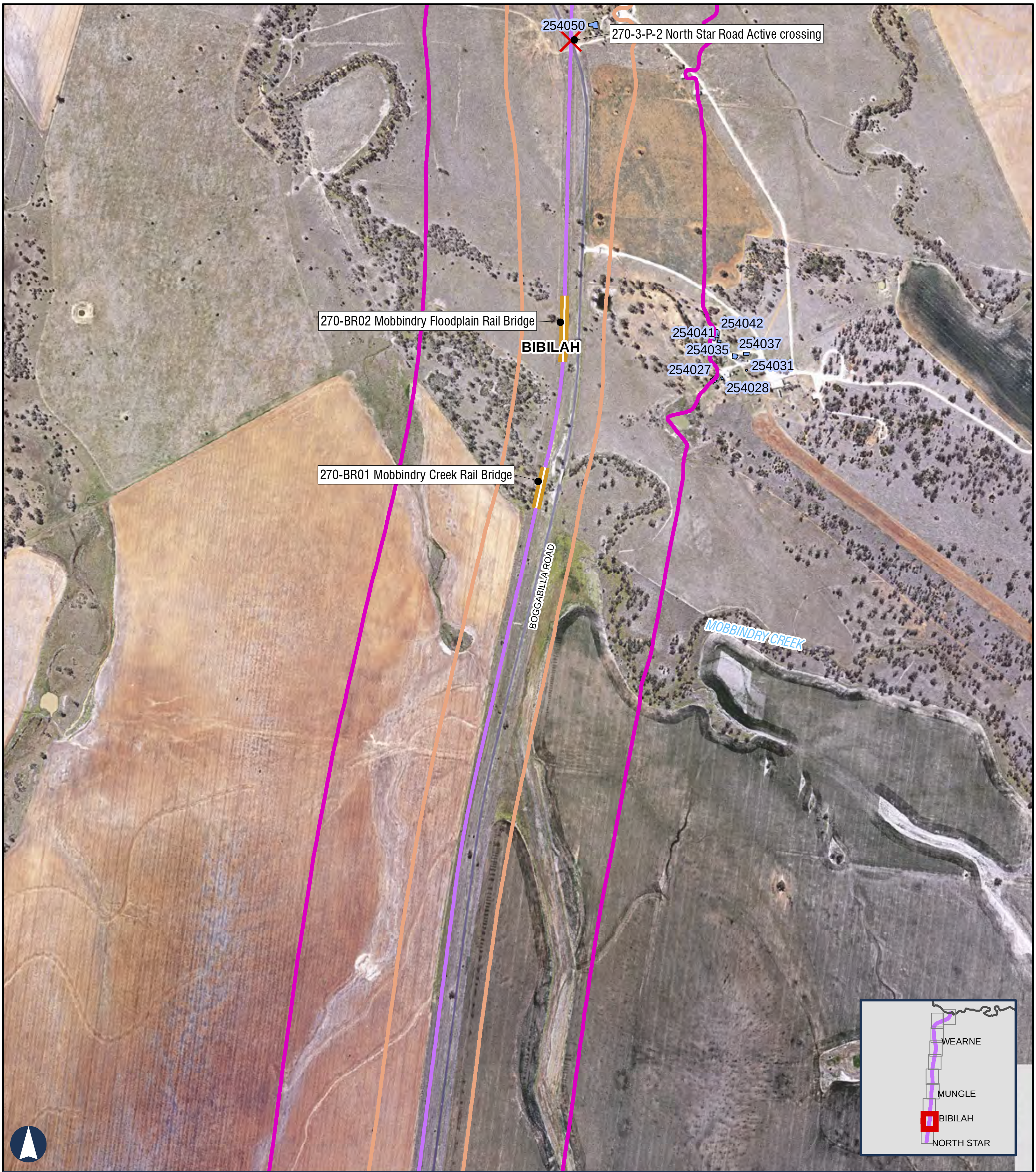

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 2 of 10

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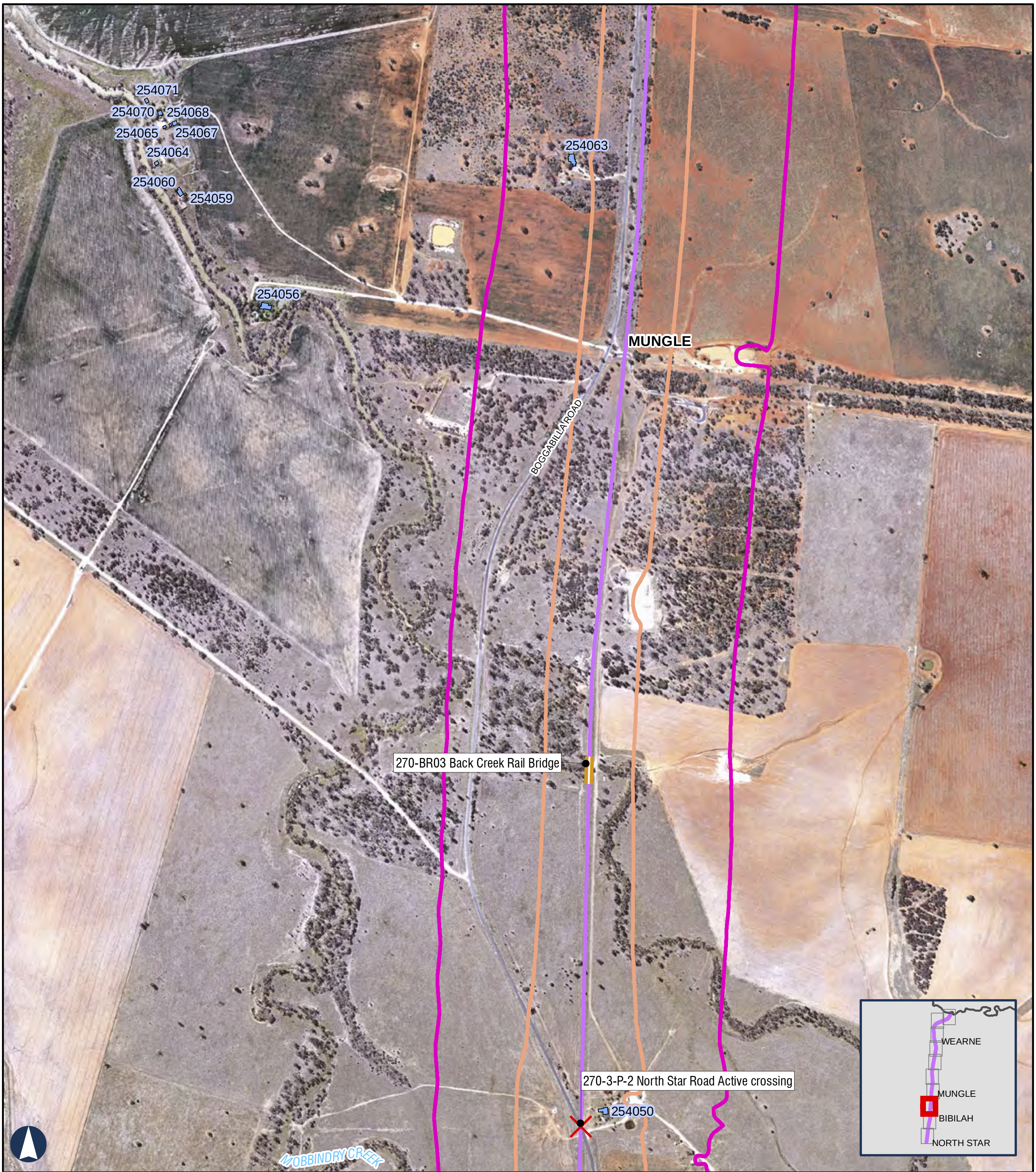

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 3 of 10

410 m

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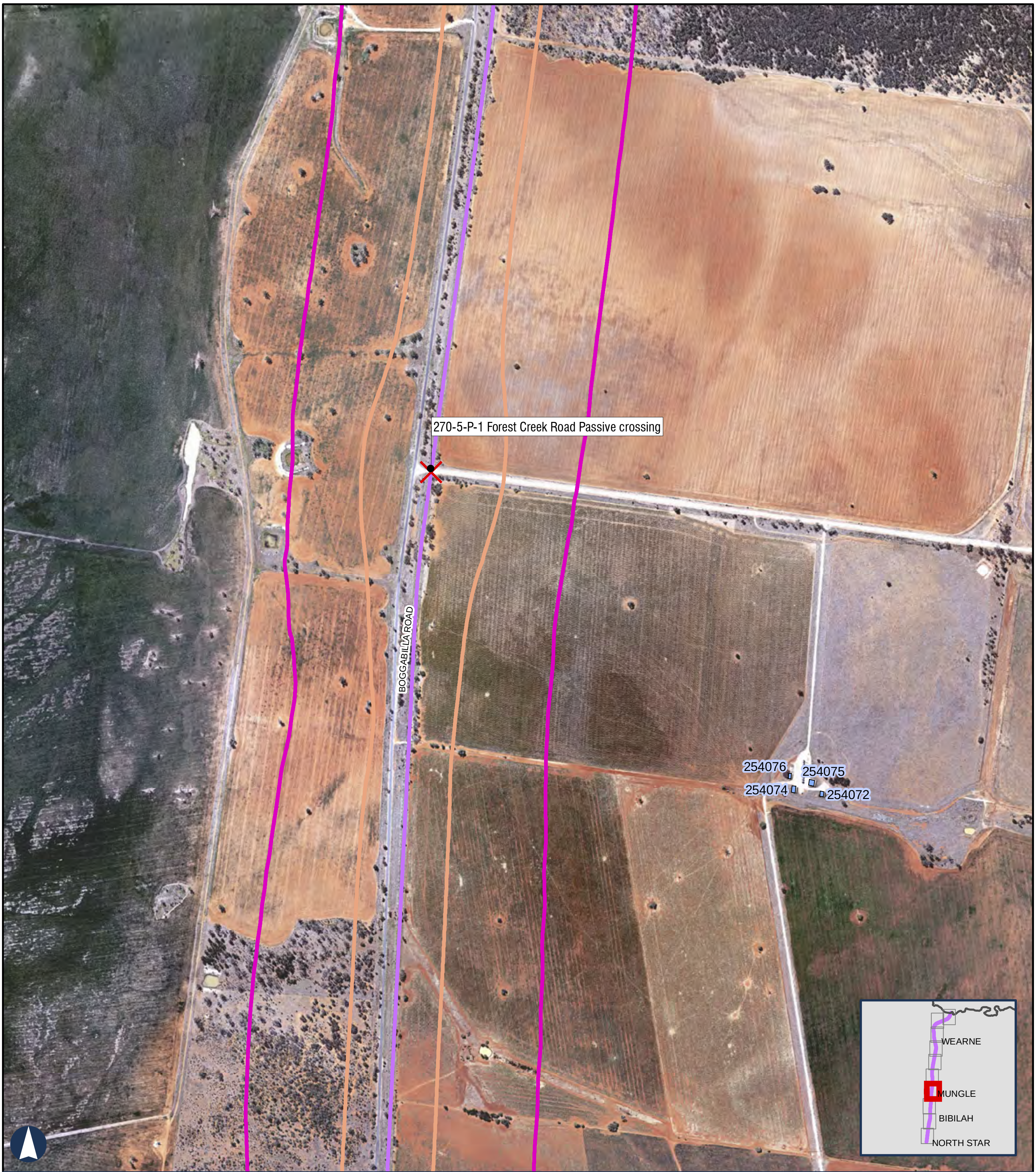

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 4 of 10

410 m

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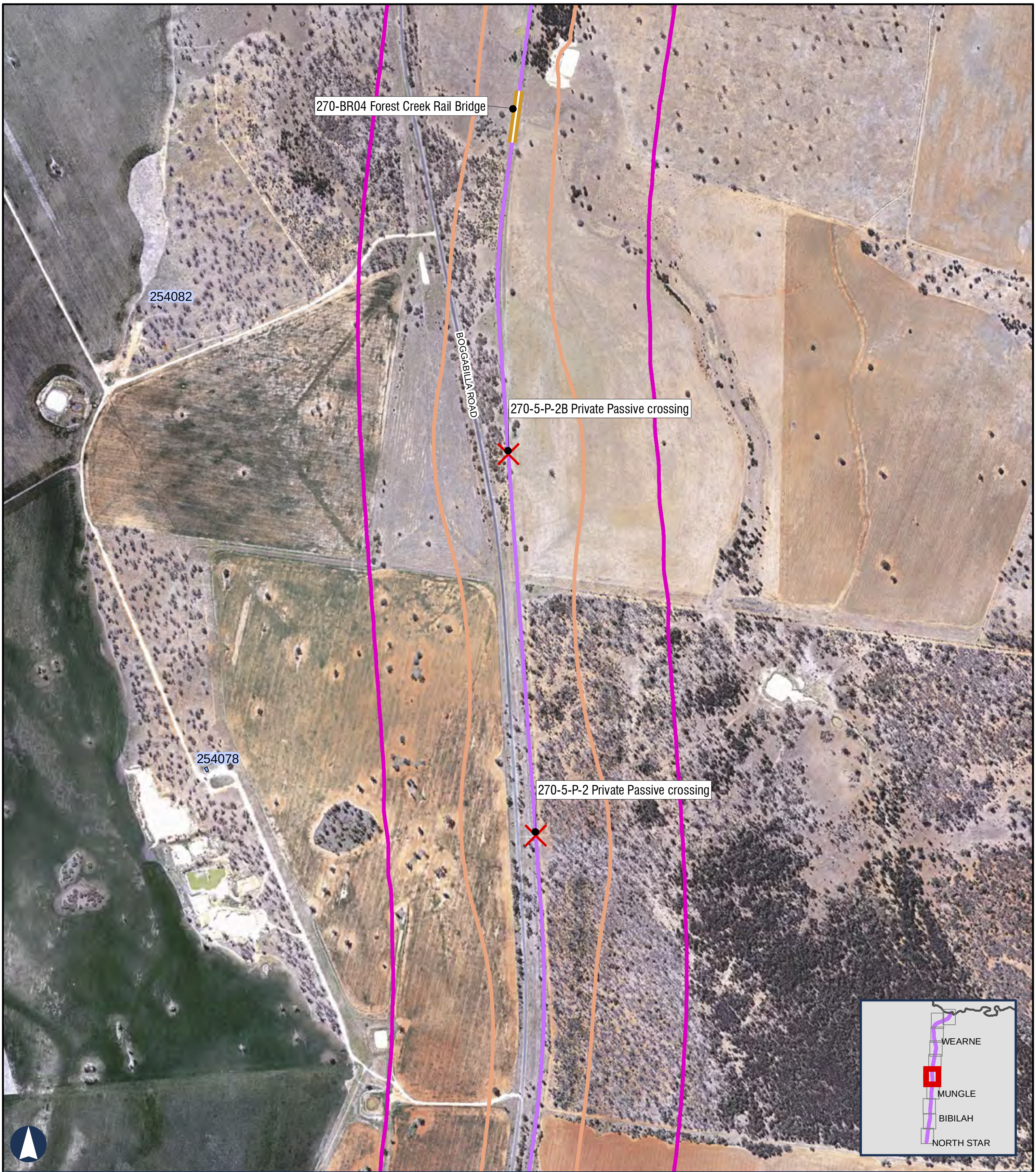

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 5 of 10

410 m

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NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 6 of 10

410 m

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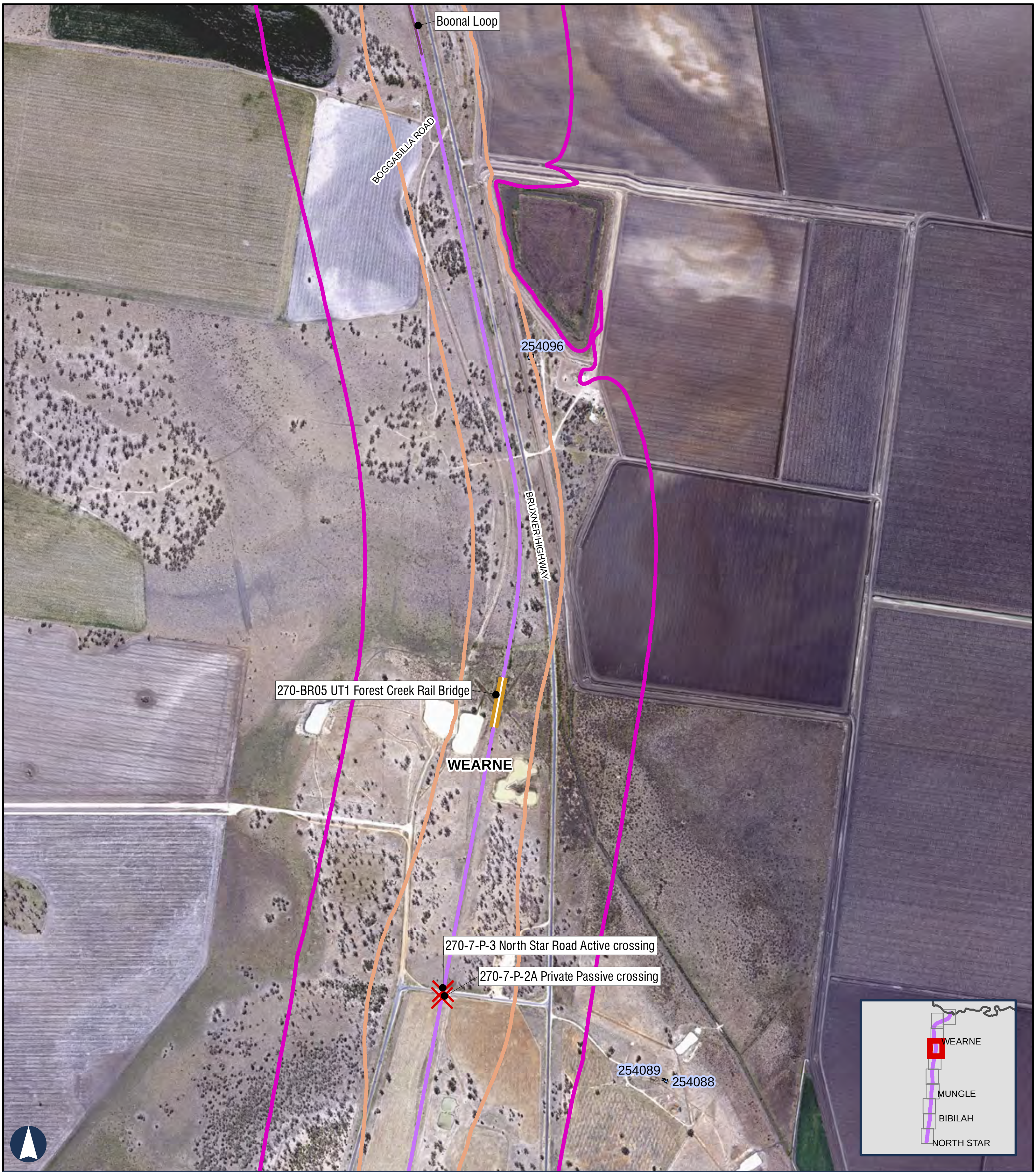

NORTH STAR TO BORDER

Year 2040 Daytime rail noise levels

APENDIX E - Map 7 of 10

410 m

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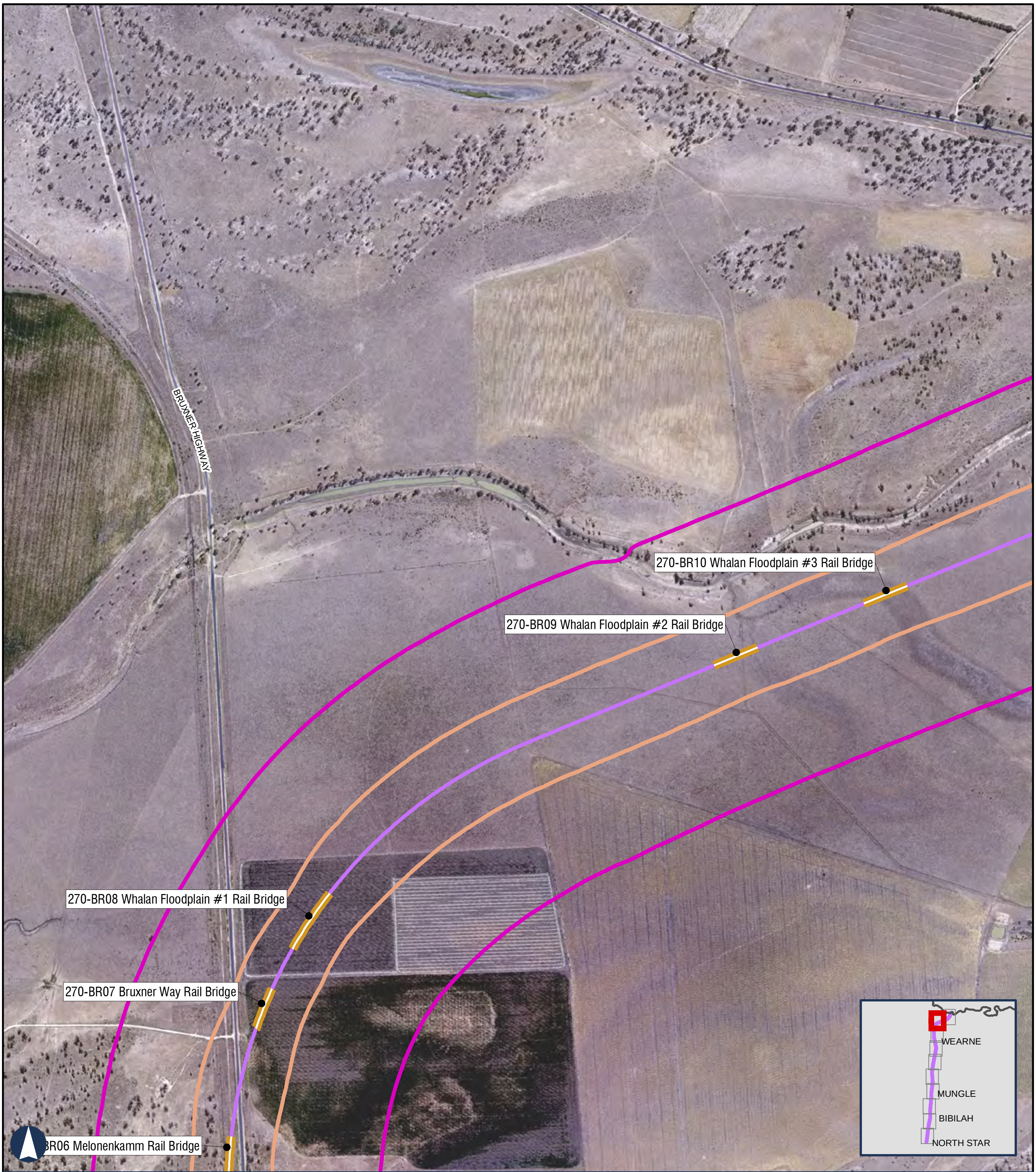

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Year 2040 Daytime rail noise levels

APENDIX E - Map 8 of 10

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NORTH STAR TO BORDER Year 2040 Daytime rail noise levels

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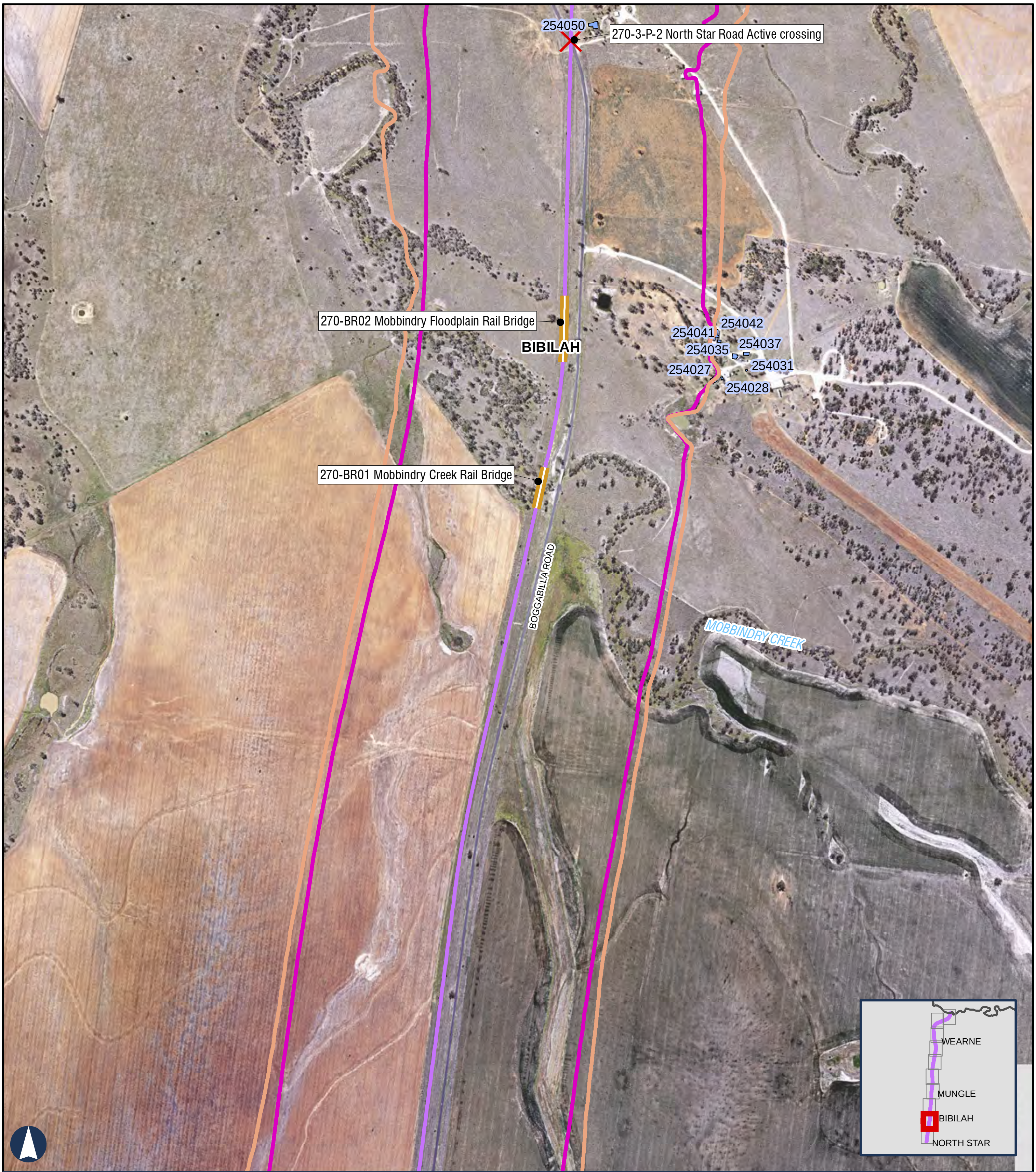

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Year 2040 Night-time rail noise levels

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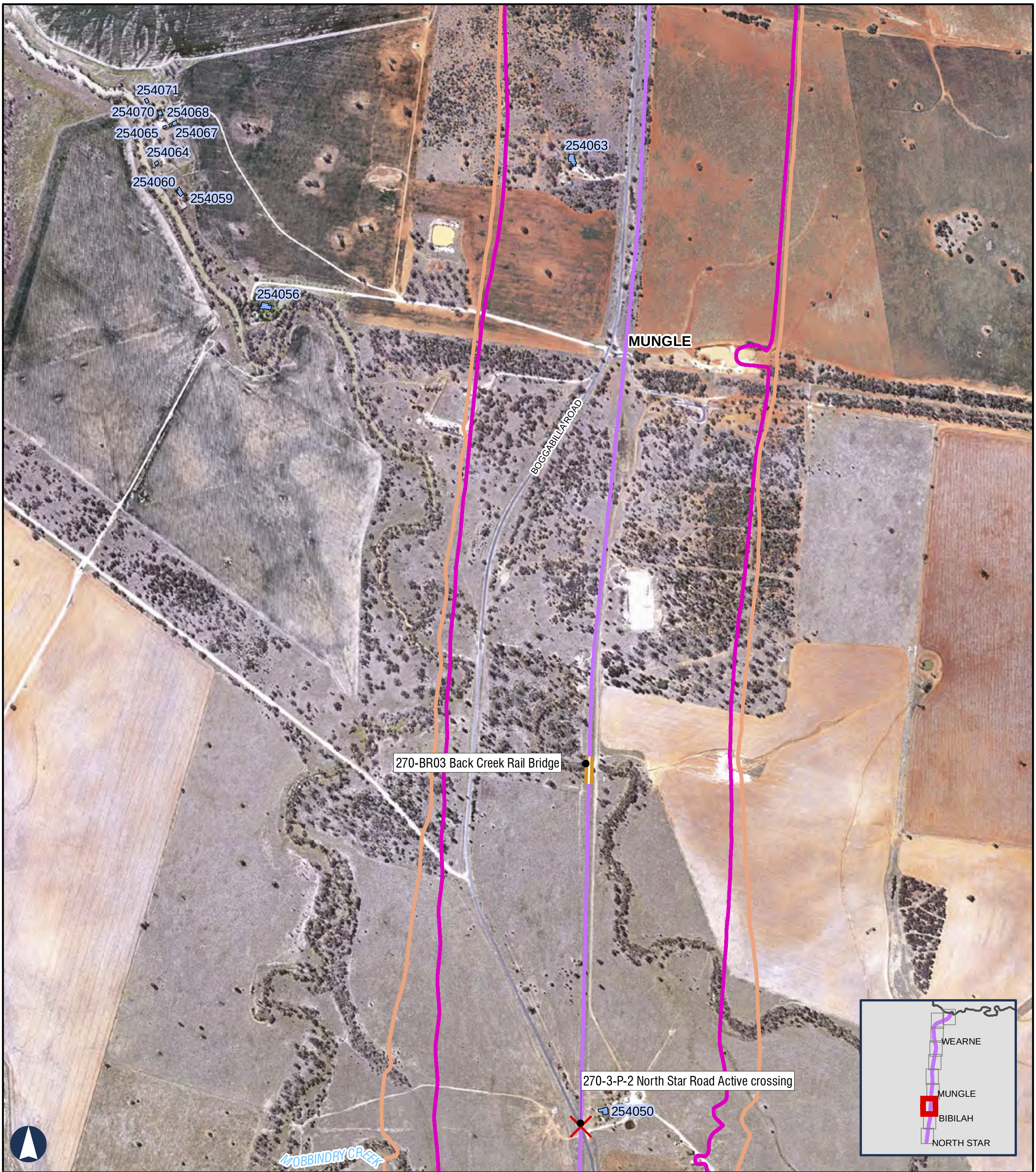

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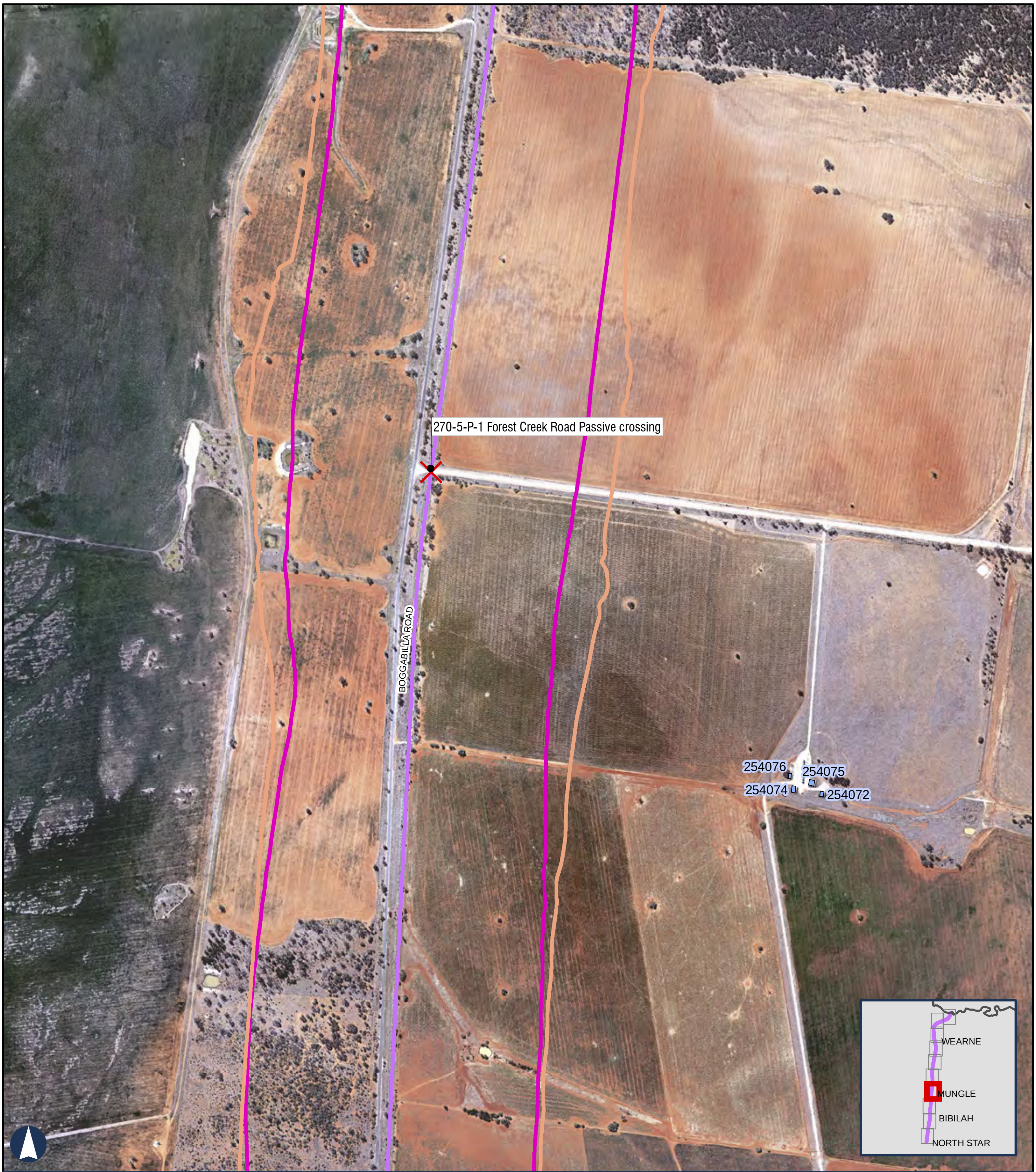

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Year 2040 Night-time rail noise levels

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- Level Crossings
- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
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- State Boundary
- Night-time noise criteria LAeq9hr 55dBA New rail corridor
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- Receptors

Noise contours are based on a set distance above the local terrain level of 2.4m.

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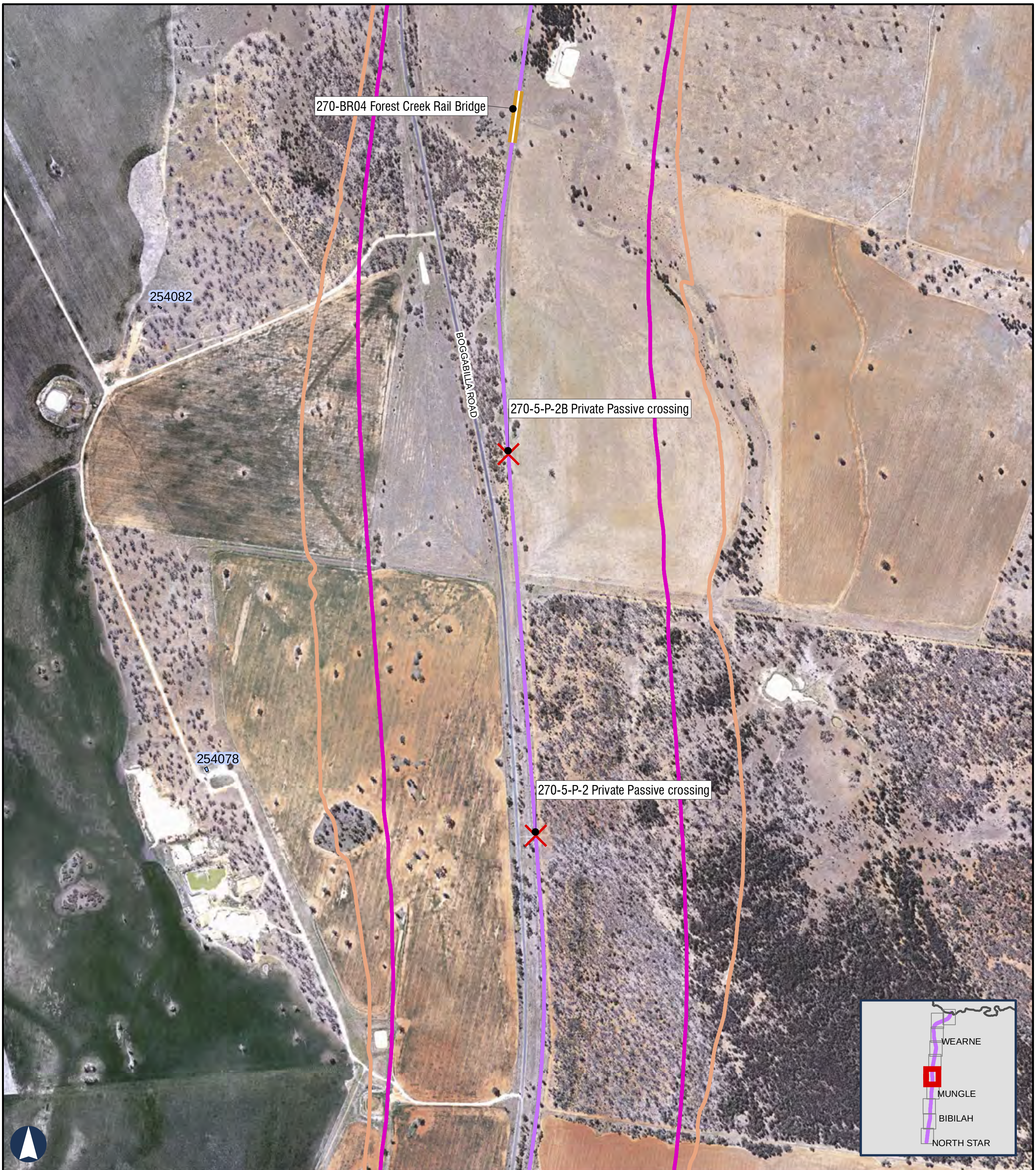
Service Layer Credits: Imagery ARTC 2015 and 2017



NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

APENDIX E - Map 5 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

APENDIX E - Map 6 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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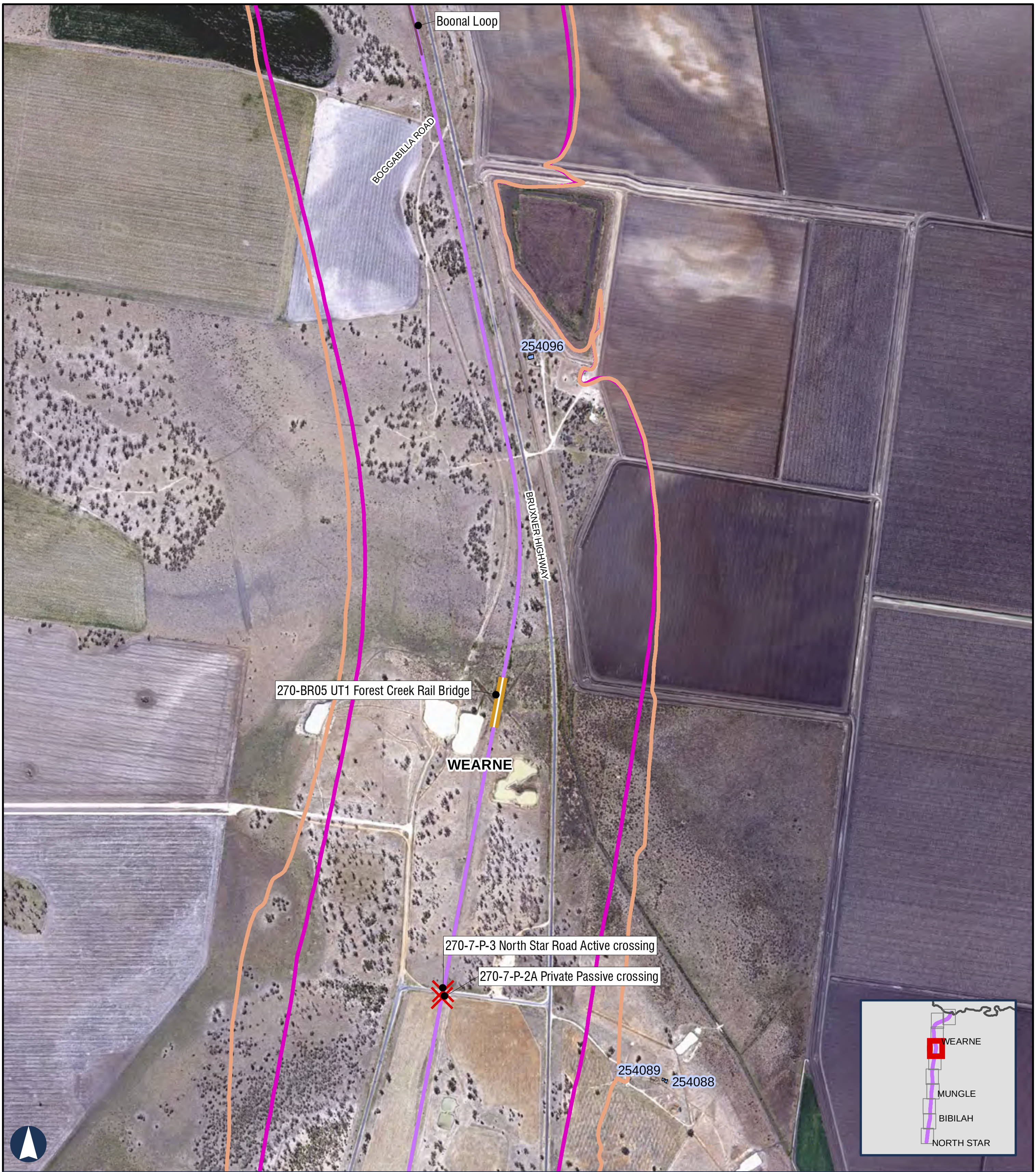

NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

APENDIX E - Map 7 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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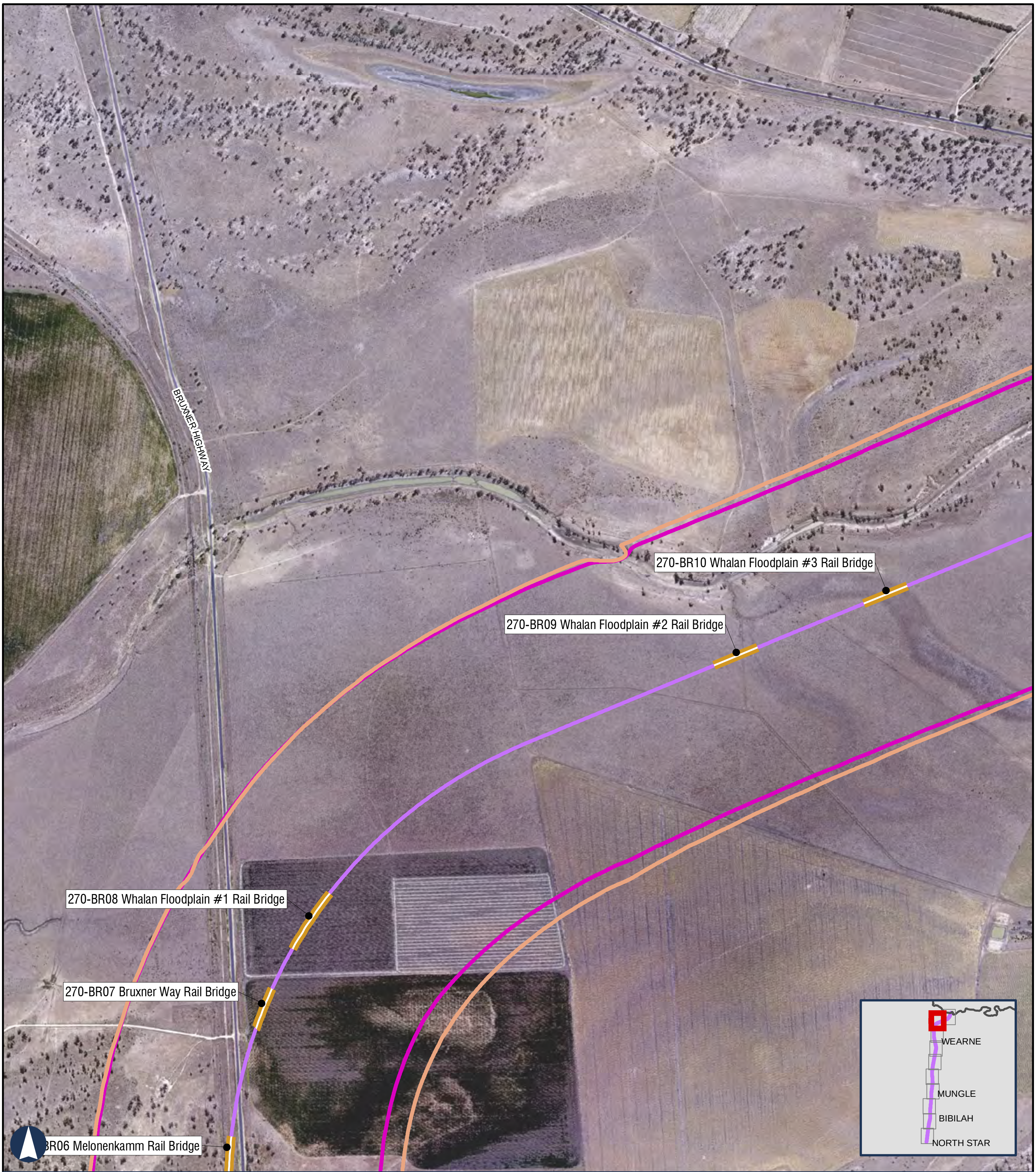

NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

APENDIX E - Map 8 of 10

410 m

Coordinate System: GDA 1994 MGA Zone 56

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NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

APENDIX E - Map 9 of 10

410 m

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NORTH STAR TO BORDER

Year 2040 Night-time rail noise levels

410 m

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