APPENDIX

Q

Operational Railway Noise and Vibration Technical Report

PART 1 OF 3

Main Report and Appendices A to C

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

IR_1381

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

INLAND RAIL - CALVERT TO KAGARU

Operational Railway Noise and Vibration Technical Report
0-0021-340-EMN-00-RP-0001

Prepared for:

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BASIS OF REPORT

EXECUTIVE SUMMARY

The Project

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail is a major national program that would enhance Australia's existing national rail network and serve the interstate freight market.

The Calvert to Kagaru project on Inland Rail is a new single track railway, approximately 53 kilometre (km) in length, connecting the existing Queensland Rail West Moreton System rail corridor near Calvert with the existing Sydney-Brisbane Interstate Line at Kagaru. On Inland Rail, the Project connects the Helidon to Calvert (H2C) project to the west and the Kagaru to Acacia Ridge to Bromelton (K2ARB) to the east.

Australian Rail Track Corporation Ltd (ARTC) ('the proponent') is seeking approval to construct and operate the Project. The Project has been declared as a coordinated project for which an Environmental Impact Statement (EIS) is required under the Queensland Government's *State Development Public Works Organisation Act 1971*. The Project is also a controlled action under the Australian Government *Environment Protection and Biodiversity Conservation Act* (1999) and requires approval from the Commonwealth Minister for the Department of Agriculture Water and the Environment.

This Report

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 impacts from the railway operations for the Project and responds to the Terms of Reference for the EIS.

The assessment presented in this report has included a review of relevant legislation and guidelines, consideration of the existing conditions and a detailed impact assessment. Recommended mitigation and management measures were identified in response to the impact assessment findings.

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, on crossing loops and at the Teviot Range Tunnel portals. The noise model covered an area 2 km either side of the alignment, which comprised a total area approximately 212 km^2 in size and 1,350 identified sensitive receptors.

The model adopted a database of noise emission levels for the 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 tight-radius curves and turnouts.

Noise levels were assessed for daytime and night-time railway operations at project opening (2026) and the design year (2040). At the majority of the sensitive receptors, the predicted noise levels meet the railway noise assessment criteria from Department of Transport and Main Roads guidelines and ARTC's approach for managing noise on Inland Rail.

The predicted noise levels were above the noise assessment criteria at 59 sensitive receptors for railway operations at the project opening (2026) and at 65 sensitive receptors (an additional six 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 with the highest forecast railway noise level up to 19 dBA above the relevant ARTC noise assessment criteria.

Considering the predicted noise levels and the location of the sensitive receptors, the reasonable and practicable 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.

The options for specific measures to mitigate or manage potential noise levels, at identified sensitive receptor properties and land-uses, will be considered further during the design and construction of the Project.

This will include further assessment of railway noise during the detailed design of the Project. This assessment will include further railway noise modelling, analysis of engineering constraints present, constructability issues and other potential and environmental matters (flooding implications and visual impacts as examples).

Consultation with directly affected landowners will continue and the verification of railway noise levels will be undertaken once Inland Rail operations commence on the Project.

Vibration from train movements

The operation of the trains on the Project, including within the Teviot Range Tunnel, can be a potential source of vibration and associated ground-borne (regenerated) noise. The ground-borne vibration levels from train movements on the track and within the tunnel were determined to meet the relevant vibration criteria at all identified sensitive receptors.

The predicted ground-borne noise levels are relatively low at the sensitive receptors adjacent to the Project and were assessed to meet the associated daytime criteria. At these receptors, the predicted levels may be at or above the more conservative night-time ground-borne noise criteria at three individual receptors.

The noise environment is expected to be dominated by the airborne railway noise which can mask the ground-borne noise. Nonetheless, meeting 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.

The Project designs include high vibration attenuation trackform for track slab sections within the tunnel and bridges and viaducts will consider the use of resilient matting for ballast retention. The railway vibration predictions at this stage indicate both of these treatments will provide adequate control of vibration from train movements.

Summary

Assuming the detailed design remains consistent with this assessment, the Project is expected to meet the objectives of DTMR policy and guidelines for the management of noise and vibration from railway operations at the majority of sensitive receptors. The best practice mitigation measures available to the Project are also expected to assist in reducing noise and vibration levels at receptors and provide the reasonable and practical control of potential impacts.

Considerate of the rural location of the Project, meeting the adopted criteria does not preclude the potential for noise and vibration emissions during railway operations to be audible and perceptible at sensitive receptors along the Project alignment.

Recommendations

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

- Review the reasonable and practicable noise and vibration mitigation options discussed in this report during the detailed design and construction of the Project. Noise mitigation options include noise screening elements in addition to at-property treatments for sensitive receptors.
- Allow for the vibration mitigation measures modelled in this report as follows:
  - For track slab sections, including within the Teviot Range Tunnel, Rheda2000/ Vossloh 300 NG series high attenuation track form or a similar trackform system with equivalent vibration attenuation performance.
  - 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 detailed design of the Project.

The railway noise and vibration levels will be verified through noise and vibration monitoring once the Project is operational. ARTC will further investigate reasonable and practicable mitigation measures where monitored noise and/or vibration levels at sensitive receptors are confirmed to not meet the adopted noise and vibration criteria.

ACRONYMS

Term	Definition
ARTC	Australian Rail Track Corporation
AS	Australian Standard
BS	British Standard
C2K	Calvert to Kagaru project
dBA	A-weighted decibel (referenced 20 µPa)
dBm	Decibel per metre
dBV	Vibration expressed as decibels (referenced level 1 nanometres/second)
DIN	Deutches Institut für Normung (German Institute for Standardisation)
DTMR	Department of Transport and Main Roads
EIS	Environmental Impact Statement
H2C	Helidon to Calvert project
HDPE	High Density Polyethylene
Hz	Hertz
ISO	International Standards Organisation
K2ARB	Kagaru to Acacia Ridge and Bromelton project
Km	Kilometres
Km/h	Kilometres per hour
Km^2	Square kilometres
LAeq	Equivalent continuous noise level, providing a representation of the cumulative level of noise exposure over a defined period.
LAeq(15hour)	The equivalent continuous noise level for the 15-hour daytime period of 7.00 am to 10.00 pm
LAeq(9hour)	The equivalent continuous noise level for the 9-hour daytime period of 10.00 pm to 7.00 am
LAeq(24hour)	The equivalent continuous noise level for the 24-hour period.
LAeq(12hour)	The equivalent continuous noise level for the 12-hour daytime period of 6.00 am to 6.00 pm
LAeq(1hour)	The equivalent continuous noise level for the busiest 1-hour period.
LAeq(T)	The equivalent continuous noise level for a defined time period 'T'.
LAmax	The maximum noise 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
mN/m	Millinewtons per metre
m/s	Metres per second
NSW	New South Wales
QLD	Queensland

Term	Definition
QR	Queensland Rail
SDPWO	*State Development and Public Works Organisation Act 1971*
SEL	The level of noise for an individual event normalised to a 1-second event (Sound Exposure Level), allowing noise events of different duration to be compared.
SEM	Single Event Maximum is the arithmetic average of L_{ASmax} from the highest 15 single events during a 24-hour period.
TfNSW	Transport for New South Wales
ToR	Terms of Reference
VDV	Vibration Dose Value is a cumulative measure of the vibration level from all events.
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 PROJECT 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 (m) of the outermost rails; or within the boundary fence (where fences are provided) and are closer than 15 m. If the property boundary is less than 15 m, 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 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.
Reasonable	Selecting reasonable measures from those that are feasible involves judging whether the overall noise benefits outweigh adverse social, economic and environmental effects, including the cost of the measure.

Term	Definition
Rollingstock	All rail vehicles operating on the rail lines.
Rolling noise	Noise emissions from the rolling of the wheels on the rail.
Sensitive receptors	Land uses detailed in railway noise and vibration guidelines which are sensitive to potential noise and vibration impacts, such as residential dwellings, schools and hospitals.
Study area	The assessment of noise and vibration from railway operations adopted a study area comprising approximately 212 km^2 (square kilometres) based on a 2 km (kilometre) distance surrounding either side of the proposed rail alignment.
Track	The structure consisting of rails, fasteners, sleepers and ballast, which sits on the formation.
Turnout	A junction point where a rail vehicle can leave a given track for a branching or parallel track.
Vibration	The movement of particles in a medium, such as the ground soil or a building, which can result from the energy associated with train passbys on the tracks, including within the tunnel.

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1 Introduction

1.1 Overview

1.1.1 Inland Rail and the Project

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland (QLD). Inland Rail is a major national program that will enhance Australia's existing national rail network and serve the interstate freight market.

The Inland Rail route, which is approximately 1,700 kilometres (km) long, involves:

- using the existing interstate rail line through Victoria and southern NSW;
- upgrading approximately 400 km of existing track, mainly in western NSW; and,
- providing approximately 600 km of new track in NSW and south-east Queensland.

Inland Rail has been divided into 13 sections, five of which are located in Queensland. Australian Rail Track Corporation Ltd (ARTC) (the proponent) is seeking approval to construct and operate the Calvert to Kagaru section of Inland Rail (the Project).

1.1.2 Approval and assessment requirements

The Project has been declared as a coordinated project for which an Environmental Impact Statement (EIS) is required under section 26 (1) (a) of the Queensland Government's *State Development Public Works Organisation Act 1971*. The Project is also a controlled action under the Australian Government *Environment Protection and Biodiversity Conservation Act* (1999) and requires approval from the Commonwealth Minister for the Department of Agriculture Water and the Environment.

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) as part of the EIS to be provided to the Coordinator-General. The report addresses the environmental assessment requirements, as they relate to noise and vibration from railway operations, of the Terms of Reference[1] (ToR) for an environmental impact statement: Inland Rail – Calvert to Kagaru project December 2017.

1.2 The Project

The Project is a new railway infrastructure project on Inland Rail consisting of approximately 53 km of dual gauge track with four crossing loops. The Project would be constructed to accommodate double-stacked freight trains up to 1,800 metres (m) long and 6.5 m high. The Project also includes changes to some roads to facilitate construction and operation of the new section of railway, and ancillary infrastructure to support the Project.

The Project designs include infrastructure to accommodate possible future augmentation and upgrades of the track, including a possible future requirement for 3,600 m long trains. The impacts of the increased train length have not been included in this study as they are associated with future upgrades and will require separate assessment at a later stage (subject to business needs).

[1] The Department of State Development, Tourism and Innovation, *Terms of reference for an environmental impacts statement: Inland Rail – Calvert to Kagaru project, dated December 2017*.

1.2.1 Location

The Project is generally within the Southern Freight Rail Corridor (SFRC), which was protected as future railway land under the *Transport Infrastructure Act 1994*[2] in November 2010. The majority of the Project is within a greenfield corridor where there is no existing railway infrastructure.

Approximately 4 km of the alignment is a brownfield development where, at the eastern and western extents of the alignment, the Project railway infrastructure will be collocated within the existing rail corridors.

The Project starts within the existing Queensland Rail (QR) West Moreton System rail corridor to the east of Calvert, where it travels to the south east and will be a new railway line within the SFRC railway corridor traversing the localities of Lanefield, Rosewood, Lower Mount Walker, Ebenezer, Willowbank, Purga, Peak Crossing and Washpool.

The Project then deviates to the north of the SFRC through the Teviot Range, which includes an approximate 1 km long tunnel. The alignment emerges from the tunnel and realigns with the SFRC on the eastern side of the Teviot Range and continues through to Undullah until it joins the existing Interstate Line at Kagaru.

1.2.2 Key features

The key design features of the Project include:

Rail infrastructure

- A new 53 km long rail corridor between Calvert and Kagaru;
- A single-track standard gauge railway and track formation within the new rail corridor;
- Four crossing loops, at Ebenezer, Purga Creek, Washpool Road and Undullah;
- Bridges and viaducts over rivers and other watercourses, floodplains and roads;
- A new rail tunnel through the Teviot Range;
- Level crossings; and,
- New rail connections to the QR West Moreton System and Interstate Line.

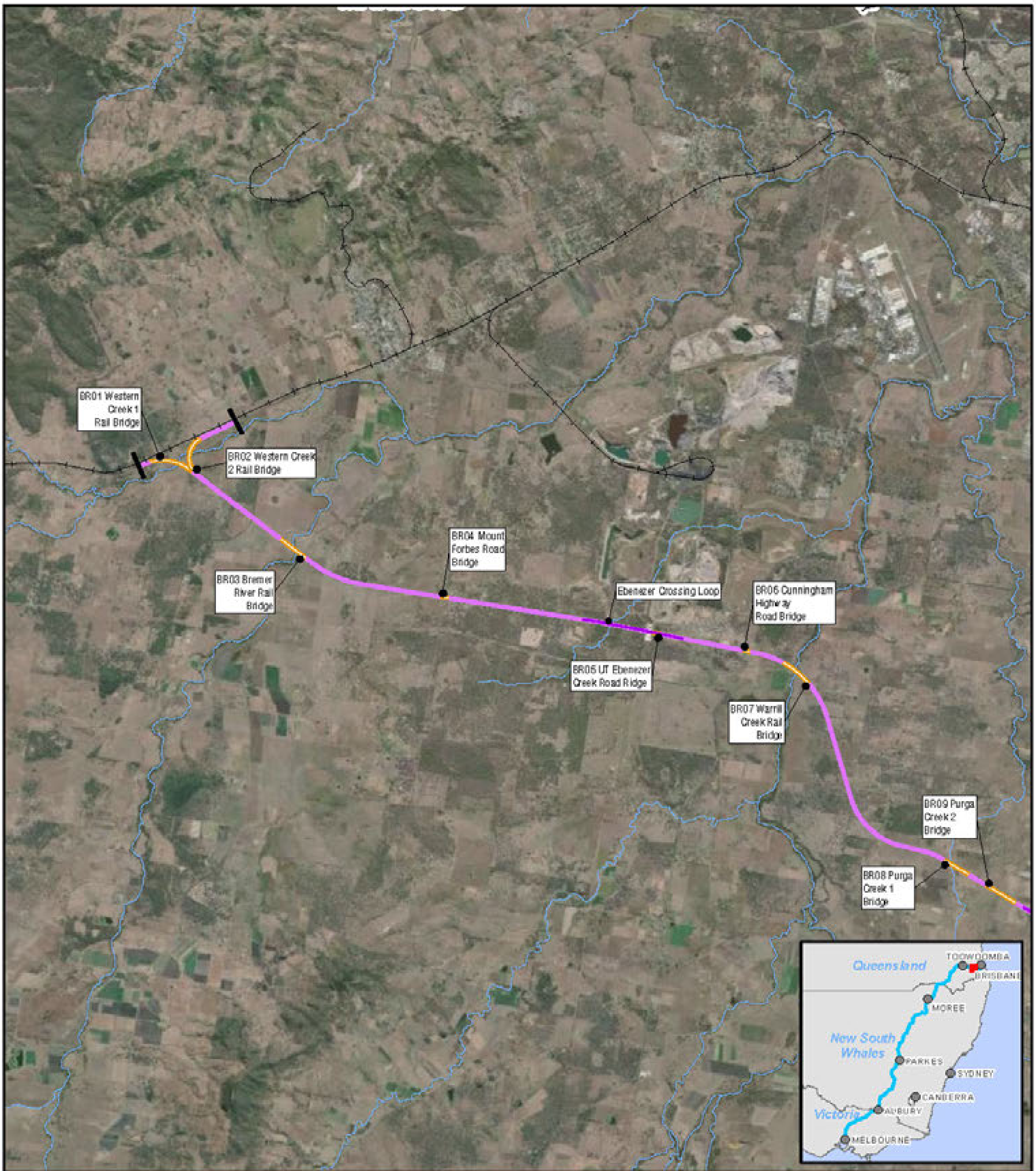
Road infrastructure

- Road realignments at various locations; and,
- Limited road closures.

Ancillary infrastructure to support the Project would include signalling and communications, drainage, signage and fencing, and services and utilities. Further information on the Project is provided in the EIS.

The key features of the rail infrastructure are shown in **Figure 1**.

[2] Queensland Government, 1994. *Transport Infrastructure Act 1994*.



CALVERT TO KAGARU

Overview of the Project

FIGURE 1 - Map 1 of 2

3 km

Coordinate System: GDA 1994 MGA Zone 56

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- Project Extent
- Watercourses
- Existing Railway
- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- Teviot Range Tunnel

Paper: A4 Scale: 1:112,500
Date: 17-Mar-2020
Author: JG

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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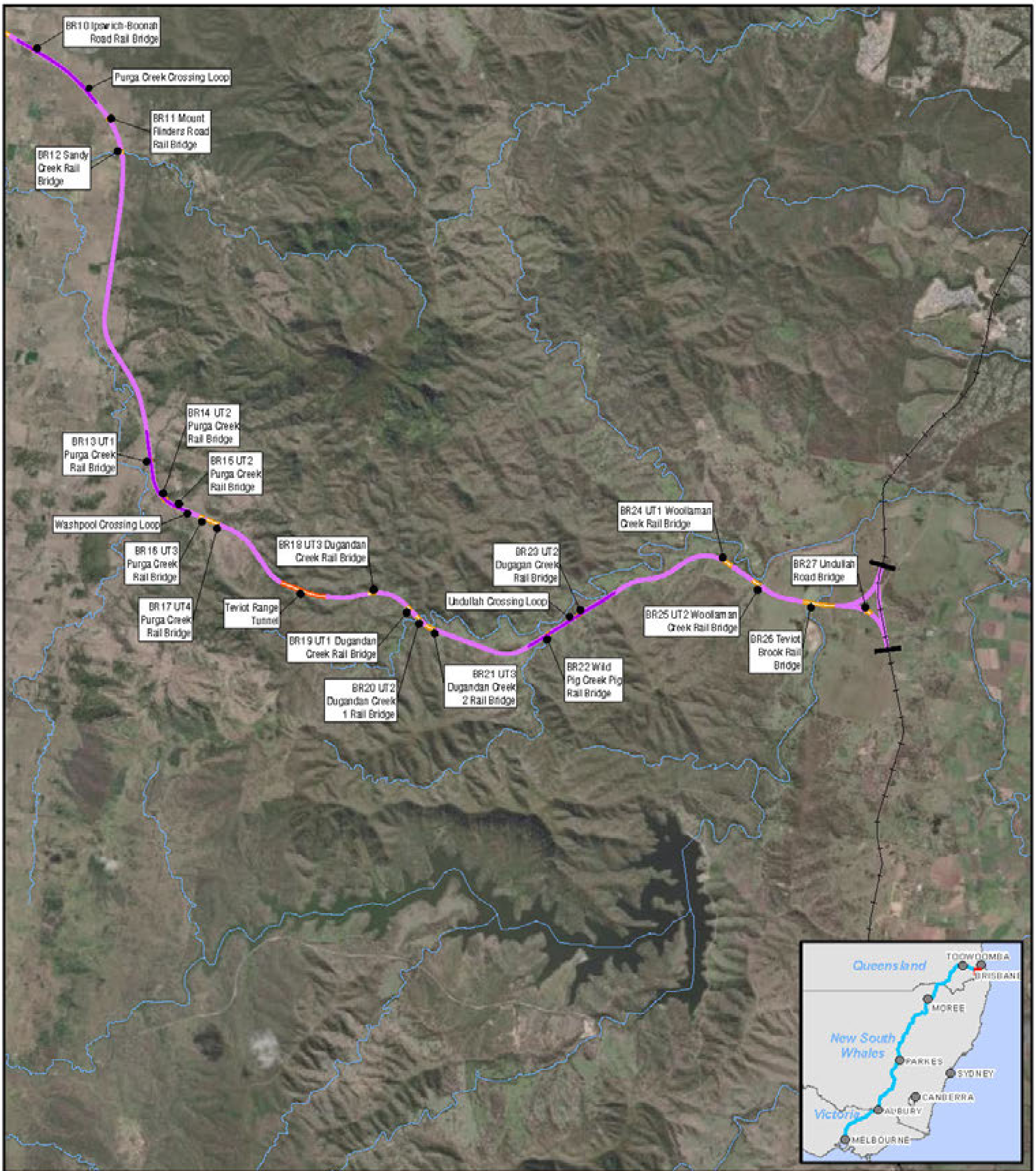
Service Layer Credits: Imagery ARTC 2016 and 2017



CALVERT TO KAGARU

Overview of the Project

FIGURE 1 - Map 2 of 2

3 km

Coordinate System: GDA 1994 MGA Zone 56

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ARTC InlandRail

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

Paper: A4 Scale: 1:112,500
Date: 17-Mar-2020
Author: JG

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Service Layer Credits: Imagery ARTC 2016 and 2017

1.2.3 Railway operations

The project would form part of the future rail network that will include train services provided by a variety of operators. It is estimated that Inland Rail would be trafficked by an average of 12 of the Express freight and Superfreighter trains per day (both directions) in 2026, increasing to about 15 of the Express freight and Superfreighter trains per day (both directions) in 2040.

This rail traffic would be in addition to the other future rail services and the existing rail traffic on the QR West Moreton System that will be collocated within the future rail corridor provided by the Project. In total, it is forecast that train movements would be an average of 42 trains per day (both directions) in 2026 and an average 51 trains per day (both directions) in 2040.

The overall train operations would be a mix of grain, bulk freight, coal and the Westlander passenger service. Train speeds would vary according to axle loads and range from 80 kilometres per hour (km/h) to 115 km/h. The railway operations are discussed further in **Section 2**.

1.3 Purpose and scope of this report

The purpose of this report is to assess the potential noise and vibration impacts from the railway operations of the Project and:

- address the relevant Terms of Reference (ToR) listed in **Table 1**;
- describe the existing environment with respect to railway noise and vibration sensitive receptors and the existing ambient and background noise levels;
- assess the potential noise and vibration impacts of railway operations of the Project at sensitive receptors, including the daily train movements and the operation of level crossings and crossing loops; and,
- recommend reasonable and practicable measures to mitigate and manage the impacts identified.

This report is specific to railway operations and the impact assessment for the construction works, road transport and stationary (fixed) infrastructure is detailed in Appendix P of the EIS; *Non-operational Noise and Vibration Technical Report* (Future Freight Joint Venture, 2020).

Table 1 Terms of Reference relevant to this assessment

ToR reference	Specific assessment requirements	Addressed in this report
Existing environment		
11.118	Describe the existing noise and vibration environment that may be affected by the project in the context of the environmental values.	An assessment of operational rail noise within the existing environment surrounding the Project is provided in **Section 5** and **Section 7**.
11.119	Describe and illustrate on maps at a suitable scale, the locations of all sensitive noise and vibration sensitive receptors adjacent to all project components and estimate typical background noise and vibration levels based on surveys at representative sites.	Receptors identified as potentially sensitive to noise and vibration are discussed in **Section 5.1** and identified in the maps in **Appendix A**.

ToR reference	Specific assessment requirements	Addressed in this report
11.120	If the proposed project could adversely impact on the noise and vibration impact, undertake baseline monitoring at a selection of sensitive receptors potentially affected by the project. Describe the results of any baseline monitoring.	Baseline noise and vibration monitoring was carried out for the project and is detailed in *Appendix P – Non-operational Noise and Vibration Technical Report*. The monitoring information is summarised in **Section 5.4**.
Impact assessment		
11.121	Describe the characteristics of the noise and vibration sources that would be emitted when carrying out the activity (point source general emissions). Describe noise and vibration emissions (including fugitive sources) that may occur during construction, commissioning and operation.	Sources of noise and vibration emissions from railway operations are discussed in **Section 6**. Refer also to *Appendix P – Non-operational Noise and Vibration Technical Report*.
11.122	Predict and map the impacts of the noise and vibration emissions from the construction and operation of the project on the environmental values of the receiving environment, including sensitive receptors.	Details of the rail noise predictions are provided in **Sections 7, 8** and **9** for airborne noise. The assessment of ground-borne vibration and ground-borne noise are detailed in **Section 11** and **Section 12**. Maps of predicted noise levels are provided in **Appendix D** and **Appendix E**.
	The assessment of impacts on noise and vibration would consider, applicable the following:	
	(a) Environmental Protection (Noise) Policy 2008, using recognised quality assured methods.	Not applicable to the infrastructure considered in this assessment as transport noise is excluded from the Environmental Protection (Noise) Policy 2008 (now the 2019 version). Refer also to *Appendix P – Non-operational Noise and Vibration Technical Report*.
	(b) Environmentally Relevant Activities – DES Application Requirements for ERAs with noise impacts (Guideline ESR/2015/1838).	Each chapter of this report provides information to address the requirements of the guideline.
	(c) Construction – The Department of Transport and Main Roads Transport Noise Management Code of Practice: Volume 2 – Construction Noise and Vibration dated March 2016 and gazetted on 29 July 2016.	The referenced Code of Practice is not applicable to the assessment of noise and vibration from railway operations. Refer also to *Appendix P – Non-operational Noise and Vibration Technical Report*.
	(d) Operational noise – The Department of Transport and Main Roads Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure Version 2, 10 May 2013 (Rail noise external criteria contained in Table 3 of the document).	Discussed in **Section 3.2** with operational rail noise levels assessed in **Sections 7, 8** and **9** .
	(e) Operational vibration – British Standard BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings – Vibration sources other than blasting. British Standards Institution, London.	The assessment of ground-borne vibration is detailed in **Section 11**.
	(f) The Department of Transport and Main Roads Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure Version 2, 10 May 2013 (refer to criteria contained in Table 6 of the document).	The assessment of ground-borne vibration is detailed in **Section 11**

ToR reference	Specific assessment requirements	Addressed in this report
11.123	Discuss separately the key project components likely to present an impact on noise and vibration for the construction and operation phases of the project.	The key project infrastructure and operations which could impact operational noise and vibration, are discussed in **Section 2**. Refer to *Appendix P – Non-operational Noise and Vibration Technical Report*.
11.124	Taking into account the practices and procedures that would be used to avoid or minimise impacts, the impact prediction must address the:	
	(a) activity's consistency with the objectives of documentation referenced in 11.122.	Details of the rail noise predictions are provided in **Sections 7, 8** and **9** for airborne noise. The assessment of ground-borne vibration and ground-borne noise are detailed in **Section 11** and **Section 12**. Maps of predicted noise levels are provided in **Appendix D** and **Appendix E**.
	(b) cumulative impact of the noise and vibration with other known emissions of noise associated with existing major projects and/or developments and those which are progressing through planning and approval process that are publicly available.	A cumulative assessment is provided in **Section 13**.
	(c) Potential impacts of any low frequency (<200 Hz) noise emissions.	Discussion on low frequency noise is provided in **Section 10.6**.
Mitigation measures		
11.125	Describe how the proposed project would be managed to be consistent with the best practice environmental management for the activity. Where a government plan is relevant to the activity, or the site where the activity is proposed, describe the activity's consistency with the plan.	Measures to manage and mitigate potential noise and/ or vibration impacts from the operation of the project are provided in **Section 14**.
11.126	Describe any expected exceedances of noise and vibration goals or criteria following the provision or application of mitigation measures and how any residual impacts would be addressed.	Details of the rail noise and vibration predictions are provided in **Sections 7, 8** and **9** and **10** (airborne noise), **Section 11** (ground-borne vibration) and **Section 12** (ground-borne noise). Residual impacts are assessed in **Section 15**.
11.127	Describe how the achievement of the objectives would be monitored and audited and how corrective actions would be managed.	Recommendations for monitoring noise and vibration levels once the project is operational have been discussed in **Section 14.6**.
11.166	Describe the climate patterns with particular regard to discharges to water and air and the propagation of noise related to the project.	Discussion on the effects of the climate on the propagation of noise are detailed in **Section 10.5**.

Source The Department of State Development, Tourism and Innovation, Terms of reference for an environmental impacts statement: Inland Rail – Calvert to Kagaru project, dated December 2017.

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 reported findings.

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

As the Project progresses through its detailed 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.

2 Description of the railway infrastructure

2.1 Overview

The Project 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. Where feasible, the Project has been designed to be within the existing SFRC. The key components of the Project are summarised in **Table 2**.

Table 2 Key infrastructure for the Project

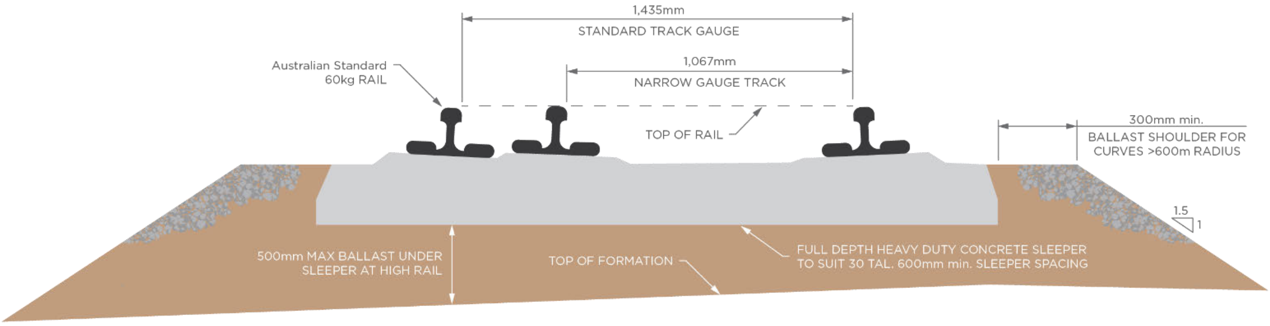
Key component	
Start and finish point	Calvert to Kagaru in Queensland
Local government areas	Scenic Rim Regional Council, Logan City Council and Ipswich City Council
Length of alignment	53 km
Track dimensions	Rail corridor minimum 40 m width, consisting of a single-track dual gauge railway line to facilitate rail traffic in both directions. The corridor extends wider where earthworks, structures and other associated infrastructure are required.
New level crossings	Nine including eight active level crossings and one passive level crossing
New rail bridges and viaducts	27 of which 24 are rail bridges for crossing roads and waterways
Connection with existing rail lines	Tie-ins to the QR West Moreton System and Sydney to Brisbane Interstate Line
Crossing loops	Four loops initially up to 1,800 m in length at Ebenezer, Purga Creek, Washpool & Undullah.
Tunnels	Approximately 1,015 m long tunnel traversing the Teviot Range
Construction period	2021 to 2026

2.2 Rail design

A single-track, dual gauge railway line (standard (1,435 millimetre (mm)) and narrow (1,067 mm) gauge) is proposed to facilitate the travel of trains in both directions within this section.

The mainline track structure is typically a ballasted track system consisting of continuously welded rail, resilient track fasteners, rail pads and concrete dual gauge full-depth sleepers at 600 mm centres and ballast between 250 mm and 500 mm in depth with 300 mm shoulder width for lateral restraint. A typical section for a dual gauge ballasted track is shown in **Figure 2**.

Figure 2 Indicative design for new track

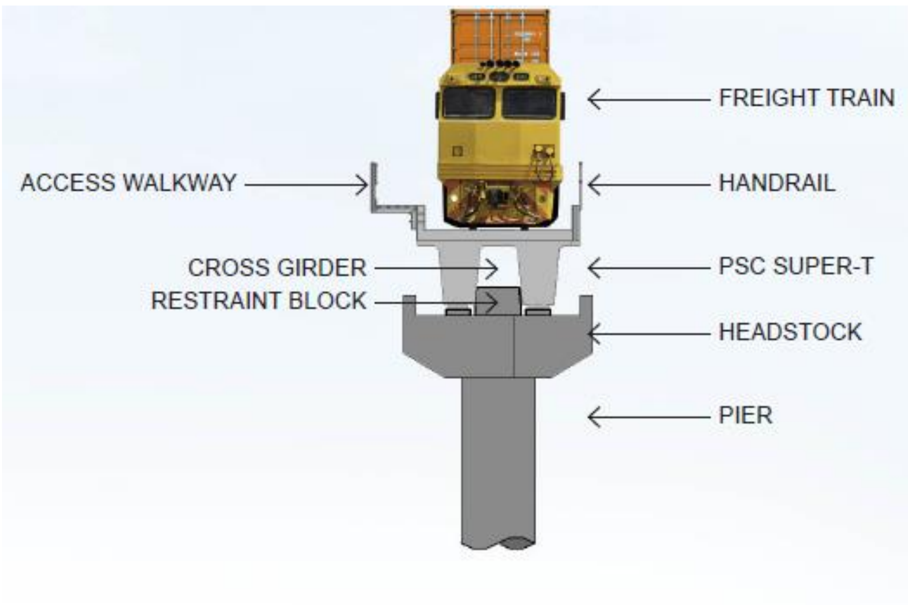


2.3 Bridges and viaducts

The Project requires 27 new bridge and viaduct structures of which 24 are for rail to cross over roads and waterways and three are to enable roads to cross over the rail corridor. 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.

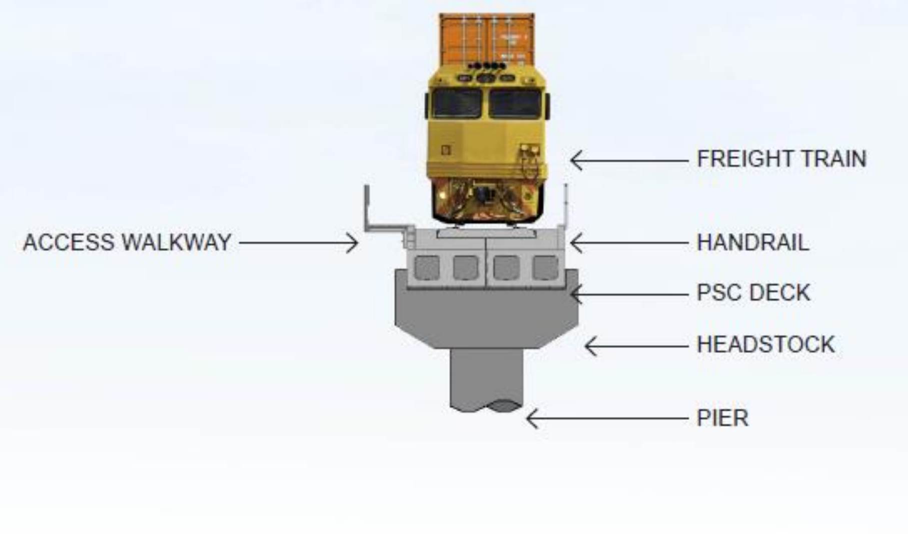
The sub-formation and ballast height will be approximately the same as the deck edge. The bridges may be either Super-T girders or pre-stressed concrete slab spans as illustrated in **Figure 3** and **Figure 4**.

Figure 3 Typical pier with pre-stressed concrete Super-T girder



Note Not shown to scale.

Figure 4 Typical pier with pre-stressed concrete slab span



Note Not shown to scale.

Details of each of the 27 bridges and viaducts are provided in **Table 3** and the location of the bridges and viaducts is presented in **Figure 1**.

Table 3 Rail bridges and viaducts on the Project

Bridge/ viaduct name	Crossing type	Bridge/ viaduct length, m
Western Creek 1 Rail Bridge	Waterway and road	966
Western Creek 2 Rail Bridge	Waterway and road	782
Bremer River Rail Bridge	Waterway and road	684
Mount Forbes Road Bridge	Road over the rail	72
UT Ebenezer Creek Rail Bridge	Waterway	207
Cunningham Highway Bridge	Road over the rail	53
Warril Creek Rail Bridge	Waterway	713
Purga Creek 1 Rail Bridge	Waterway	621
Purga Creek 2 Rail Bridge	Waterway	759
Ipswich Boonah Road Rail Bridge	Road	79
Mount Flinders Road Rail Bridge	Road	69
Sandy Creek Rail Bridge	Waterway	115
UT1 Purga Creek Rail Bridge	Waterway	115
UT2 Purge Creek Rail Bridge	Waterway	138
Washpool Road Rail Bridge	Road	69
UT3 Purga Creek Rail Bridge	Waterway	98
UT4 Purga Creek Rail Bridge	Waterway	299
UT3 Dugandan Creek Rail Bridge	Waterway	184
UT1 Dugandan Creek Rail Bridge	Waterway and road	138
Dugandan Creek 1 Rail Bridge	Waterway	211

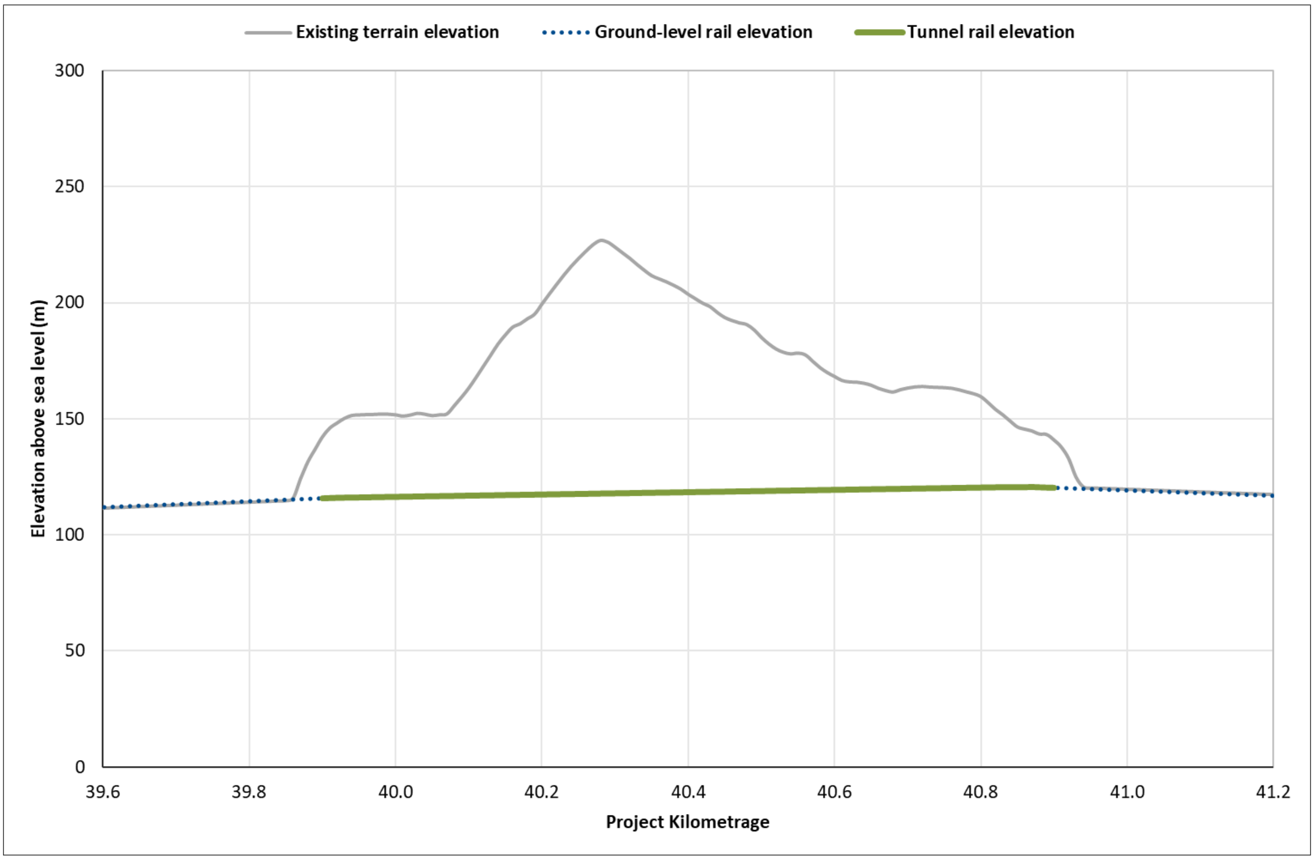
Bridge/ viaduct name	Crossing type	Bridge/ viaduct length, m
Dugandan Creek 2 Rail Bridge	Waterway	230
Wild Pig Creek Rail Bridge	Waterway	115
UT2 Dugandan Creek Rail Bridge	Waterway	161
UT1 Woollaman Creek Rail Bridge	Waterway	207
UT2 Woollaman Creek Rail Bridge	Waterway	230
Teviot Brook Rail Bridge	Waterway and road	722
Undullah Road Bridge	Road over the rail	70

2.4 Teviot Range Tunnel

The Teviot Range Tunnel is on a generally straight alignment and is approximately 1 km in length. The varying depth of the rail track within the tunnel alignment is shown in **Figure 5**, along with the existing ground surface (terrain) level.

The tunnel will be a concrete lined structure with the rail track constructed on a reinforced concrete slab (slab track). The track in the tunnel is proposed to use the Rheda2000 system with a Vossloh 300NG series highly resilient rail fastener.

Figure 5 Rail levels within the Teviot Range Tunnel



The single-track is to be located close to the centre of the tunnel to deliver the internal space necessary to facilitate the ventilation requirements. At the extents of the tunnel, tunnel portals shall be excavated to facilitate the transition between the ballasted surface track and the slab track within the tunnel structure.

This technical report has assessed the noise and vibration emissions associated with the trains operating within the tunnel. The noise and vibration associated with the supporting ventilation and substation infrastructure has been assessed in *Non-Operational Noise and Vibration Technical Report*, (Appendix P of the EIS).

2.5 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 level crossing.

The location of the level crossings on the Project are summarised in **Table 4**.

Table 4 Level crossings on the Project

Road name	Treatment
Hayes Road	Active level crossing
Mount Hines Road	Passive level crossing
Glencairn Road	Active level crossing
Middle Road	Active level crossing
Dwyers Road	Active level crossing
Washpool Road	Active level crossing
Wild Pig Creek Road	Active level crossing
Wild Pig Creek Road	Active level crossing
Private road	Active level crossing

2.6 Turnouts

A turnout is a point where a train can leave a given track for a branching or parallel track. There are 15 turnouts on the Project required to manage train movements at the following locations:

- connections between the Project and the QR West Moreton System and Interstate Line;
- cross overs to connect two parallel rail tracks; and,
- each of the four crossing loops and the maintenance siding at each loop.

2.7 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 a different speeds.

The Project incorporates four new crossing loops, designed to initially accommodate a maximum train length of 1,800 m. Each 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.

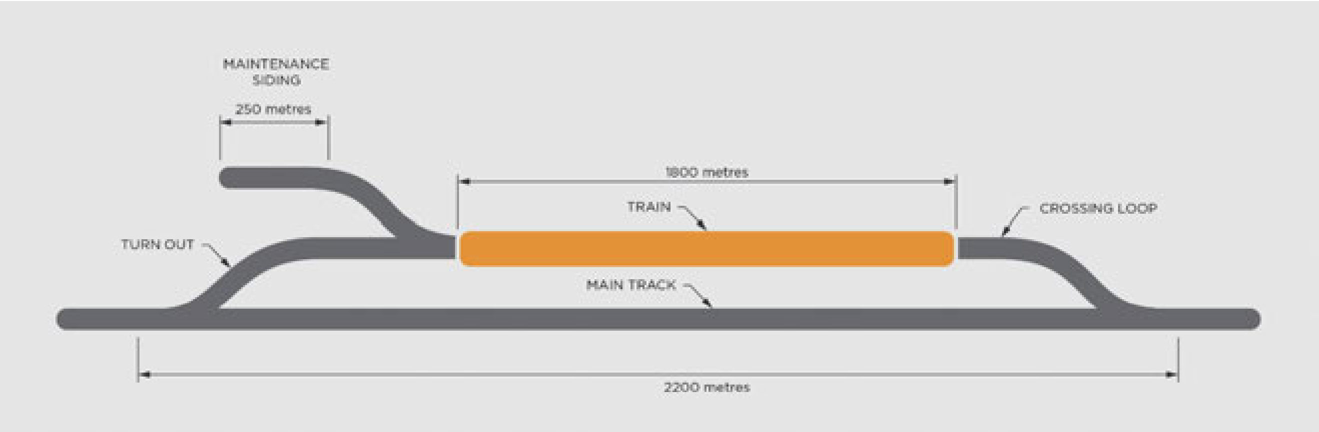
The loops would be new sections of track parallel to the existing track at a distance of approximately 4.5 m spacing from the mainline track and incorporate a maintenance siding to enable maintenance of rollingstock without obstructing the track.

The proposed location of the crossing loops are summarised in **Table 5** and the indicative design of the crossing loop and maintenance siding is shown in **Figure 6**.

Table 5 Crossing loop locations

Crossing loop	Location
Ebenezer	Parallel to the main track adjacent to Paynes Road
Purga Creek	Parallel to the main track between Purga Creek 2 bridge and Ipswich Boonah rail bridge.
Washpool	Parallel to the main track adjacent to Washpool Road
Undullah	Parallel to the main track adjacent to Wild Pig Creek

Figure 6 Indicative design for crossing loop and maintenance siding



3 Environmental assessment criteria

3.1 Referenced documentation

Based on the requirements of ToR, 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
Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure (2013)	Department of Transport and Main Roads	- Noise assessment criteria for land developed adjacent to transport corridors. - Ground vibration assessment criteria for land developed adjacent to transport corridors.
Interim Guideline, Operational Railway Noise and Vibration, Government Support Transport Infrastructure (2019).	Department of Transport and Main Roads	- 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.
British Standard BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings – Vibration sources other than blasting (2008)	British Standards	- Establishment of assessment criteria for ground vibration. - Assessment methodologies for ground vibration.

3.2 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 in the following sections, including the airborne noise criteria applied by ARTC for the assessment and management of railway noise from the Project.

3.2.1 DTMR assessment criteria

The ToR requires the assessment of railway noise from the Project to consider the objectives and assessment criteria from the Department of Transport and Main Roads (DTMR) *Policy for Development on Land Affected by Environmental Emissions from Transport and Transport Infrastructure Version 2* (DTMR Policy); specifically, the external rail noise criteria contained in Table 3 of the DTMR Policy.

The external rail noise criteria from the DTMR Policy are reproduced in **Table 7**.

Table 7 DTMR Policy railway noise criteria

Development type	Location with development	Environmental criteria
Accommodation activities	All facades	≤65 dBA LAeq(24hour) façade corrected
		≤87 dBA (single event maximum (SEM) sound pressure level) façade corrected
	Outdoor spaces for passive recreation	≤62 dBA LAeq(24hour) free field
		≤84 dBA (SEM sound pressure level) free field
Educational establishments, childcare centres	All facades	≤65 dBA LAeq(1hour)) façade corrected[1]
		≤87 dBA (SEM sound pressure level) façade corrected
	Outdoor education areas, outdoor play areas	≤62 dBA LAeq(12hour) free field between 6.00 am and 6.00 pm
		≤84 dBA (SEM sound pressure level) free field
Health care services, hospitals, community uses, places of worship	All facades	≤65 dBA LAeq(1hour) façade corrected[1]
		≤87 dBA (SEM sound pressure level) façade corrected
	Outdoor spaces for passive recreation	≤62 dBA LAeq(12hour) free field between 6.00 am and 6.00 pm
		≤84 dBA (SEM sound pressure level) free field

Note 1 Maximum hour during normal opening hours

In 2019, the DTMR issued the Interim Guideline Operational Rail Noise and Vibration – Government Supported Transport Infrastructure[3] (Interim Guideline). The Interim Guideline is a published standard under the *Transport Infrastructure Act 1994*. The railway noise assessment criteria from the Interim Guideline are reproduced in **Table 8** and are more stringent than the railway noise assessment criteria in the DTMR Policy (refer **Table 7**).

Table 8 DTMR Interim Guideline railway noise criteria

Type	Location at sensitive land use	External operational railway noise criteria[1]		
		Single Event Maximum[3]	LAeq(24hour)	LAeq(12hour)
New railway	All facades	≤ 82 dBA façade corrected	≤ 60 dBA façade corrected	-
	Outdoor spaces for passive recreation Outdoor education area Outdoor play area[2]	≤ 79 dBA free field	-	≤ 57 dBA free field
Upgrading existing railway or existing railway	All facades	Development increases existing LAeq(24hour) or LAeq(12hour) rail noise levels by 2 dB or more, or existing SEM rail noise levels by 3 dB or more and predicted rail noise levels exceed:		
		≤ 87 dBA façade corrected	≤ 65 dBA façade corrected	-
Upgrading existing railway or existing railway	Outdoor spaces for passive recreation Outdoor education area Outdoor play area[2]	≤ 84 dBA free field	-	≤ 62 dBA free field

Note 1 The façade corrected prediction height is commonly adopted at 1.8 m and 4.6 m above the building platform level for the ground floor and first floors respectively. For free-field land uses the criteria applies at 1.5 m above the ground level.
Note 2 For outdoor educational, outdoor play and passive recreational areas greater than 2,000 m^2, the criterion level is to be achieved for a minimum 2,000 m^2. For areas less than 2,000 m^2, the criterion shall be achieved for the whole area.
Note 3 Arithmetic average of the LAFmax from the highest 15 single events (i.e. rolling stock passby) during a Use Period within a 24-hour period.

[3] Department of Transport and Main Roads, 2019. *Interim Guideline, Operational Railway Noise and Vibration, Government Support Transport Infrastructure.*

The guideline is specific to the assessment and management of railway noise and vibration from new rail infrastructure and upgrades to existing railway infrastructure. The Interim Guideline is considered to be more suitable for the assessment of noise from railway infrastructure than the noise criteria from Table 3 of the DTMR Policy.

The Interim Guideline is not directly referenced in the ToR, because the ToR predated the release of the guidelines. Notwithstanding, ARTC has considered the relevant aspects of the Interim Guideline in the development of approaches to assess and manage railway noise on the Project.

3.2.2 Management of railway noise on Inland Rail

ARTC is implementing a uniform approach for the assessment and management of operational railway noise across Inland Rail to ensure potential noise related impacts to public health, amenity and disturbance are managed consistently.

Where the predicted rail noise levels are above the assessment criteria, ARTC will investigate reasonable and practicable mitigation measures with the aim of reducing noise levels to meet the criteria and minimising potential noise impacts at sensitive receptors.

The rail noise criteria from the DTMR Policy, Interim Guideline and other Australian railway noise guidelines were considered in the development of the airborne railway noise criteria for the Project. The airborne noise criteria adopted by ARTC for residential receptors are detailed in **Table 9**. Residential land use, as defined by the DTMR Policy, has been adopted for the assessment.

Table 9 Airborne railway noise criteria for residential receptors

Type of development	Noise assessment criteria at residential receptors (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	$L_{Aeq(9 hour)}$ 55 dBA
	L_{AFmax} 80 dBA	L_{AFmax} 80 dBA
Upgrade of existing rail line[2]	Development increases existing $L_{Aeq(period)}$ rail noise levels by 2 dB or more, or existing L_{Amax} rail noise levels by 3 dB or more and predicted rail noise levels exceed:	
	$L_{Aeq(15hour)}$ 65 dBA	$L_{Aeq(9 hour)}$ 60 dBA
	L_{AFmax} 85 dBA	L_{AFmax} 85 dBA

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

Note 2 An upgraded line is a development on land that is within an existing operational rail corridor, where a line is or has been operational or is immediately adjacent to an existing operational rail line which may result in the widening of an existing 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.

There are different assessment criteria for new railways and for upgrading existing railway infrastructure. The criteria for new railways are 5 dBA lower (more stringent) based on the assumption that noise mitigation can be more readily implemented on newly constructed sections of railway infrastructure.

The ARTC approach includes rail noise criteria for sensitive receptors other than residential land uses. The noise criteria for these receptors types is detailed in **Table 10**.

Table 10 Airborne noise assessment criteria for other sensitive receptors

Other sensitive receptors	Noise assessment criteria (when receptor premises are in use)	
	New rail line development[1]	Upgrade of existing rail line[2]
	Resulting rail noise levels exceed:	Development increases existing rail noise levels by 2 dBA or more in L_{Aeq} for that period, and resulting rail noise levels exceed:
Schools, educational institutions and childcare centres	$L_{Aeq(1\ hour)}$ 40 dBA (internal)	$L_{Aeq(1\ hour)}$ 45 dBA (internal)
Places of worship	$L_{Aeq(1\ hour)}$ 40 dBA (internal)	$L_{Aeq(1\ hour)}$ 45 dBA (internal)
Hospital wards	$L_{Aeq(1\ hour)}$ 35 dBA (internal)	$L_{Aeq(1\ hour)}$ 40 dBA (internal)
Hospital other uses	$L_{Aeq(1\ hour)}$ 60 dBA (external)	$L_{Aeq(1\ hour)}$ 65 dBA (external)
Open space – passive use (e.g. parkland, bush reserves)	$L_{Aeq(15hour)}$ 60 dBA (external)	$L_{Aeq(15hour)}$ 65 dBA (external)
Open space – active use (e.g. sports field, golf course)	$L_{Aeq(15hour)}$ 65 dBA (external)	$L_{Aeq(15hour)}$ 65 dBA (external)

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

Note 2 An upgraded line is a development on land that is within an existing operational rail corridor, where a line is or has been operational or is immediately adjacent to an existing operational rail line which may result in the widening of an existing rail corridor.

3.2.3 Summary of airborne noise assessment criteria

The assessment of noise must consider the DTMR Policy, as required by the ToR, and also the Interim Guideline. As discussed in **Section 3.2.2**, further to these guidelines ARTC is implementing railway noise criteria specifically for the management of railway noise on Inland Rail.

For the purpose of this study, it is preferential to have one set of noise criteria for railway operations to provide consistency in the assessment of railway noise and the management of any railway noise impacts. A review of the criteria from the Interim Guideline and the approach to be implemented by ARTC on Inland Rail was undertaken to establish a conservative approach for the assessment and management of noise on the Project.

Detailed below in **Table 11**, the railway noise criteria adopted by ARTC are generally more stringent than the Interim Guideline. Accordingly, where the Project meets the ARTC railway noise criteria at sensitive receptors the railway noise criteria from the DTMR Policy and Interim Guideline would also be met.

Table 11 Review of assessment criteria for airborne noise

Aspect	Interim Guideline criteria	ARTC noise criteria	Commentary
Assessment periods	Noise levels assessed for the total rail operations in each 24-hour period.	Noise levels assessed separately for the daytime and night-time rail operations in each 24-hour period.	The ARTC criteria account for the variation in rail operations during the 24-hour period. Assessing the potential night-time noise levels acknowledges the need to protect the community during this more sensitive period (including sleep disturbance). On this basis, ARTC is applying the more stringent criteria.

Aspect	Interim Guideline criteria	ARTC noise criteria	Commentary
Noise criteria (all facades)	The LAeq and SEM[1] noise criteria are 5 dBA more stringent for new railways than for upgrading existing railway infrastructure.	The LAeq and LAmax noise criteria are 5 dBA more stringent for new railways than for upgrading existing railway infrastructure. The daytime LAeq noise criteria are 5 dBA more stringent than the night-time LAeq noise criteria.	The LAeq noise criteria are the same for the 24-hour period in the Interim Guideline and the 15-hour daytime period with the ARTC criteria. The night-time LAeq noise criteria applied by ARTC are 5 dBA more stringent than the 24-hour noise criteria in the Interim Guideline. The ARTC maximum noise criteria are 2 dBA more stringent than the Interim Guideline[2].
Application to sensitive receptors	The guideline adopts external rail noise criteria at sensitive receptors. The guideline applies both LAeq and SEM noise criteria.	The ARTC adopts external noise criteria for residential receptors. Internal LAeq criteria are provided to maintain the use of some building types.	The Interim Guideline defines sensitive receptors for a wider range of building uses. The ARTC approach for non-residential receptors is more rigorous by assessing internal noise levels. For non-residential sensitive receptors, the Interim Guideline provides assessment criteria for both LAeq and LAmax noise metrics, whereas the ARTC approach only considers LAeq criteria.

Note 1 Single Event Maximum (SEM)

Note 2 The Interim Guideline and ARTC management levels have different approaches to deriving the maximum rail noise level. This may influence the significance of the 2 dBA variations in the criteria levels.

3.3 Noise criteria for new and upgraded railway infrastructure

The study area for the railway noise assessment was an area 2 km surrounding either side of the Project alignment. The study area is constrained to the eastern and western extents of the Project and the assessment of noise (and vibration) within the environments immediately outside of the Project extents is being considered as part of the environmental assessments prepared for the Helidon to Calvert and Kagaru to Acacia Ridge and Bromelton projects on Inland Rail.

This study has adopted ARTC's proposed criteria for the management of railway noise on Inland Rail as primary railway noise assessment criteria for the Project, refer **Table 9** and **Table 10**. The criteria provide noise investigation thresholds specific to sections of new railway and upgrades to sections of existing rail infrastructure.

Within the study area, the noise assessment criteria for sensitive receptors were based on the defined sections of new rail corridor and the sections of upgraded existing railway infrastructure.

There are locations where the Project transitions between new rail corridors and the existing rail corridors and sensitive receptors are located either side of the rail alignment in these locations. The railway noise will propagate (travel) outside the defined extents of the new and existing rail corridor sections. There may be some sensitive receptors that, whilst adjacent to sections of new rail corridor, already experience noise from the nearby existing railway operations.

Accordingly, assigning the noise criteria at the sections of new and upgraded rail corridors considered the locations where the introduction of the additional railway infrastructure with the Project could change the existing railway noise levels at potentially affected sensitive receptors.

There is limited guidance on defining the extents where the railway noise criteria are to apply, so the noise criteria for the upgrade of existing railway infrastructure was applied to sensitive receptors located within an approximate 750 m off-set either side of the sections of existing rail corridor within the study area.

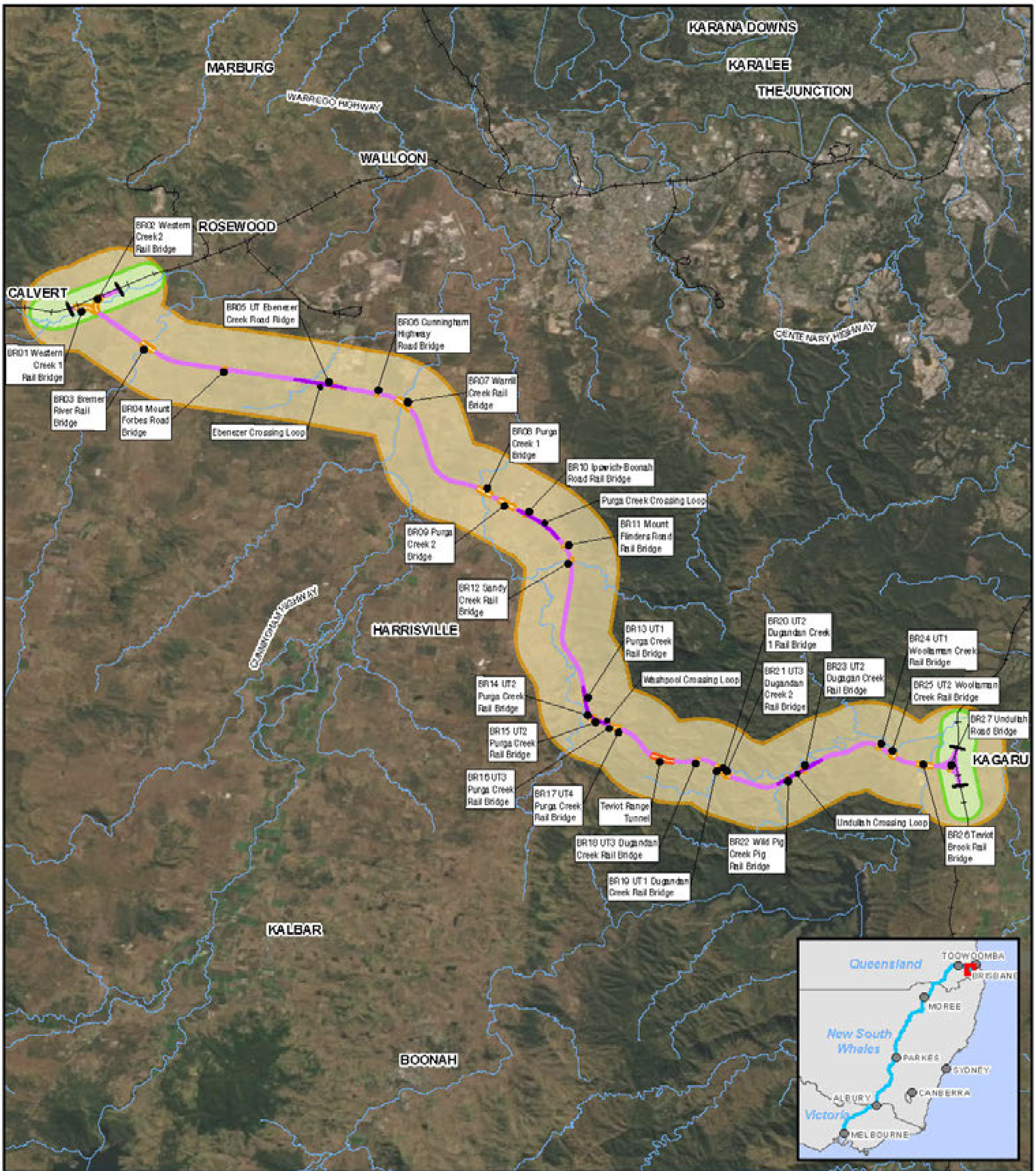
The 750 m off-set distance from the sections where the Project will upgrade the existing rail corridors considered the following key factors:

- Potential distances from the existing rail corridor where the noise criteria would be met from current railway operations.
- The environment surrounding the Project alignment where railway noise levels could be reasonably anticipated to increase by at least L_{Aeq} 2 dBA or at least L_{Amax} 3 dBA in the daytime or night-time periods with the future Inland Rail operations.
- Locations where railway noise from current railway operations could potentially influence the existing daytime and night-time noise environments.
- Off-set distance achieved a 1.5 km diameter noise assessment footprint around the existing rail corridors, which is representative of a typical length of coal and freight trains and enabled the assessment to consider the complete passby of existing rail traffic.
- Implementation of the noise criteria to provide an assessment of railway noise to support the evaluation of reasonable and practicable noise mitigation.
- The approach aimed for neighbouring and nearby sensitive receptors to be assessed against the same noise criteria to enable equitable outcomes during the consideration of noise mitigation measures.

The areas where the assessment applied the noise criteria for new rail infrastructure and the noise criteria for the upgrade of existing infrastructure are detailed in **Table 12** and shown in **Figure 7**.

Table 12 Application of the railway noise criteria for the Project

Project Alignment Locations	Designation for the assessment	Key factors
The start of the Project at Calvert where the Project is collocated within the QR West Moreton System.	Upgrade of existing railway infrastructure.	The project is collocated within the QR West Moreton System from the Project start to the Rosewood connection adjacent to Waters Road.
Where the Project departs from the QR West Moreton System through to the tie-in to the Interstate Line.	New railway corridor (including the Teviot Range Tunnel).	The new railway infrastructure is within the SFRC railway land.
At the eastern extent of the Project where it joins the Interstate Line near Kagaru.	Upgrade of existing railway infrastructure.	The project ties into the Interstate Line at Undullah Road in Kagaru.



CALVERT TO KAGARU

Application of Railway Noise Criteria for the Project

FIGURE 7

5 km

Coordinate System: GCS GDA 1994

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Paper: A4 Scale: 1:250,000
Date: 04-Mar-2020
Author: JG

- Project Extent
- Existing Railway
- Watercourses
- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- Teviot Range Tunnel
- Noise Assessment Area Upgraded Railway Infrastructure
- 2km Study Area/ Noise Assessment Area New Rail Corridor

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: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

3.4 Ground-borne vibration guidelines

Railway vibration is generated by dynamic forces at the interface of the rail and train wheels. For railway operations within the Teviot Range Tunnel and on elevated bridges and viaducts, the railway generated vibration can be transmitted into buildings near to the alignment via the tunnel or bridge and viaduct structures, and the surrounding ground.

If the levels of vibration are sufficiently high, 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. 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.

3.4.1 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 ToR requires potential ground-borne vibration impacts to be assessed with reference to British Standard BS 6472 Part 1[4] and the DTMR Policy. The Interim Guideline also includes ground-borne vibration criteria for the management of vibration from railway operations. The criteria to manage vibration disturbance impacts are generally consistent between the documents.

The vibration assessment criteria in **Table 13** were referenced from the Interim Guideline as they are specific for the assessment of ground vibration associated with railways. The British Standard advises the vibration levels in **Table 13** are expected to be just perceptible in typical residential environments, and likely to result in a low probability of adverse comment.

Table 13 Ground-borne vibration criteria for sensitive receptors

Type of development	Sensitive receptors	Internal ground-borne vibration criteria	
		Use period[1]	Vibration dose value
New railway or upgrading existing railway	Accommodation activities	Daytime	≤ 0.20 $m/s^{1.75}$
		Evening	
		Night-time	≤ 0.13 $m/s^{1.75}$
	Educational establishments, childcare centres, health care services, hospitals, community uses, places of worship and offices	While in use	≤ 0.40 $m/s^{1.75}$ (all areas)
			≤ 0.10 $m/s^{1.75}$ (critical areas)

Note 1 Daytime 6.00 am to 6.00 pm, evening 6.00 pm to 10.00 pm and night-time 10.00 pm to 6.00 am.

The vibration criteria in **Table 13** 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] British Standards, 2008. *BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting, 2008*.

3.4.2 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 DTMR Policy and Interim Guideline, a discussion of various standards relevant to vibration and its effects on buildings is provided in **Table 14**.

Table 14 Referenced standards associated with cosmetic building damage risk

Reference	Notes
British Standard BS 5228.2[5] British Standard BS 7385.2[6]	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[7]	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.

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 accuracy the dominant (or resonant) frequencies of vibration at each building during train passby events. The vibration criteria irrespective of frequency, that is essentially the lowest applicable value, is a conservative assessment approach.

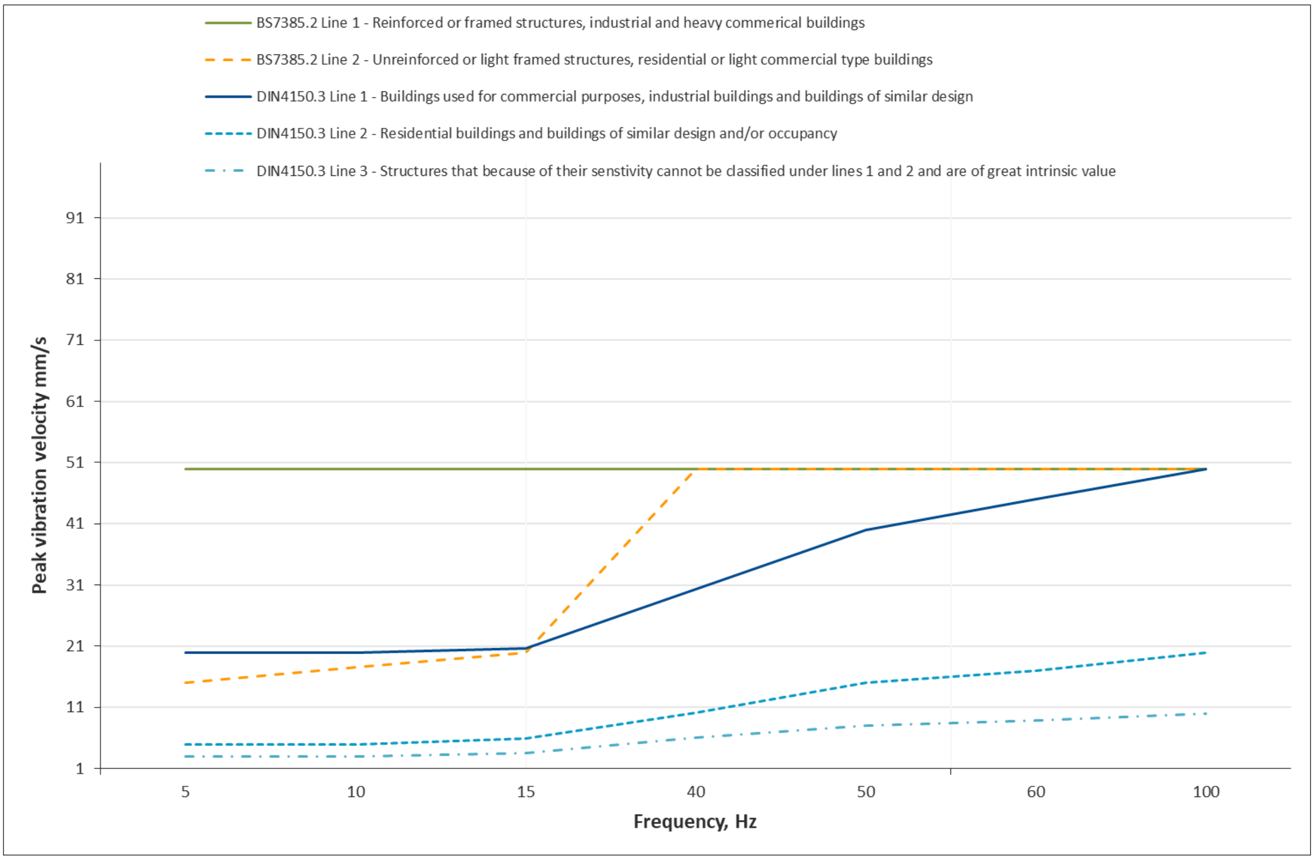
Based on **Table 14**, the relevant PPV guidance values for assessment of ground-borne vibration at heritage sites are presented in **Figure 8**. From this figure it can be seen that Line 3 of German Standard DIN 4150.3 is the lowest, most conservative vibration level, including where the vibration levels 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.

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.

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

Figure 8 Guidance values for short term vibration



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

ARTC is applying the criteria in **Table 15** to assessment potential for ground-borne noise impacts on the Project. The assessment criteria were developed with reference to the ground-borne noise criteria from the Interim Guideline and other railway noise and vibration guidelines.

Table 15 Ground-borne noise trigger levels

Type of development	Sensitive receptors	Internal ground-borne noise trigger levels	
		Use period[1]	LASmax[2]
New railway or upgrading existing railway	Accommodation activities	Daytime	≤ 40 dBA
		Evening/ night-time	≤ 35 dBA
	Educational establishments, childcare centres, health care services and hospitals	While in use	≤ 35 dBA
	Community uses, places of worship and offices		≤ 40 dBA
	Court of law (court rooms)		≤ 30 dBA
	Court of law (court reporting and transcript areas, Judges' chambers)		≤ 35 dBA

Note 1 Daytime 7.00 am to 6.00 pm, evening 6.00 pm to 10.00 pm and night-time 10.00 pm to 7.00 am.
Note 2 Maximum noise level not exceeded for 95% percent of rail passby events.

The criteria generally trigger the investigation of reasonable and practicable measures for the management and control ground-borne noise (and vibration) where the rail induced ground-borne noise levels are higher than the airborne noise from the railway operations. In such circumstances there is potential for the ground-borne noise from train passbys to be audible within habitable rooms.

4 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 212 km^2 (>21,100 hectares) was applied as the study area for railway noise and vibration.
- The 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 Helidon to Calvert and Kagaru to Acacia Ridge and Bromelton 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 ToR and ARTC's proposed approach for managing noise and vibration on Inland Rail.
- Noise and vibration assessment scenarios were determined for the proposed rail operations based on the project description and the requirements of the ToR. The year 2026 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 railway operations on the ground-level track and within the Teviot Range Tunnel 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 ToR.
- The investigation of reasonable and practicable 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 land uses, after mitigation is implemented, was evaluated and recommendations were prepared for future noise and vibration assessment and monitoring works through the detailed design.

5 Existing environment

5.1 Sensitive receptors

The DTMR Policy and Interim Guideline identify the typical receptors that can be potentially sensitive to noise and vibration from railway operations. The description of the various sensitive receptors is detailed in **Table 16**.

When applying the noise and vibration criteria in **Section 3**, the criteria for residential receptors are commonly applied to the range of receptors described under accommodation activities.

Table 16 Sensitive receptors

Sensitive receptors	Inclusions
Accommodation activities	Caretaker's accommodation, community residence, dual occupancy, dwelling house, dwelling unit, home-based business, multiple dwelling, nature-based tourism, non-resident workforce accommodation, relocatable home park, residential care facility, resort complex, retirement facility, rooming accommodation, rural workers' accommodation, short term accommodation and tourist park.
Education establishments	Primary and secondary schools, colleges, technical institutes, universities or other educational institutions.
Childcare centres	Crèches, early childhood centres, kindergartens and preschools.
Health care services	Medical centres, health clinics, surgeries and other medical institutions.
Hospitals	-
Community uses	Courts of law, art galleries, community halls, libraries and museums.
Places of worship	-
Offices	-
Mixed use	A mix of the uses listed above.

Source Section 2.1 of the DTMR Interim Guideline, operational Railway Noise and Vibration, Government Supported Transport Infrastructure, March 2019.

To determine the sensitive receptors included in the assessment of railway noise and vibration, all buildings over 9 m^2 within the study area of the Project alignment were identified using a national geospatial dataset of buildings from 2018.

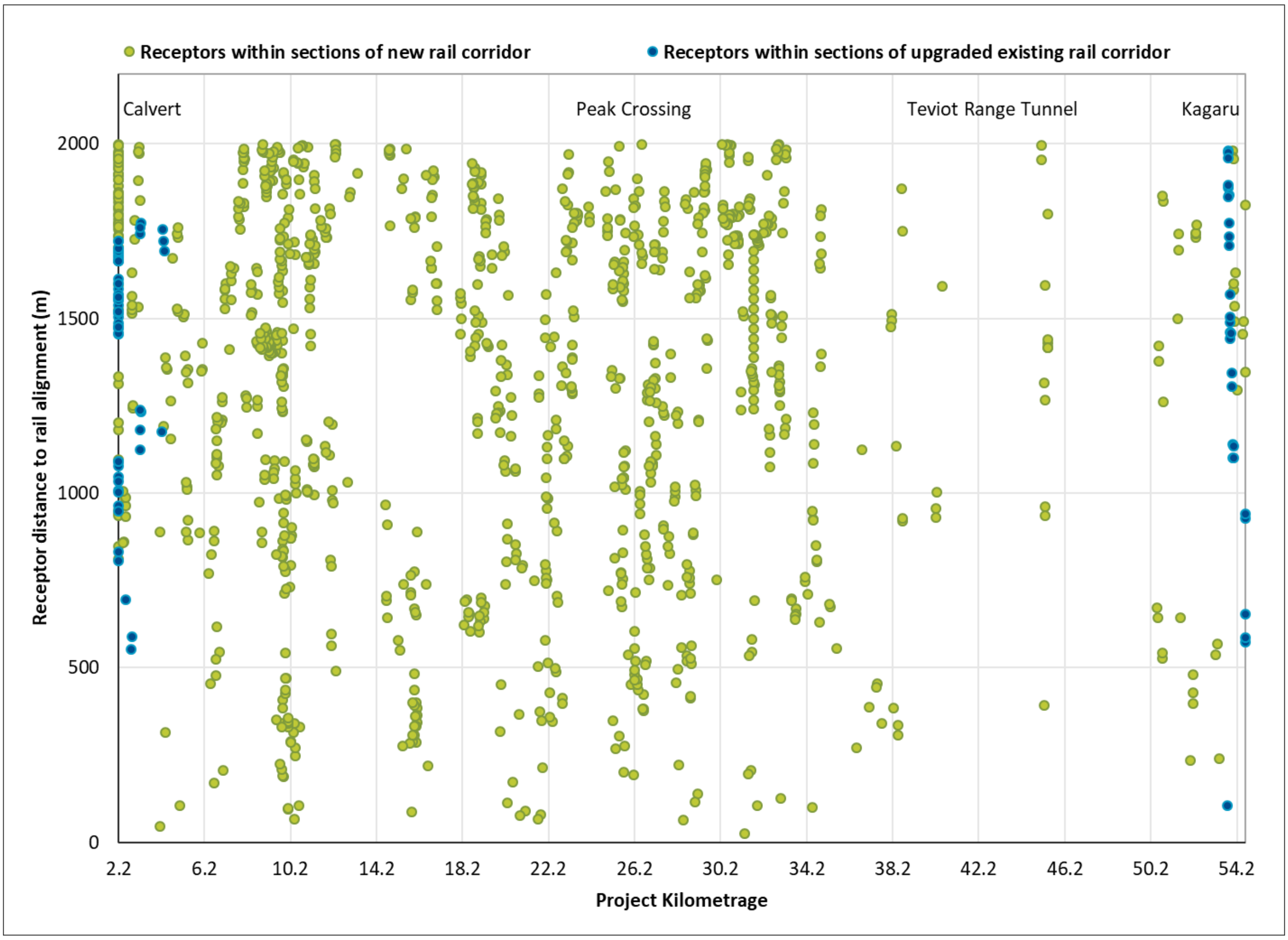
A total of 2,650 buildings were identified within the study area and each building was assigned a unique identification number for the purpose of the assessment.

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 identified non-sensitive buildings.

Six buildings were identified as being within the railway alignment and disturbance footprint of the Project, these buildings were excluded as it is likely they will be acquired by the Construction Authority.

Of the buildings identified, 1,350 receptors were identified as being potential noise and vibration sensitive receptors within the study area. The location of these sensitive receptors along the Project alignment is presented in **Figure 9**. The individual sensitive receptors are detailed in the maps provided in **Appendix A**.

Figure 9 Distribution of sensitive receptors along the Project alignment



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

5.2 Sensitive receptors other than residential

The review of the existing property, buildings and land-uses did not identify any sensitive receptors, other than residences, within the study area.

5.3 Heritage sites

Referencing the cultural heritage assessment for the Project, the 13 non-indigenous sites in **Table 17** were identified as sites of potential heritage significance. Details of each site are provided in *Appendix T: Non-Indigenous Heritage Survey Report*[8] prepared for the EIS.

Of the sites which are described as homesteads, all were identified as being sites of existing residences and were included as noise sensitive residential receptors in the assessment of operational railway noise and vibration. A total of nine sites were identified as being within the permanent disturbance footprint of the Project and are expected to be managed or mitigated as part of the Project. The remaining four sites, including two residences, were considered in the assessment of ground-borne vibration from railway operations.

[8] Inland Rail: Phase 2 – Calvert to Kagaru, Appendix T – Non-Indigenous Cultural Heritage Technical Report.

Table 17 Non-Indigenous heritage sites

Site ID	Site name	Site description	Proximity to the Project
C2K-19-H1	Brooklands Homestead	Original homestead was demolished in the mid-20th century, other original elements remain including garden plantings and a ruined dairy.	Approximately 90 m from the rail spurs connecting to the Interstate Line
C2K-19-H2	Kagaru Station	Former Kagaru Station, some elements remain such as timber road bridge, water standpipes and plantings.	Approximately 150 m from the Project alignment and within 60 m of the Interstate Line.
C2K-19-H3	Kenny's Hut[1]	No evidence of a residential dwelling, well-built set of yards was identified.	Within permanent disturbance footprint
C2K-19-H4	Hut and yards	Small hut built of partially of timber slabs and dilapidated yards.	Within permanent disturbance footprint
C2K-19-H5	O'Neill's Hut	Disused corrugated iron clad hut, yards and cattle dip.	Within permanent disturbance footprint
C2K-19-H6	Creamery and dairy	Includes a creamery, concrete slab marking the former dairy and building stumps and fence posts.	Within permanent disturbance footprint
C2K-19-H7	Washpool	No specific evidence of heritage items was identified	Within permanent disturbance footprint
C2K-19-H8	Yards and shed	Contains a large shed, set of yards and remains of a horse drawn wagon.	Within permanent disturbance footprint
C2K-19-H9	House	House and out-buildings identified.	Approximately 68 m from the rail centreline
C2K-19-H10	House	House and out-buildings identified	Approximately 95 m from the rail centreline
C2K-19-H11	Multiple structures	12 buildings range from large sheds to small huts.	Within permanent disturbance footprint
C2K-19-H12	Dairy and creamery	Remains of a dairy and creamery	Within permanent disturbance footprint
C2K-19-H13	Homestead complex	Remains of dairy and yards, possible house and shed site.	Within permanent disturbance footprint

Source Appendix T: Non-Indigenous Heritage Technical Report.

Note 1 No evidence of historical structures or other heritage items was identified in the Appendix T: Non-Indigenous Cultural Heritage Technical Report.

5.4 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 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 *Appendix P: Non-operational Noise and Vibration Technical Report* (Appendix P of the EIS).

Existing noise levels were monitored at 10 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 18** 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 assessment criteria for the Project.

Table 18 Existing environmental noise levels

Monitoring location	Rating background levels, dBA		
	Daytime	Evening	Night-time
C2K_01 Newcastle Street, Calvert	35	32	27
C2K_02 Paynes Road, Ebenezer	33	31	23
C2K_03 Paynes Road, Ebenezer	33	28	23
C2K_04 Middle Road, Purga	32	33	25
C2K_05 Mount Flinders Road, Peak Crossing	39	32	22
C2K_06 McNeills Road, Peak Crossing	34	39	35
C2K_07 Dwyers Road, Peak Crossing	29	29	22
C2K_08 Ipswich-Boonah Road, Peal Crossing	35	31	23
C2K_09 Washpool Road, Washpool	35	25	<21
C2K_10 Undullah Road, Kagaru	<21	<21	<21

Note 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.

5.5 Existing railway noise levels

The Project is collocating within the existing QR West Moreton System and connecting to the Interstate Line. The assessment of railway noise was required to consider the railway noise from the existing rail movements, which shall still operate with the Project, and the additional railway operations facilitated by the Project.

For large-scale transport infrastructure such as the Project, the existing railway noise levels at sensitive receptors are often determined through detailed calculation. A noise prediction model was applied to determine the potential daytime and night-time existing railway noise levels within the study area.

The noise prediction modelling methodology is detailed in **Section 6** and the calculated railway noise levels for the existing rail corridor are detailed in **Section 7**.

6 Railway noise modelling

6.1 Prediction of railway noise

Noise emissions from the railway operations on the Project were calculated through detailed noise prediction modelling using SoundPLAN (version 7.4) noise prediction modelling software.

The noise prediction model included a detailed terrain model to develop a 3-dimensional (3D) representation of the Project and the 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 and infrastructure, and the surrounding environment. The resultant terrain model represented the future environment with the Project.

The vertical and horizontal designs for the Project were digitised in the model, including; cuttings, embankments, tunnel portals 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.

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.

The Interim Guideline recommends noise levels are 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 1,350 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 stumps or a traditional Queenslander property construction. 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 allowed calculation of railway noise with a more direct line of sight between the rails and the receptor facades and represents a conservative approach to modelled noise levels.

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

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 calculate noise emissions from the operation of rollingstock, the model applied the Nordic Rail Traffic Noise Prediction Method (Kilde 130) methodology[9].

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

The SoundPLAN modelling software and the Nordic prediction methodology are widely applied in Australia for the prediction of railway noise levels and are endorsed as acceptable methodologies under the DTMR guidelines.

To confirm the suitability of the noise modelling on the Queensland sections of Inland Rail, a survey of existing railway noise levels was undertaken in 2019 at discrete locations on the QR West Moreton System rail corridor. Details of the monitored railway noise levels and the noise model verification are provided in **Appendix B**.

6.1.1 Daily railway operations

To calculate the existing railway noise levels the typical daily train movements were determined for the QR West Moreton System and Interstate Line from monthly rail operations supplied by DTMR and ARTC. The adopted existing daily general freight and coal train services are detailed in **Table 19**.

Table 19 Daily train movements on the existing rail corridors

Train service	Train movements[2,3]		
	Daytime	Night-time	Total 24-hour period
QR West Moreton System near Calvert			
General freight services[1]	1	1	2
Coal services	14	10	24
Interstate line at Kagaru			
Intermodal freight services	4	2	6
Steel freight services	1	1	2
Passenger services	1	1	2

Note 1 General freight services includes services such as grain and livestock and exclude maintenance, shunting and tuition services.

Note 2 Two infrequent weekly passenger (heritage) services were excluded.

Note 3 The train movements are the total northbound and southbound rail traffic in each 24-hour period. A 50:50 distribution of traffic in the northbound and southbound directions was assumed in the noise modelling.

The calculation of railway noise from existing operations on the QR West Moreton System applied a line speed of 80 km/h for all train classes. The intermodal freight and steel freight services on the Interstate Line also adopted a constant line speed of 80 km/h with the XPT passenger services at 100 km/h.

The locomotive class and train length for the purpose of calculating the noise from existing rail services is summarised in **Table 20**. The current services on the QR West Moreton System are understood to typically have two locomotives and a consist of up to 50 wagons. This information was applied to assess a typical train length.

Table 20 Train lengths and locomotive class

Train service	No. locomotives	Total locomotive length	Length of wagons	Total train length
QR West Moreton System				
General freight services[1] (NR class)	2	44 m	850 m	894 m
Coal services[1] (82 class)	2	36 m	850 m	886 m
Interstate line at Kagaru				
Intermodal freight services (NR class)	2	44 m	1,214 m	1,258 m
Steel freight services (NR class)	2	44 m	894 m	938 m
Passenger services (XPT)	-	-	-	167 m

Note 1 The NR class locomotives have been adopted to represent the range of locomotives operating on the existing QR network.

6.1.2 Future daily train movements with Inland Rail

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 (2026) and the design year (2040). The daily train movements associated with the Project included the following principles:

- Daily train numbers include the existing freight and coal services that will be accommodated on the Project.
- The future number of coal services changes from existing railway operations as the future coal trains are anticipated to be longer which would reduce the number of existing daily services.
- 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 the northbound and southbound directions.
- 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 21** for project opening in year 2026.

Table 21 Daily train movements on the Project (year 2026)

Train service	Train movements		
	Daytime	Night-time	Total 24-hour period
Year 2026 project commencement			
Inland Rail Express	2	2	4
Inland Rail Superfreighter	5	3	8
Toowoomba Export Container freight	1	0	1
Narrabri Export Container freight	1	1	2
Queensland grain, Narrabri to Fisherman Island	1	1	2
Queensland cotton	0	1	1
Queensland grain services	4	1	5
SEQ Livestock	1	1	2
Coal services (including 1 from Rosewood)	7	9	16
Ebenezer IMEX (from Rosewood)	1	0	1
Daily totals year 2026 project commencement	**23**	**19**	**42**

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

The daily train movements detailed in **Table 22** are for the design year (year 2040).

Table 22 Daily train movements on the Project (year 2040)

Train service	Train movements		
	Daytime	Night-time	Total 24-hour period
Year 2040 project commencement			
Inland Rail Express	2	2	4
Inland Rail Superfreighter	8	3	11
Toowoomba Export Container freight	1	0	1
Narrabri Export Container freight	1	1	2
Queensland grain, Narrabri to Fisherman Island	1	1	2
Queensland cotton	0	1	1
Queensland grain services	5	1	6
SEQ Livestock	1	1	2
Coal services (including 1 from Rosewood)	9	12	21
Ebenezer IMEX (from Rosewood)	1	0	1
Daily totals year 2040	**29**	**22**	**51**

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

6.2 Operational railway noise model inputs

6.2.1 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 is related to the noise emission, with higher notch settings generally causing higher noise levels.

The noise prediction modelling applied the following principles for the assessment of locomotive notch settings:

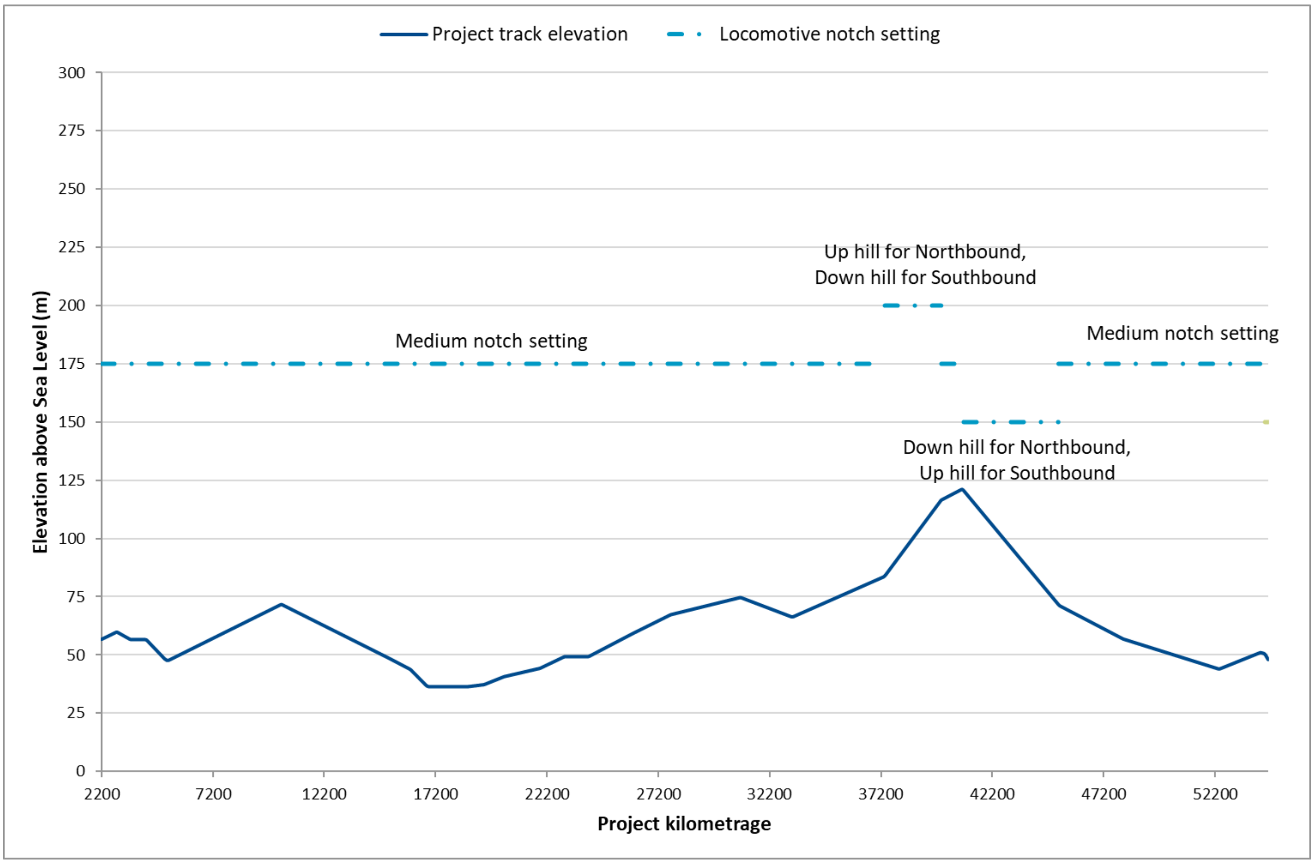
- When operating on relatively flat or moderate gradients the locomotive would generally be operated at a medium notch setting (notch settings 3, 4 or 5).
- On downhill gradient track trains are often in low notch setting or can use dynamic braking where the traction motors that drive each locomotive 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 the use dynamic braking will be determined by the driver. 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 10**.

Figure 10 Track elevation and locomotive notch setting



6.2.2 Train speeds

The trains on the Project are required to operate at their designated line speed of up to 115 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 included a modelled 8 percent 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 loops 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 11** (northbound) and **Figure 12** (southbound). The acute changes in train speed are associated with entry to and exit from each crossing loop.

Figure 11 Example track speed profiles, Calvert to Kagaru direction

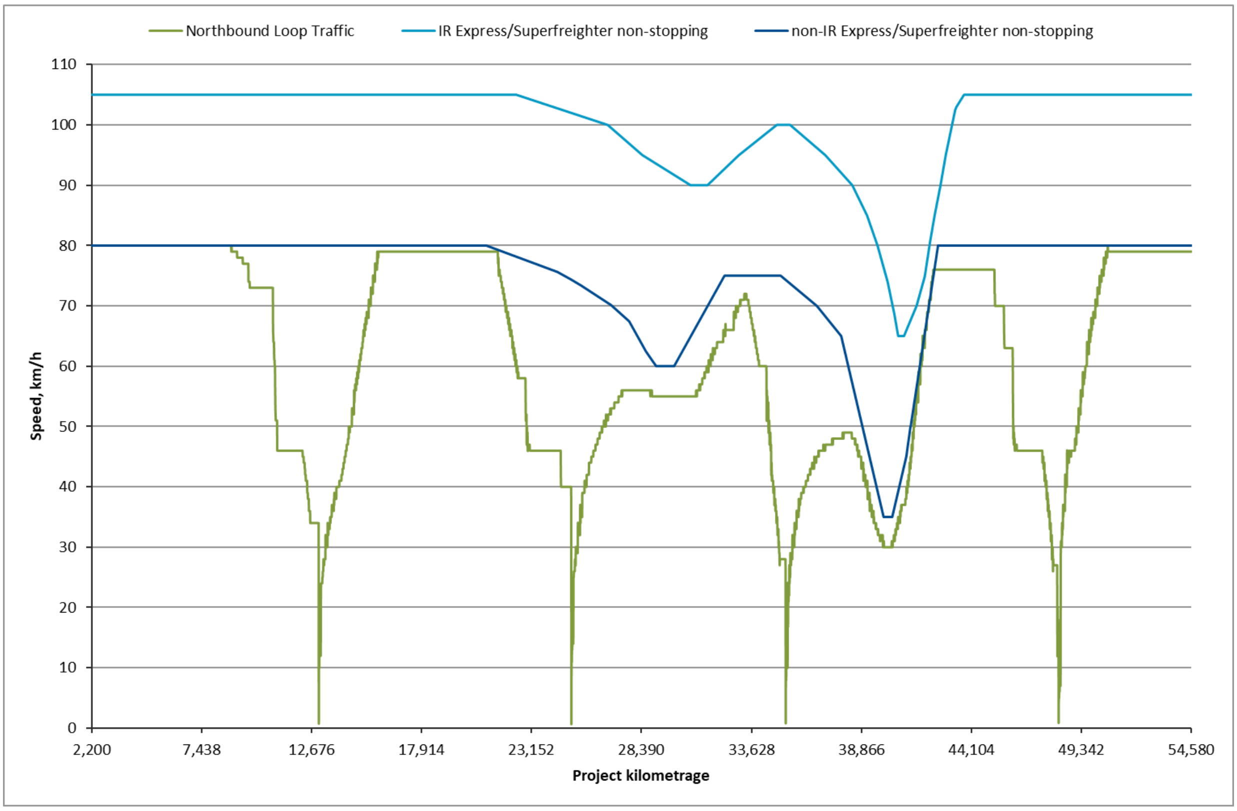
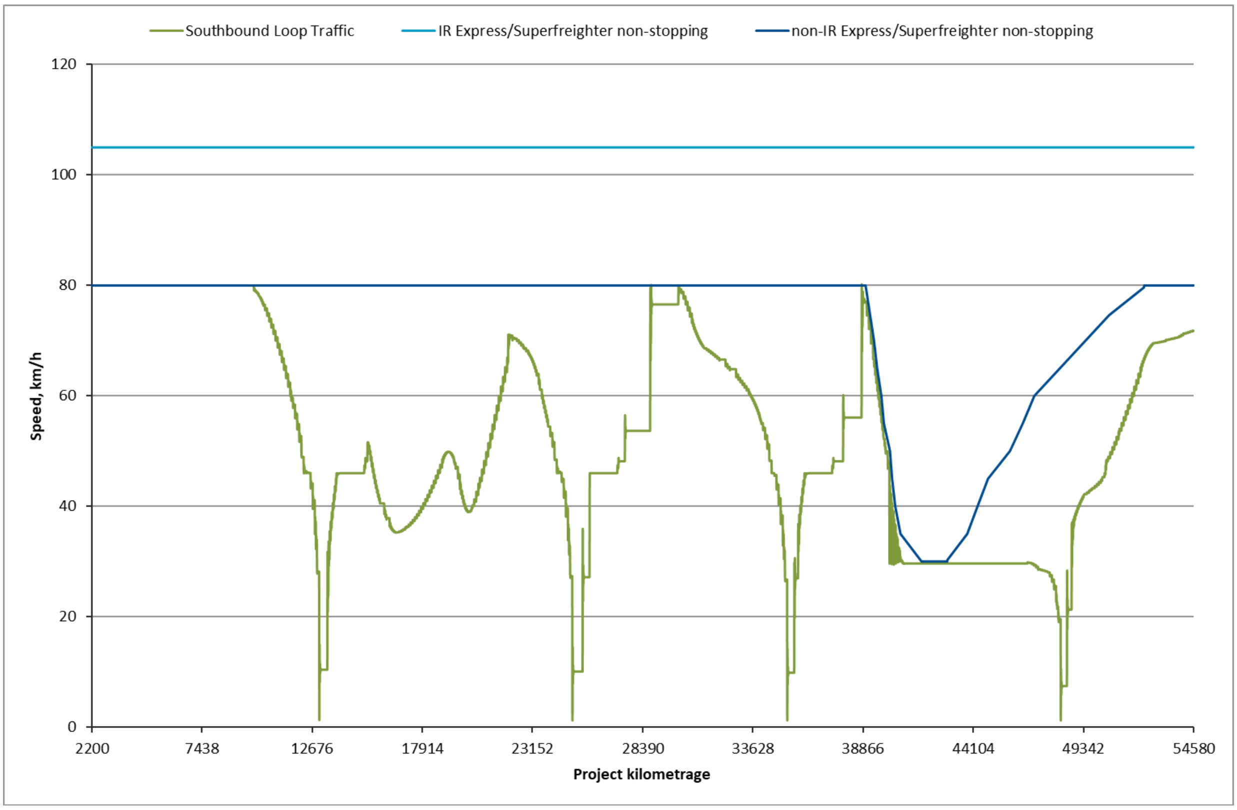


Figure 12 Example track speed profiles, Kagaru to Calvert direction



6.2.3 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 23**. The train data was derived from ARTC's forecast daily train movements on Inland Rail.

Table 23 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
Toowoomba Export Container freight (82 class)	2	44 m	600 m	644 m
Narrabri Export Containers (82 class)	2	44 m	580 m	624 m
Ebenezer IMEX (NR Class)	3	66 m	870 m	886 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
Queensland grain services (PR22L class)	3	54 m	560 m	614 m
SEQ Livestock (PR22L class)	3	54 m	800 m	854 m
Coal services[1] (PR22L class)	3	54 m	920 m	974 m

Note 1 Train operations for all coal services were supplied to SLR with the same train length and locomotive class.

6.2.4 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. For railway infrastructure projects in Queensland, the rollingstock noise emissions are often referenced from a noise emission database maintained by QR. The database is specific to rollingstock operating on existing rail networks in Queensland and does not provide the noise emission data for all the rollingstock proposed for the Project and Inland Rail.

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[10] and Australian Standard AS 2377[11].

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.

Inland Rail may utilise the PR22L class locomotives on the rail network. 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 in Australia.

[10] International Standards, 2013. ISO 3095 Railway applications – Acoustics – Measurement of noise emitted by railbound vehicles.
[11] Australian Standards, 2002. AS 2377 Acoustics – Methods for the measurement of railbound vehicle noise.

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

- The Sound Exposure Level (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 set 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.

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.

The source noise emission levels for each rollingstock category are detailed in **Table 24**. Inspection of the source noise emission levels indicates that the adopted noise emission levels for the noise modelling are generally higher (more conservative) than the QR database.

Table 24 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.

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.

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 anomalies.

6.2.5 Consideration of double-stack container freight

The Project will potentially 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.

ISO 3095 provided 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 reduce 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 is provided in **Appendix C** and the survey determined the following:

- Consistent with ISO 3095, individual wagons with double-stacked containers have LAeq 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 24**.

6.2.6 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.

Track with tight-radius curves can experience curving noise as the train wheels negotiation the turn, typically this can occur where the curve radius is under 500 m.

Recent studies have shown that elevated noise emissions from curved track vary and are dependent on a number of site specific features such as; the age and conditions of the track, track fastening type and the type and speed of the trains using the line. In cases where the curve radius is closer to 300 m or less, the curving noise levels during a train passby have been observed to be up to 21 dBA or more when compared to straight track conditions.

The Project designs includes a potentially tight radius curved track for the rail spurs where the Project alignment connects with the QR West Moreton System. The radius of the rail spurs are approximately 485 m, which is near the upper range of track radius the potential for curving noise.

A curving noise correction of +3 dBA was applied to both the SEL and L_{Amax} noise emissions based on the Project installing a lubrication system to the newly constructed rail spurs. The lubrication system would likely be installed as part of a strategy to control potential curving noise from the new infrastructure should the design of the rail spurs have a track radius of less than 500 m.

The railway noise level corrections in **Table 25** 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 25 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
QR West Moreton System tie-in tracks (radius 485 m)	+3	+3

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

6.2.7 Teviot Range Tunnel

To navigate the undulating topography, the Teviot Range Tunnel is to be located from east of Washpool to the west of Woolooman. The surface rail line enters and departs the tunnel through tunnel portals at the east and west extents of the tunnel alignment.

To enable the surface track to access the tunnel at formation level, each tunnel portal includes a constructed cutting within the existing terrain and forms part of civil earthworks design for the Project.

The train movements within the tunnel are not a source of airborne noise as the noise emissions are contained within the tunnel structure. The tunnel portals are a potential source of airborne railway noise from the direct noise from the train passby and the contribution of the build-up of reverberant (reflected) sound from within the tunnel. As such, the airborne noise from the tunnel portals can be a combination of both the direct and reverberant sound during the train passbys.

For the purpose of noise prediction modelling, the noise emission for the train passbys at the tunnel portals is adopted as the total sound radiating equally over the cross-sectional area of each tunnel portal. The sound power level of each tunnel portal is determined from; the total train movements accessing the tunnel in each daytime and night-time period, the dimensions of the tunnel portal and the acoustic (absorptive) properties of the tunnel material.

The tunnel portal object within the SoundPLAN noise prediction model was utilised to calculate the railway noise from the trains at the tunnel portals during the daytime and night-time rail operations. The adopted sound power levels for a semi-circular tunnel portal opening are summarised in **Table 26**.

Table 26 Estimated tunnel portal sound power level emissions

Railway operations	Estimated source sound power level, dBA	
	LAeq,T	LAmax
Year 2026 daytime	105	110
Year 2026 night-time	104	110
Year 2040 daytime	106	110
Year 2040 night-time	105	110

Analysis of the SoundPLAN noise model determined an additional 10 dBA contribution to the in-tunnel railway noise, to account for the potential reverberant build-up of sound, increased the overall railway noise outside the tunnel by approximately 1 dBA at 200 m from the tunnel portal where there was a direct, unobscured line of sight to the tunnel portal.

Because the nearest sensitive receptors are located more than 400 m from the tunnel portals, and each tunnel portal will be in a constructed cutting, correction factors for the in-tunnel reverberant sound were not included in the presented results. The railway noise levels at the nearest sensitive receptors to the tunnel are expected to be dominated by the railway noise from the train passbys on the track outside of the tunnels.

For the same reasons, a localised noise emission adjustment was not included where the ballast track outside the tunnel transitions with the slab track within the tunnel.

6.2.8 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 m above ground level was applied for the crossing alarm bells and a source height 4 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 ISO 9613-2[12] method for calculating the outdoor noise propagation was applied. The ISO 9613-2 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 27**. The noise levels were referenced from SLR's measurement of train horn and alarm bell events on existing freight corridors.

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

Table 27 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.

6.2.9 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 each 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 28**.

Table 28 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 2026	6	5	6	5
Year 2040	7	6	7	6

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 with a source noise emission height of 4 m above the residual ground level. 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 source noise emission levels for rolling noise, including potential wagon bunching, were referenced from noise measurements of the existing coal and freight train movements in Queensland. 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. A source noise emission height of 1 m above residual ground level was adopted for the bunching noise sources.

The noise prediction modelling for the crossing loops applied the ISO 9613-2 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 29**.

Table 29 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

7 Airborne railway noise levels – Existing railway operations

The railway noise levels were predicted for the existing railway operations on the QR West Moreton System and Interstate Line. The predictions were undertaken for the sections of the existing rail corridor within the study area. For the purpose of assessment, the railway operations on the main line track were assumed to be the primary source of noise.

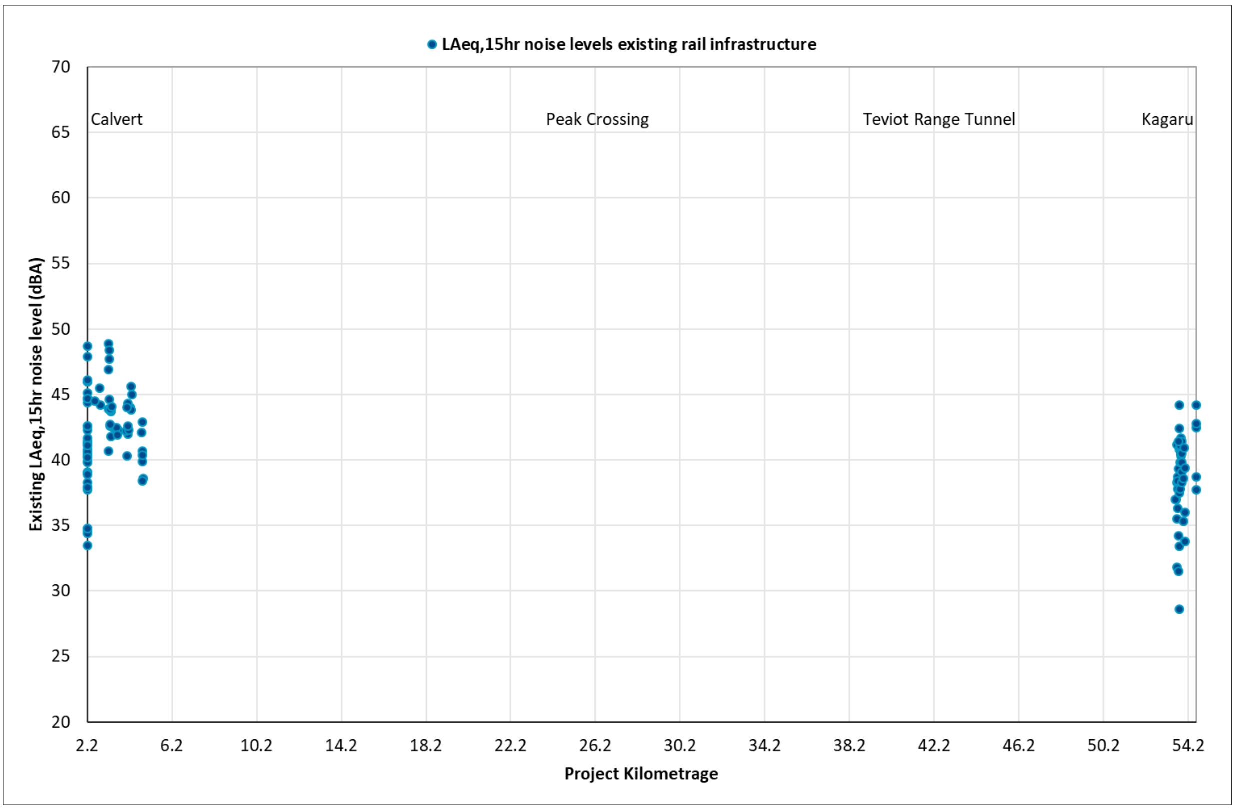
The ToR does not require an assessment of the noise levels from existing rail operations. The existing railway noise levels were predicted to assess the potential changes in railway noise where the Project is upgrading the existing railway infrastructure.

At time of the assessment, there were no known approved plans to enhance or upgrade the daily rail operations on the QR West Moreton System and the Interstate Line. The predicted noise levels were applied as the railway noise levels from existing railway infrastructure for the year 2026 and year 2040 assessment scenarios.

The predicted existing railway noise at the identified sensitive receptors is presented in **Figure 13** for the daytime $L_{Aeq(15hour)}$ noise levels and in **Figure 14** for the night-time $L_{Aeq(9hour)}$ noise levels. The predicted maximum (L_{Amax}) railway noise levels are presented in **Figure 15**.

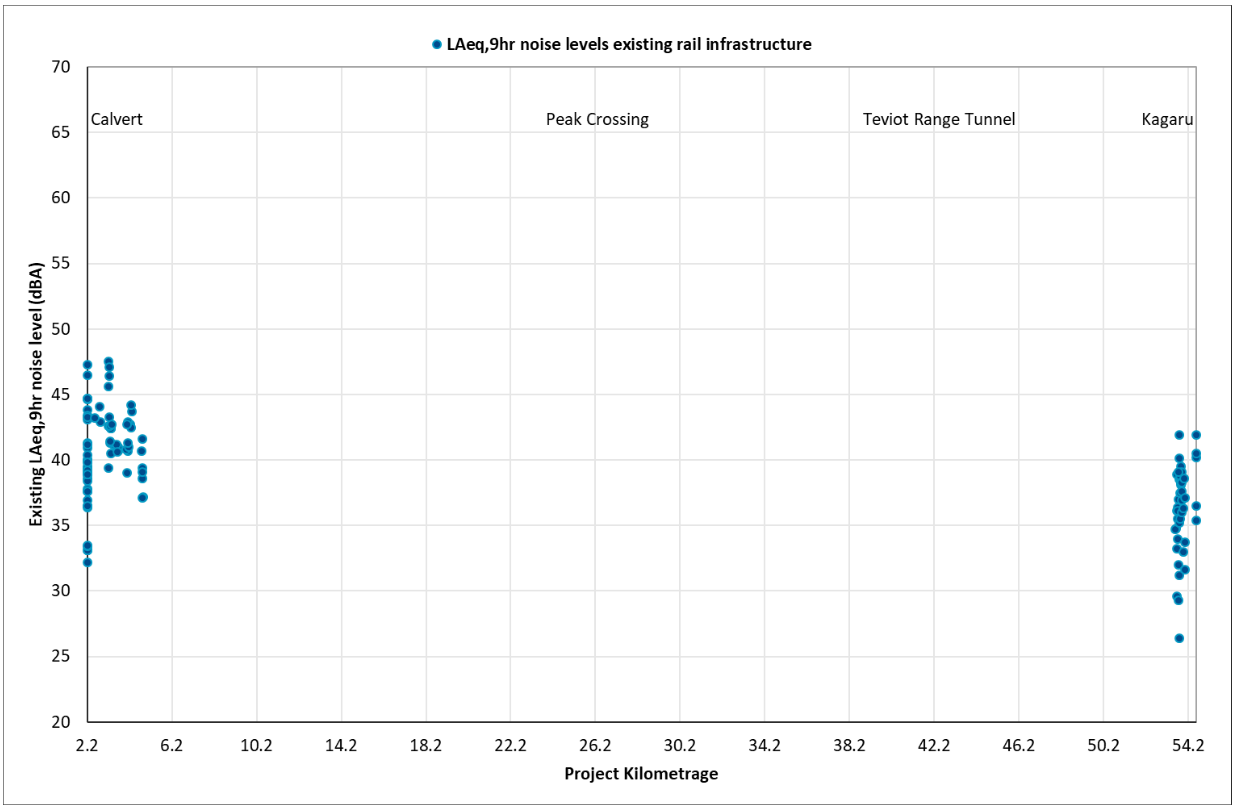
The noise levels are presented at the sensitive receptors within 750 m of the QR West Moreton System and Interstate Line, as per the adopted approach to assess railway noise at the sections where the Project is upgrading existing railway infrastructure.

Figure 13 Predicted existing daytime $L_{Aeq(15hour)}$ railway noise levels



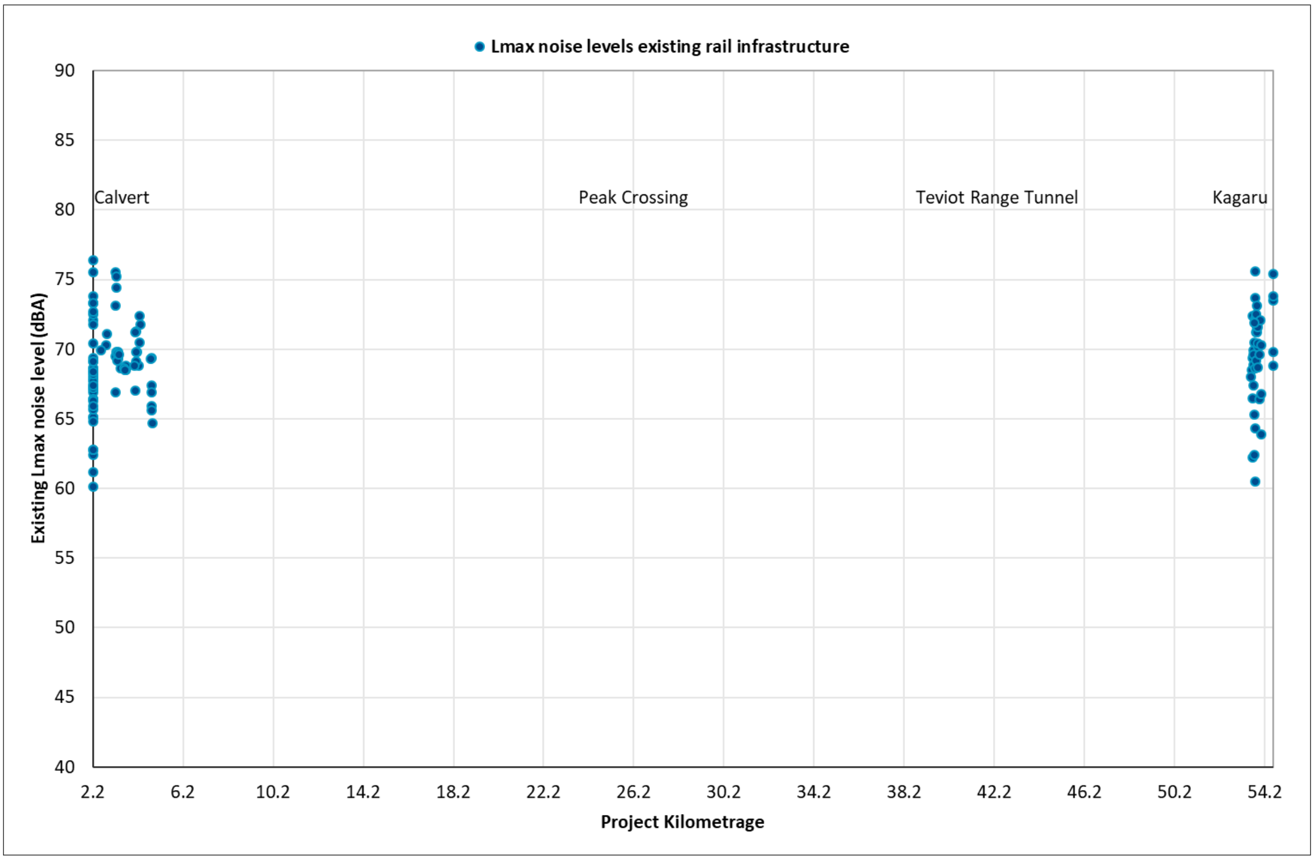
Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

Figure 14 Predicted existing night-time $L_{Aeq(9hour)}$ noise levels



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

Figure 15 Predicted existing maximum railway noise levels



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

8 Airborne railway noise levels – Project opening 2026

8.1 Overview

The predicted daytime and night-time railway noise levels for the commencement of railway operations in year 2026 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 likely be investigated.

The noise criteria implemented by ARTC on the Project are more stringent than the noise criteria from the DTMR Policy and the Interim Guideline. On this basis, where the predicted railway noise levels at the sensitive receptors meet the ARTC noise criteria, the noise levels would also be expected to meet the noise criteria from the guidelines referenced in the ToR.

8.2 Railway noise levels at sensitive receptors

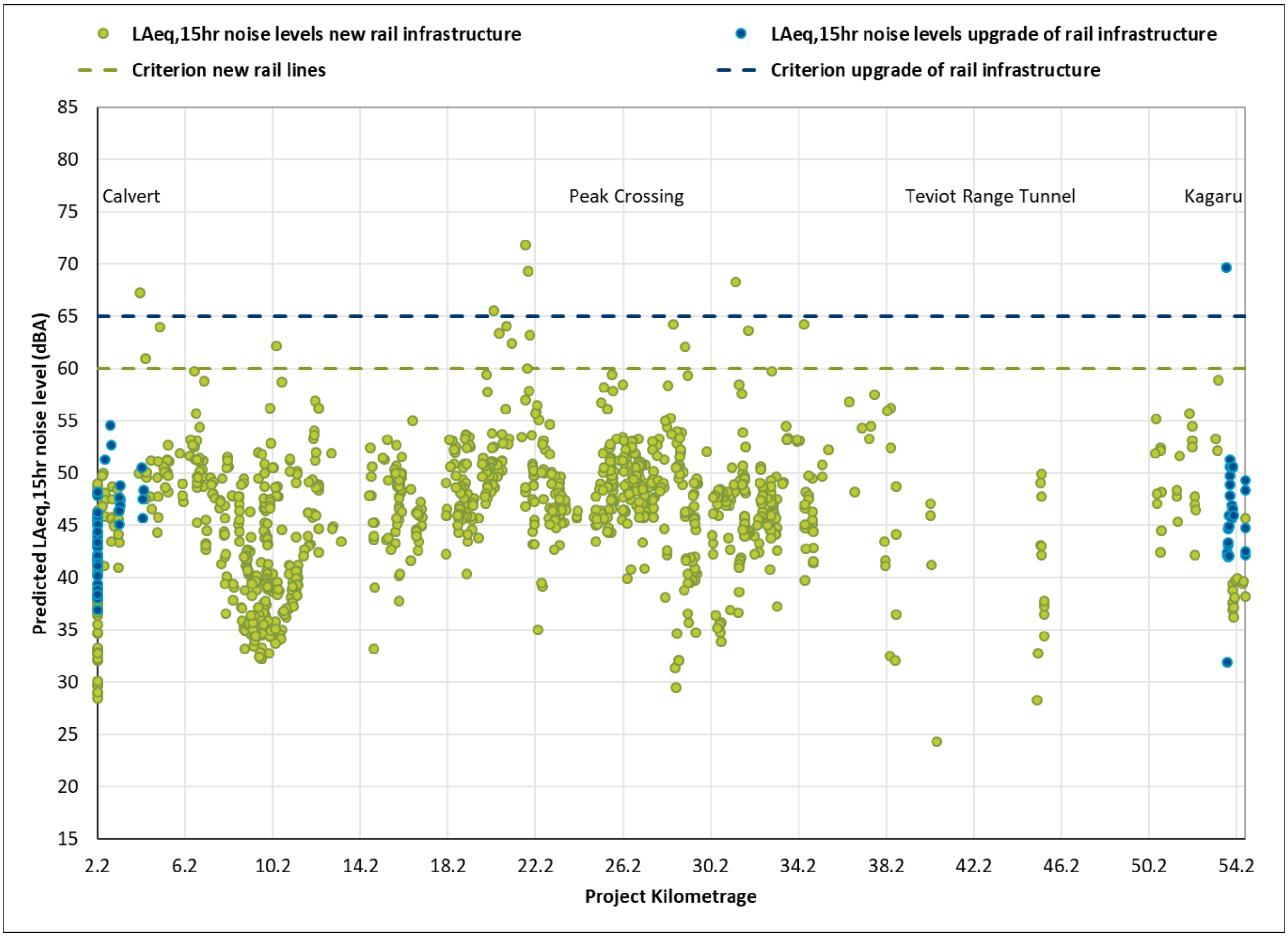
8.2.1 Daytime railway noise levels

The predicted daytime $L_{Aeq(15hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 16**. The predicted railway noise levels are presented where the Project is a new rail corridor and the sections where the Project is upgrading the existing railway infrastructure.

The predicted daytime railway noise levels meet 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 1 to 12 dBA above the noise criterion at up to 16 sensitive receptors.

In the areas where the Project will be an upgrade of existing railway infrastructure, the predicted daytime noise levels meet the $L_{Aeq(15hour)}$ 65 dBA noise criterion at the residential receptors with the exception of one receptor at Kagaru, where noise levels are 5 dBA above the daytime L_{Aeq} noise criterion.

Figure 16 Predicted daytime $L_{Aeq(15hour)}$ railway noise levels (Year 2026)

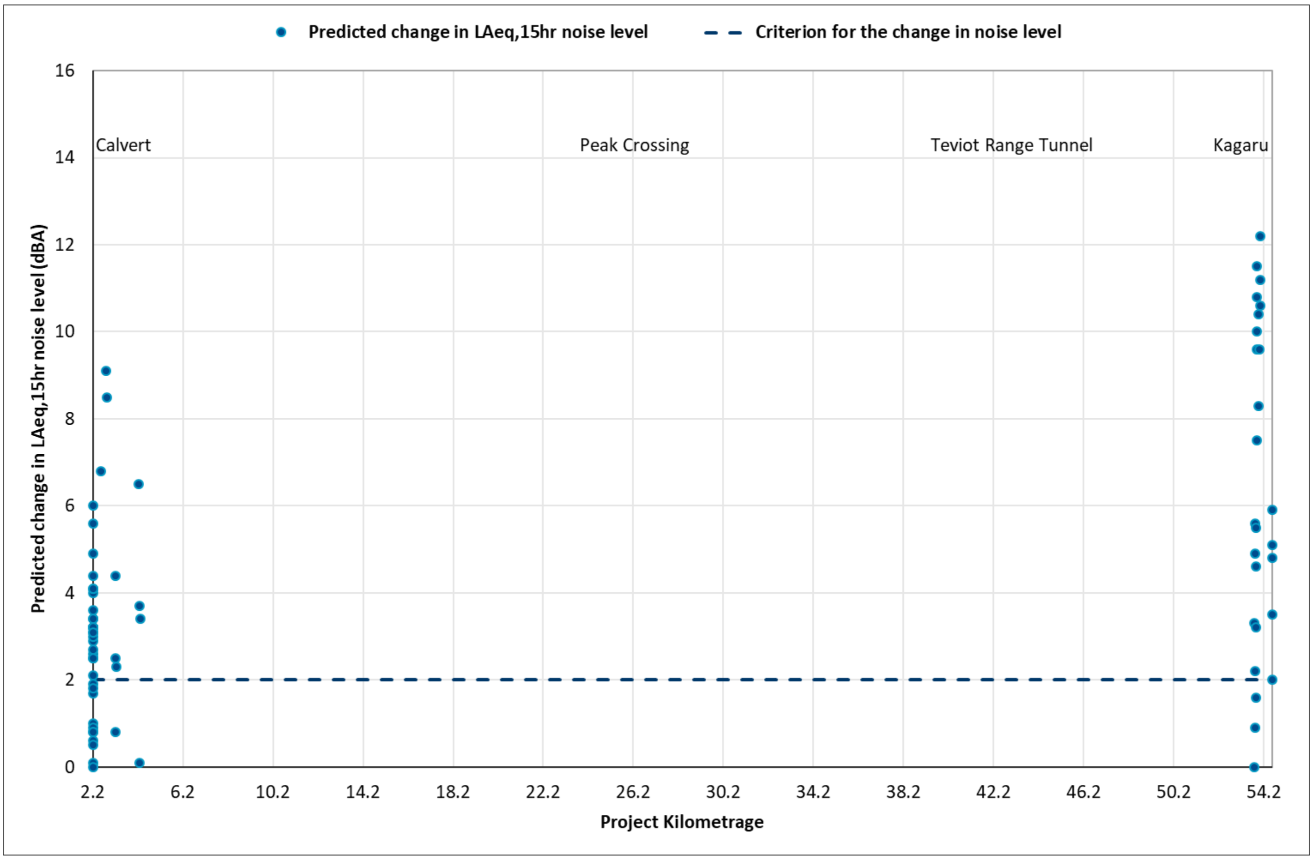


Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

Where the Project is upgrading existing railway infrastructure the noise criteria require the assessment to consider both the overall railway noise levels (**Figure 16**) and the potential change in railway noise with the railway operations introduced by the Project.

The predicted change in daytime $L_{Aeq(15hour)}$ railway noise levels with the Project are presented in **Figure 17**.

Figure 17 Predicted change from existing daytime $L_{Aeq(15hour)}$ railway noise levels (Year 2026)



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

There is an expected increase in existing daytime rail noise levels where the introduction of the Project increases the rail traffic and/or the future rail infrastructure is closer to sensitive receptors than the existing railway infrastructure.

Where railway noise levels are predicted to have a potential perceptible increase in rail noise, for example a change by 3 dBA or more, these residential receptors are located where the Project ties into the QR West Moreton System and where the Project connects with the Interstate Line near Kagaru. At these locations the transition to the new rail corridor brings railway infrastructure closer to existing properties.

Whilst the increase in daytime railway noise levels is more than the $L_{Aeq(15hour)}$ 2 dBA change in noise level criterion at some receptors, this does not trigger the investigation of noise mitigation if the overall railway noise criterion is met. At the one receptor triggering the overall daytime noise criterion for upgrading existing railway infrastructure, the railway noise level also triggers the change in L_{Aeq} rail noise criterion.

Overall, the daytime $L_{Aeq(15hour)}$ railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at up to 17 residential receptors.

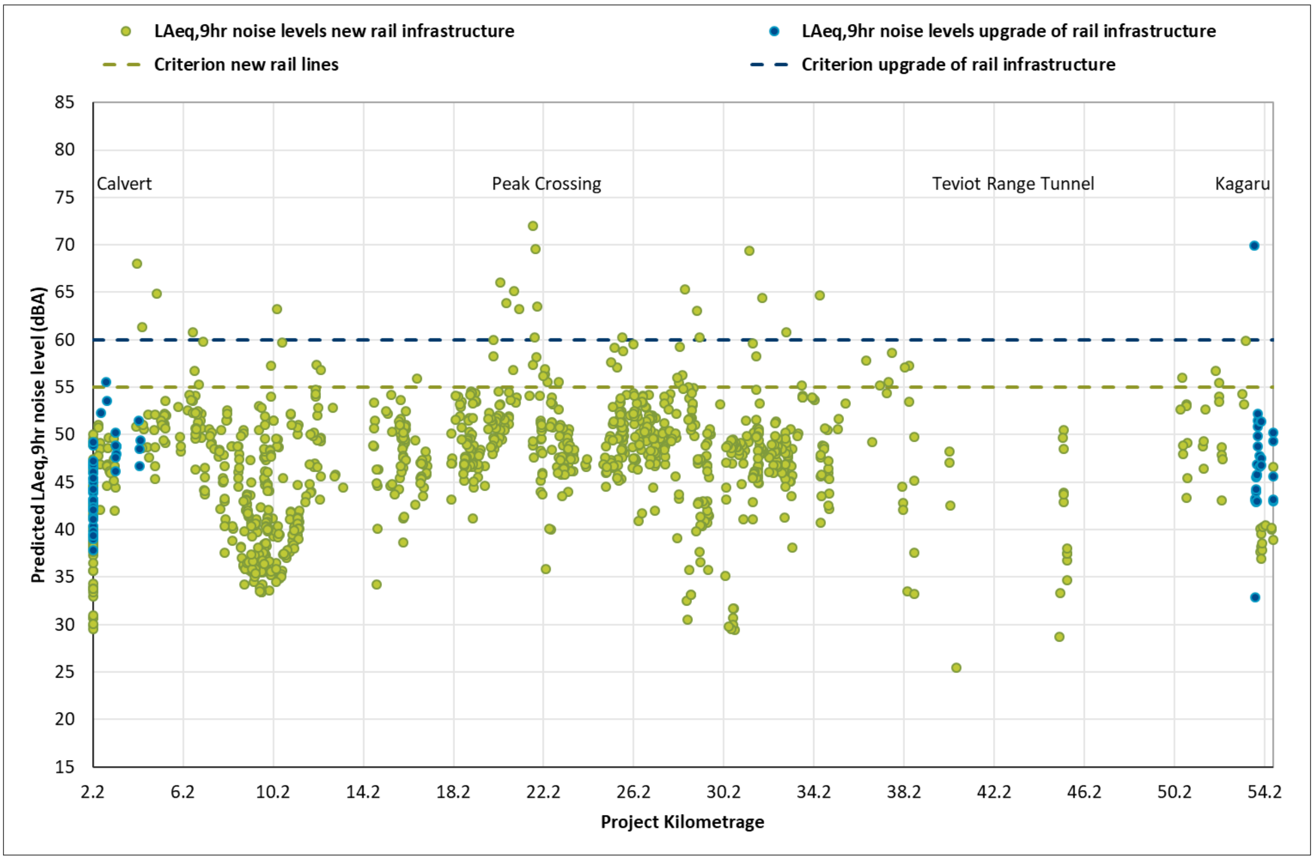
8.2.2 Night-time railway noise levels

The predicted night-time $L_{Aeq(9hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 18**. The predicted railway noise levels are presented where the Project is a new rail corridor and the sections where the Project is upgrading the existing railway infrastructure.

The predicted night-time railway noise levels meet the $L_{Aeq(9hour)}$ 55 dBA noise criterion at the majority of the residential receptors adjacent to the sections of new rail corridor. At up to 58 residential receptors the predicted noise levels are 1 to 17 dBA above the night-time L_{Aeq} noise criterion.

In the areas where the Project will be upgrading existing railway infrastructure, the predicted night-time noise levels meet the $L_{Aeq(9hour)}$ 60 dBA noise criterion at the residential receptors with the exception of one receptor where noise levels are up to 10 dBA above the night-time L_{Aeq} criterion.

Figure 18 Predicted night-time $L_{Aeq(9hour)}$ railway noise levels (Year 2026)



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

The predicted change in night-time $L_{Aeq(9hour)}$ railway noise levels with the Project are presented in **Figure 19**.

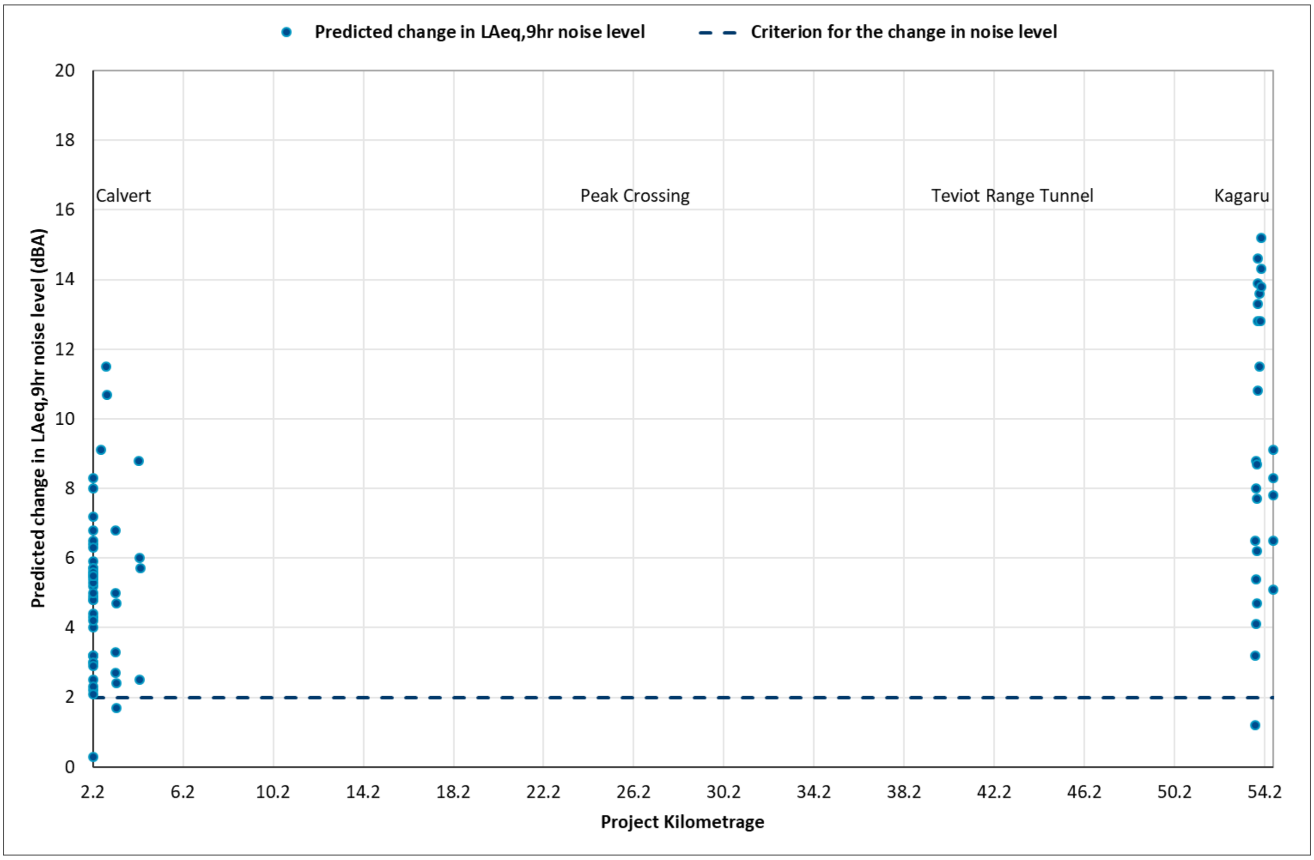
Consistent with the predicted daytime noise levels, there is an expected increase in railway noise levels where the Project increases the rail traffic and, in some cases, brings the rail corridors in closer proximity to the receptors.

Whilst the increase in night-time railway noise levels is more than the $L_{Aeq(9hour)}$ 2 dBA change in noise level criterion at some receptors, this does not trigger the investigation of noise mitigation if the overall railway noise criterion is met.

At the one residential receptor triggering the overall night-time noise criterion for upgrading existing railway infrastructure, the railway noise levels also trigger the change in L_{Aeq} rail noise criterion.

Overall, the night-time $L_{Aeq(9hour)}$ railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at up to 59 residential receptors.

Figure 19 Predicted change from existing night-time $L_{Aeq(9hour)}$ railway noise levels (Year 2026)



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

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 L_{Amax} noise levels were generally consistent at the sensitive receptors, with a variation of less than 1 dBA.

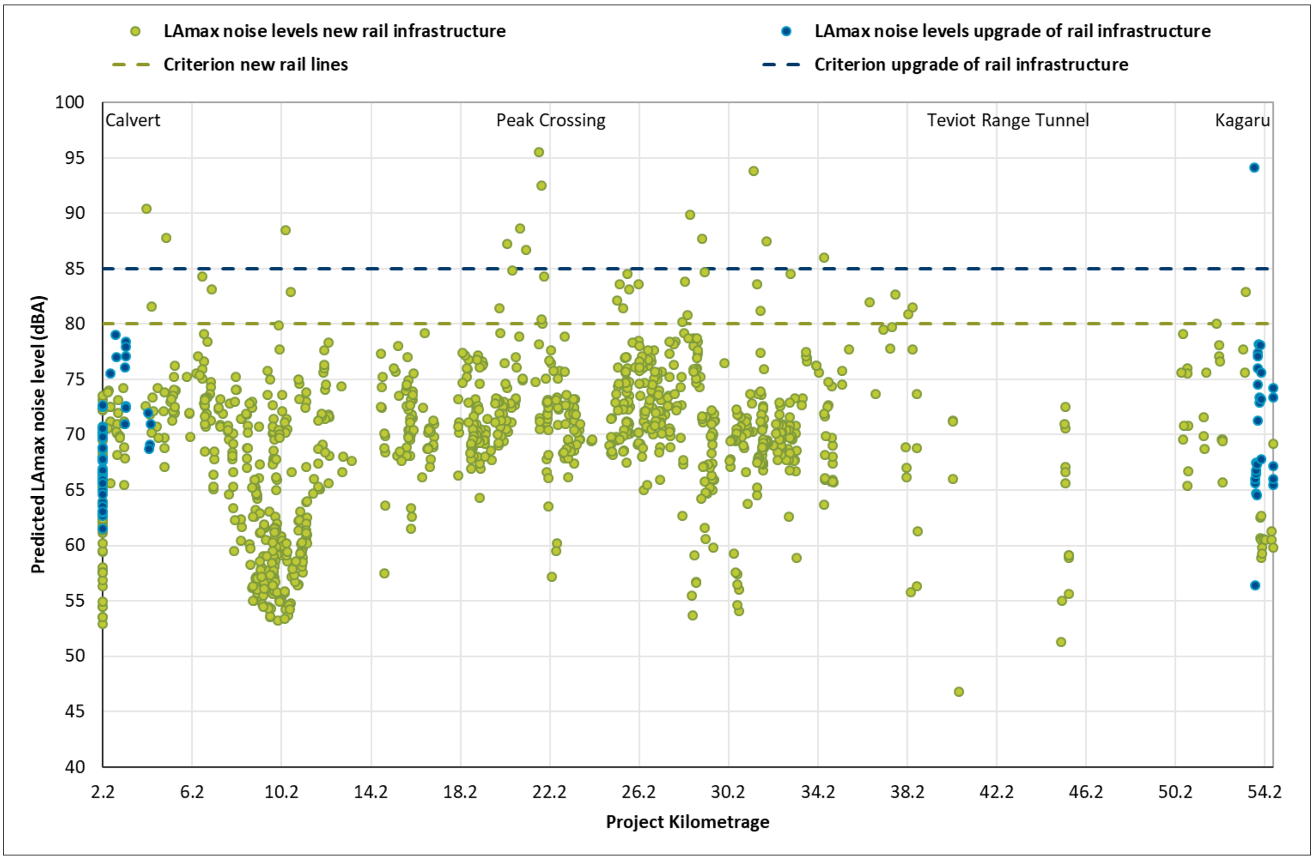
Consequently, the higher predicted L_{Amax} noise level was adopted to assess the maximum noise levels in both the daytime and night-time periods.

The predicted daytime and night-time maximum (L_{Amax}) railway noise levels at the residential receptors are presented in **Figure 20**.

The predicted railway noise levels met the L_{Amax} 80 dBA noise criterion at the majority of the residential receptors adjacent to the sections of new rail corridor. At up to 37 residential receptors the predicted noise levels are 1 to 16 dBA above the L_{Amax} noise criterion.

In the areas where the Project will be an upgrade of existing railway infrastructure, the predicted noise levels met the LAmax 85 dBA noise criterion at the residential receptors, with the exception of one residential receptor where noise levels are up to 9 dBA above the criterion.

Figure 20 Predicted daytime and night-time maximum railway noise levels (Year 2026)



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

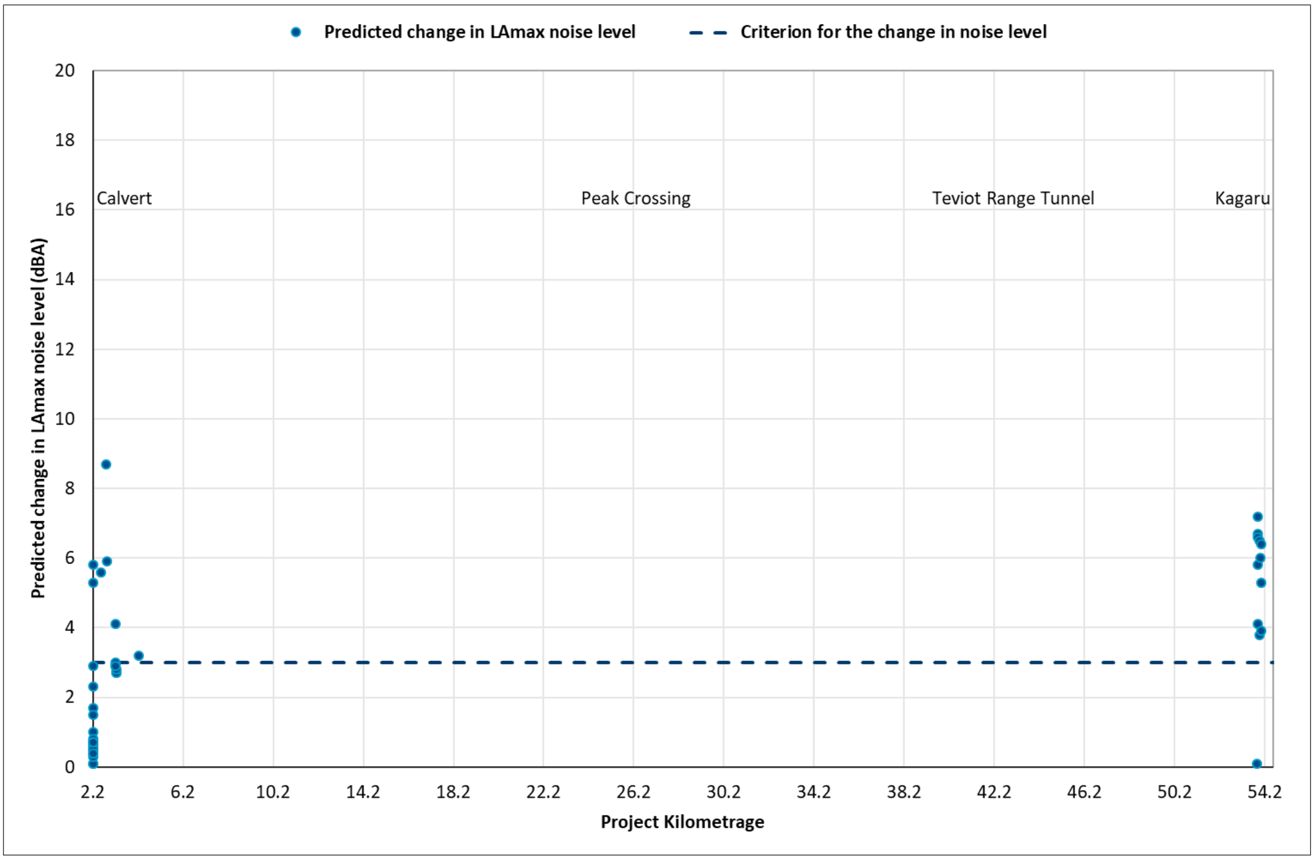
The predicted change in LAmax railway noise levels with the Project are presented in **Figure 21**. There is an expected increase in railway noise levels where the Project increases the rail traffic and, in some cases, brings the rail corridors in closer proximity to the receptors.

Whilst the increase in night-time railway noise levels is more than the LAmax 3 dBA change in noise level criterion at some receptors, this does not trigger the investigation of noise mitigation if the overall railway noise criterion is met.

At the one residential receptors triggering the overall LAmax noise criterion for upgrading existing railway infrastructure, the railway noise levels also trigger the change in LAmax rail noise criterion.

Overall, the LAmax railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at 38 residential receptors.

Figure 21 Predicted change from existing night-time L_{Amax} railway noise levels (Year 2026)



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

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.

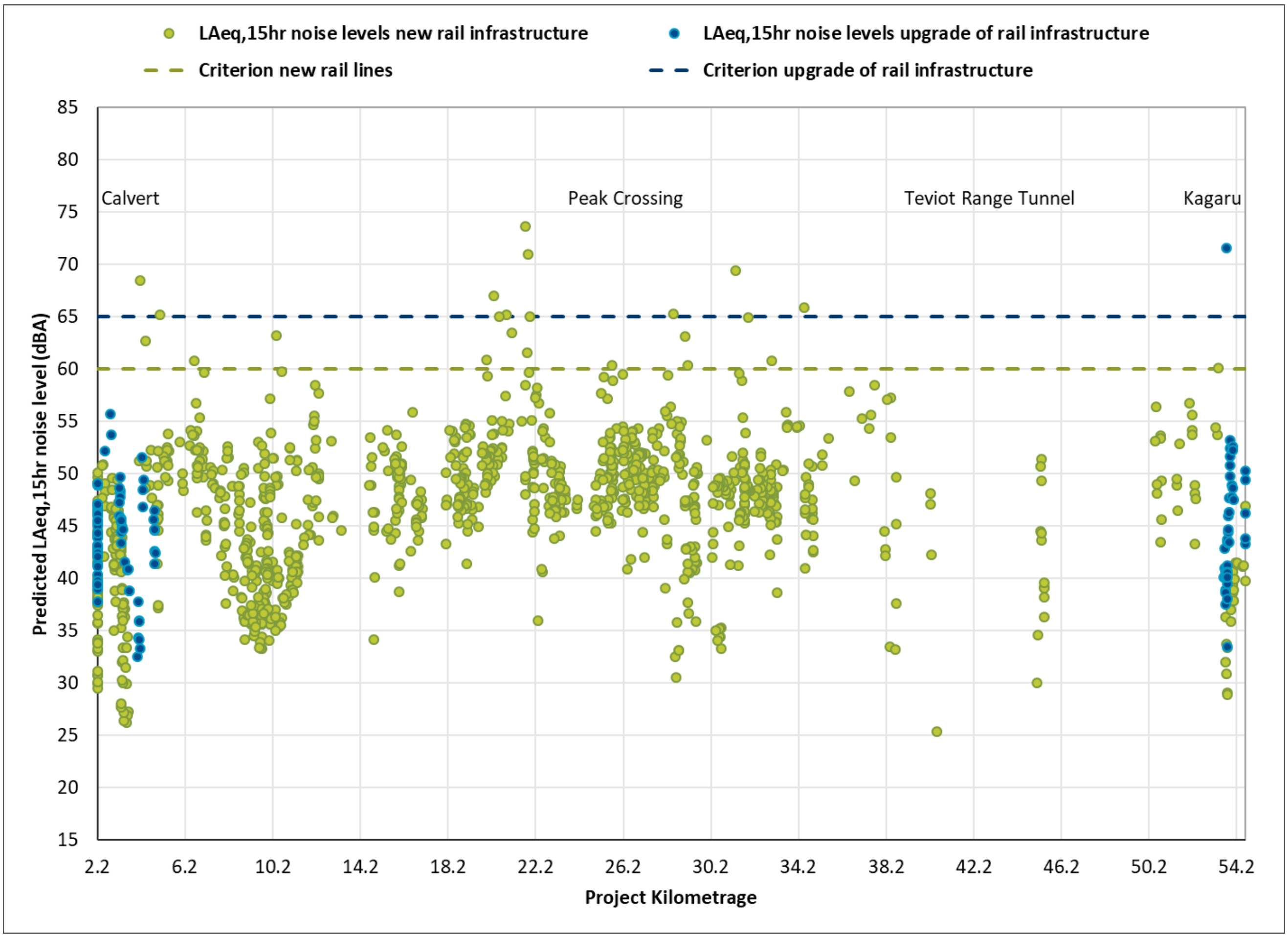
The assessment of railway noise levels for the design year 2040 has been undertaken consistent with the approach for the assessment of railway noise at the project opening in 2026 (refer **Section 8.1**).

9.2 Railway noise levels at sensitive receptors

9.2.1 Daytime railway noise levels

The predicted daytime $L_{Aeq(15hour)}$ railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 22**. The predicted railway noise levels are presented where the Project is a new rail corridor and the sections where the Project is upgrading the existing railway infrastructure.

Figure 22 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.

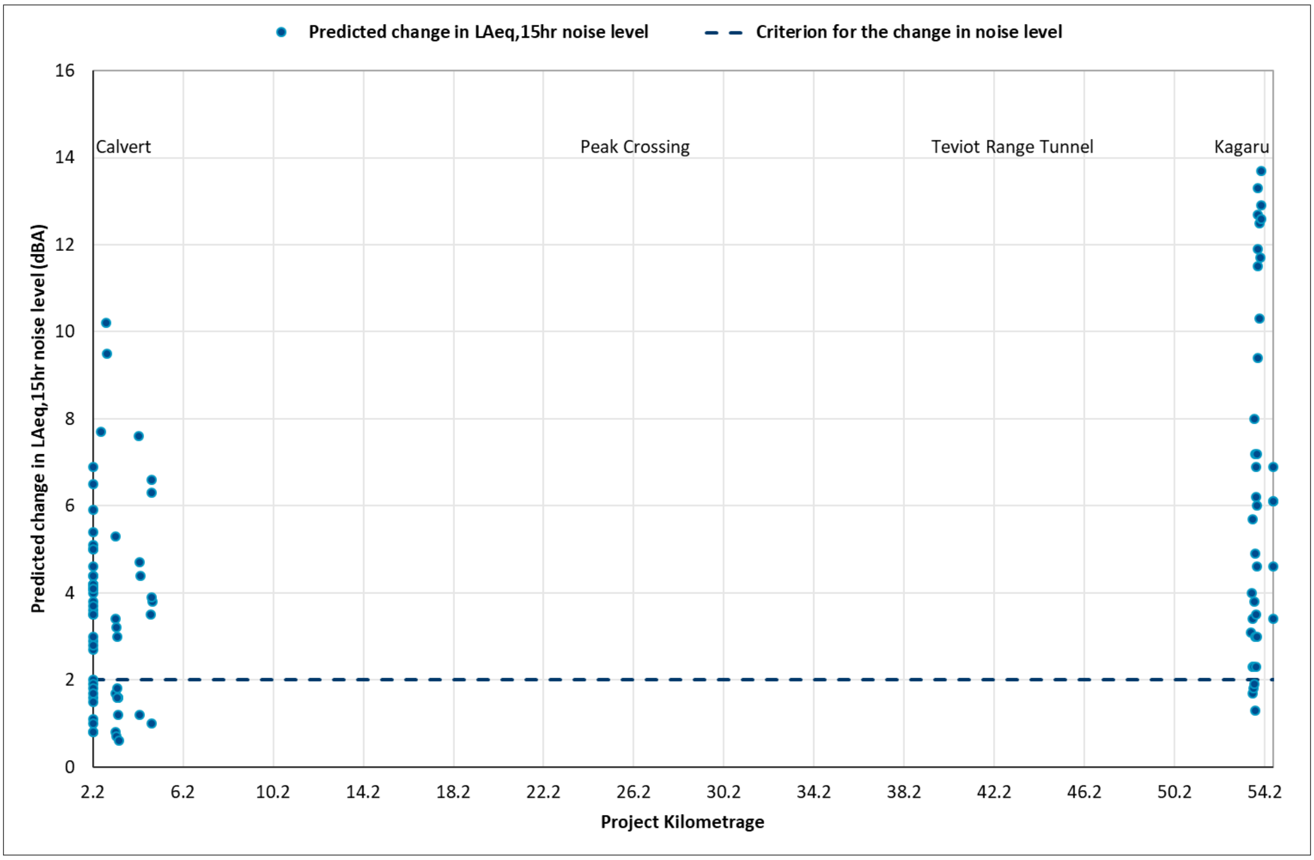
The predicted daytime railway noise levels meet the $L_{Aeq(15hour)}$ 60 dBA noise criterion at the majority of sensitive receptors adjacent to the sections of new rail corridor. The predicted daytime $L_{Aeq(15hour)}$ railway noise levels are 1 to 14 dBA above the noise criterion at up to 20 sensitive receptors.

In the areas where the Project will be upgrading existing railway infrastructure, the predicted daytime noise levels met the $L_{Aeq(15hour)}$ 65 dBA noise criterion at the residential receptors with the exception of one receptor where noise levels are up to 7 dBA above the daytime L_{Aeq} noise criterion.

Where the Project is an upgrade of existing railway infrastructure the noise criteria require the assessment to consider both the overall railway noise levels (refer **Figure 22**) and the potential change in railway noise with the railway operations introduced by the Project.

The predicted change in daytime $L_{Aeq(15hour)}$ railway noise levels with the Project are presented in **Figure 23**.

Figure 23 Predicted change from existing daytime LAeq(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.

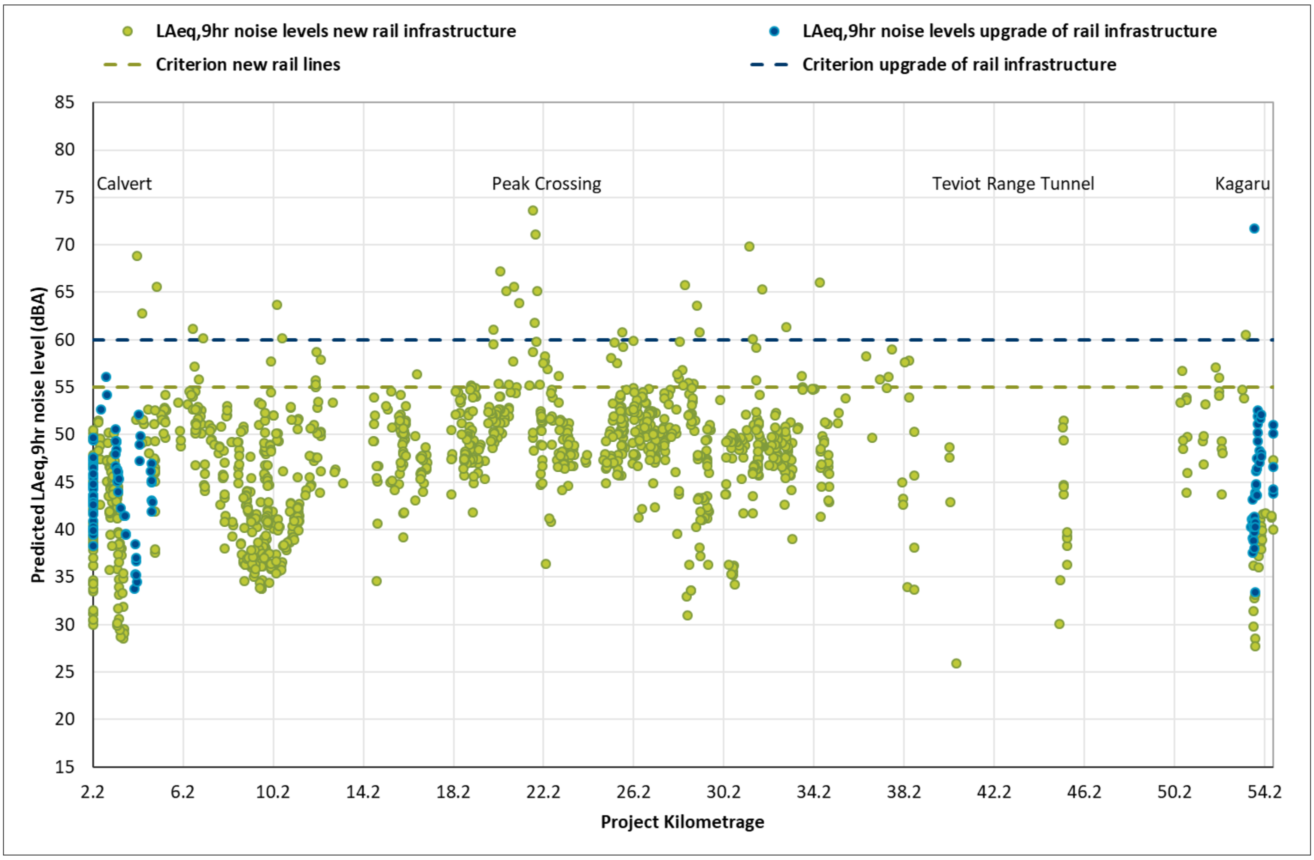
Whilst the increase in daytime railway noise levels is more than the LAeq(15hour) 2 dBA change in noise level criterion at some receptors, this does not trigger the investigation of noise mitigation if the overall railway noise criterion is met. At the one receptor triggering the overall daytime noise criterion, the railway noise levels also trigger the change in LAeq rail noise criterion.

Overall, the daytime LAeq(15hour) railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at up to 21 residential receptors.

9.2.2 Night-time railway noise levels

The predicted night-time LAeq(9hour) railway noise levels at the identified noise sensitive residential receptors are presented in **Figure 24**. The predicted railway noise levels are presented where the Project is a new rail corridor and the sections where the Project is upgrading the existing railway infrastructure.

Figure 24 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 railway noise levels meet the $L_{Aeq(9hour)}$ 55 dBA noise criterion at the majority of the residential receptors adjacent to the sections of new rail corridor. At up to 64 residential receptors the predicted noise levels are 1 to 19 dBA above the night-time L_{Aeq} noise criterion.

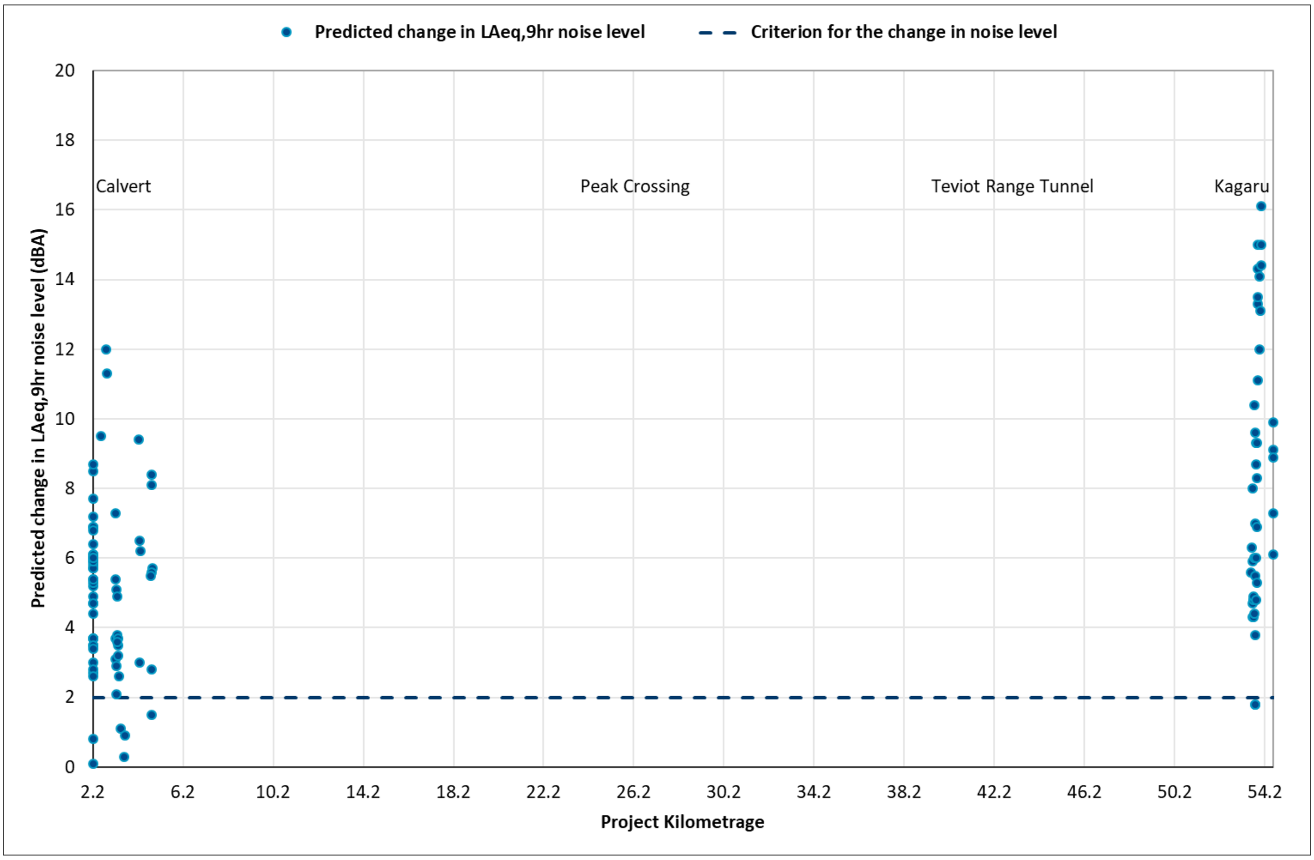
In the areas where the Project will be an upgrade of existing railway infrastructure, the predicted night-time noise levels meet the $L_{Aeq(9hour)}$ 60 dBA noise criterion at the residential receptors with the exception of one receptor where noise levels are up to 12 dBA above the night-time L_{Aeq} noise criterion.

The predicted change in night-time $L_{Aeq(9hour)}$ railway noise levels with the Project are presented in **Figure 25**.

At the one residential receptor triggering the overall night-time noise criterion for the upgrade of existing railway infrastructure, the railway noise levels also trigger the change in L_{Aeq} rail noise criterion.

Overall, the night-time $L_{Aeq(9hour)}$ railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at up to 65 residential receptors.

Figure 25 Predicted change from existing 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.

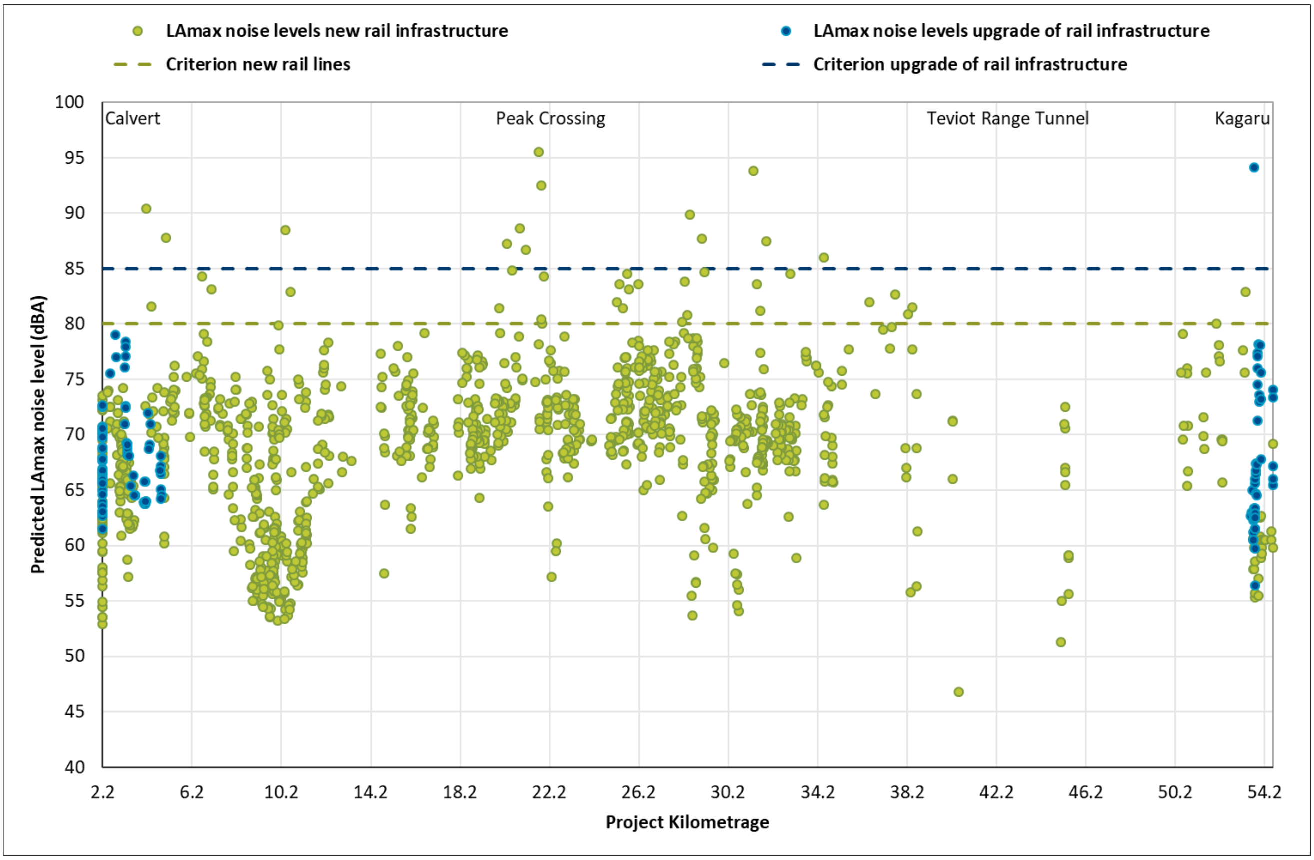
9.2.3 Daytime and night-time maximum railway noise levels

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 presented in **Figure 26**.

The predicted railway noise levels meet the L_{Amax} 80 dBA noise criterion at the majority of the residential receptors adjacent to the sections of new rail corridor. At up to 37 residential receptors the predicted noise levels are 1 to 16 dBA above the L_{Amax} noise criterion.

Figure 26 Predicted daytime and night-time LAmax railway noise levels (Year 2040)



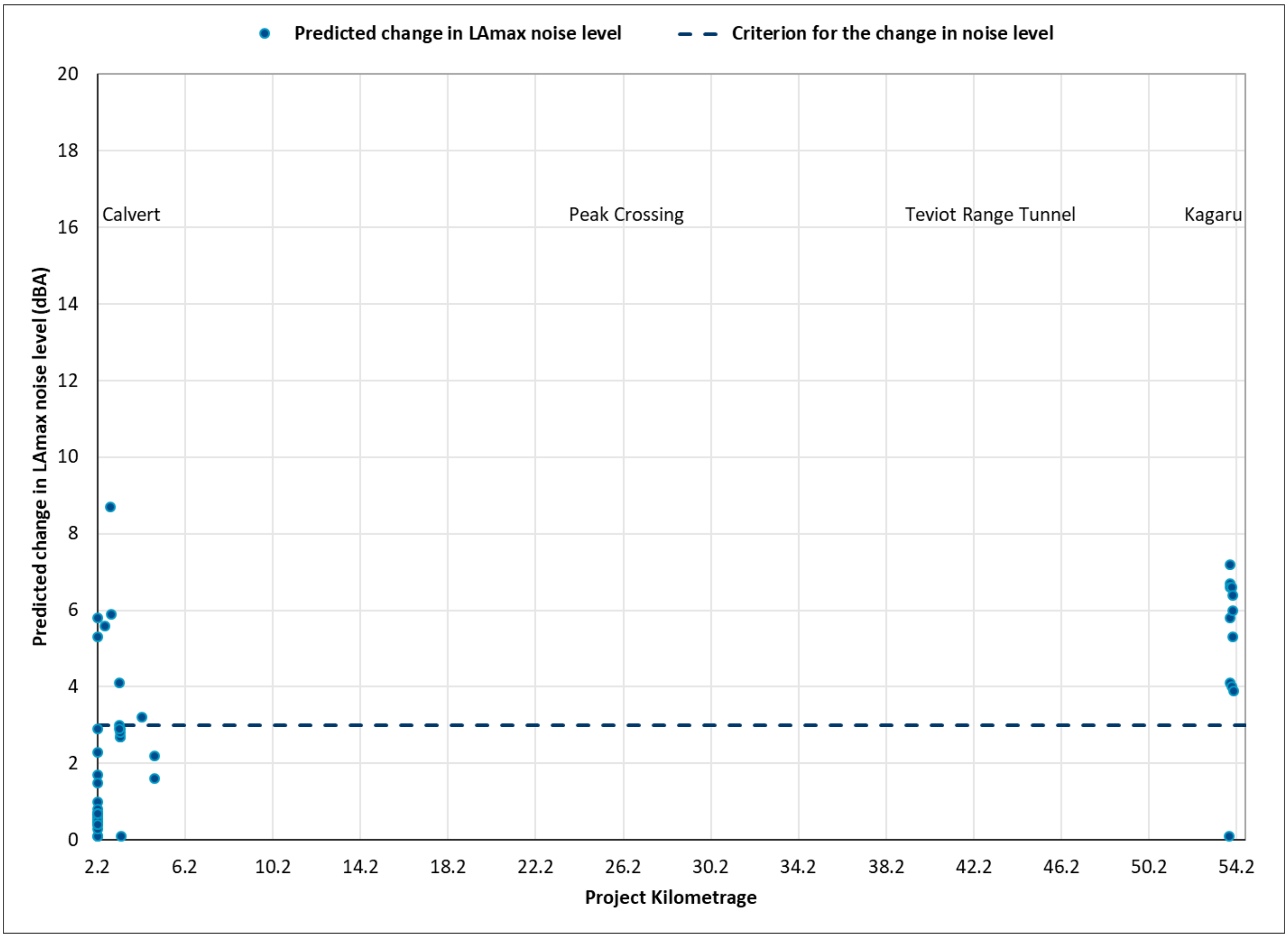
Note Some receptors are in the same location and the markers in the above scatter plot represent more than one receptor.

In the areas where the Project will be an upgrade of existing railway infrastructure, the predicted noise levels meet the LAmax 85 dBA noise criterion at the residential receptors with the exception of one receptor where noise levels are up to 9 dBA above the maximum noise criterion.

The predicted change in LAmax railway noise levels with the Project are presented in **Figure 27**. At the residential receptor triggering the overall LAmax noise criterion for the upgrade of existing railway infrastructure, the railway noise levels also trigger the change in LAmax rail noise criterion.

Overall, the LAmax railway noise levels with the Project are predicted to trigger the investigation of noise mitigation measures at up to 38 residential receptors.

Figure 27 Predicted change from existing night-time LAmax 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.

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 ARTC will investigate reasonable and practicable mitigation measures to reduce noise levels and mitigate potential impacts.

The review of noise mitigation is triggered at up to 59 individual sensitive receptors for the commencement of railway operations 2026 and up to 65 individual sensitive receptors (six additional receptors) for the design year operations in year 2040.

The sensitive receptors where noise levels were predicted to be above the night-time noise criteria are detailed in **Table 30** 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 28**.

The investigation of mitigation was most frequently triggered by the night-time $L_{Aeq(9hour)}$ 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.

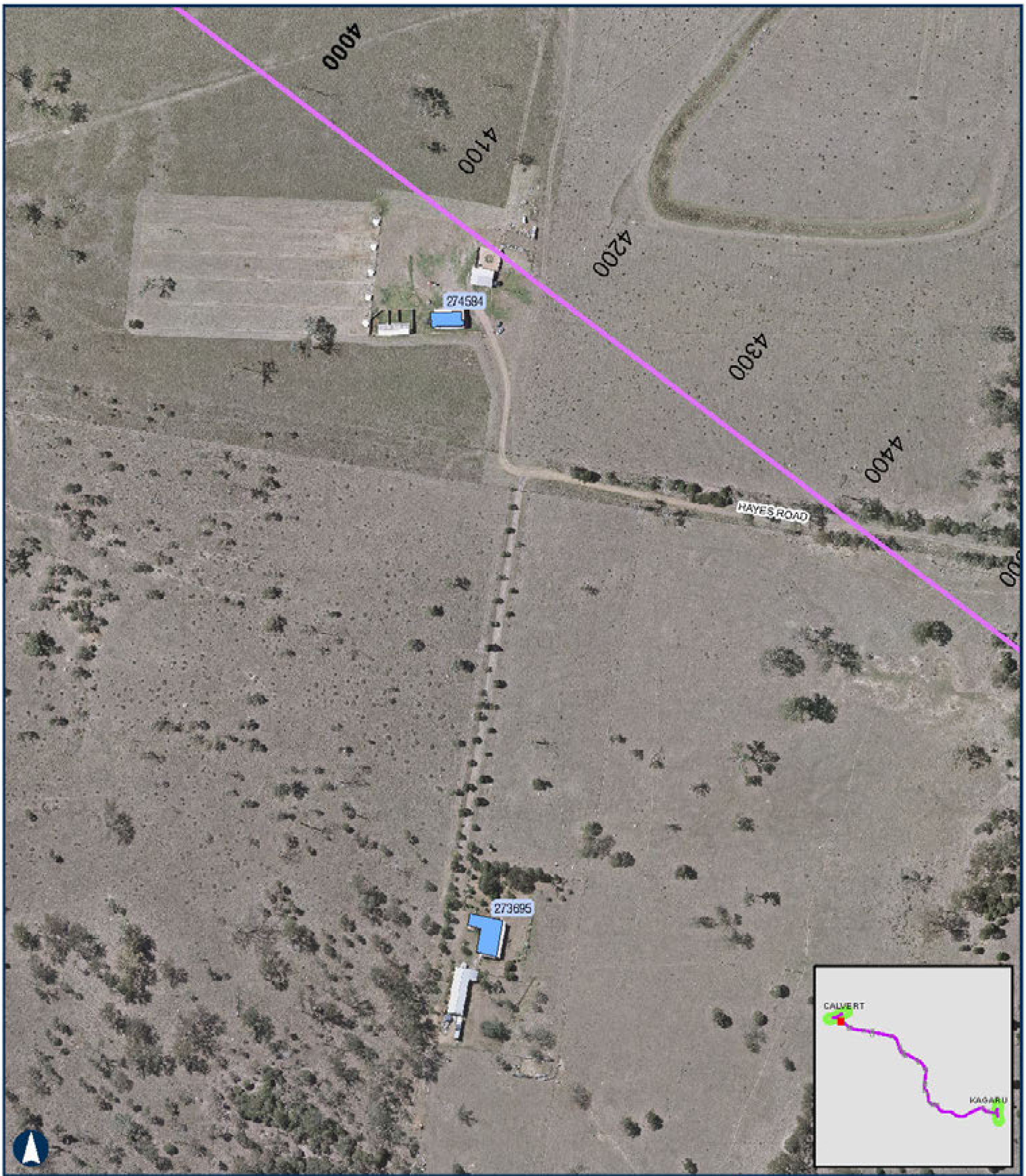
Table 30 Sensitive receptors triggering the investigation of noise mitigation

SLR ID	Railway noise levels – main line and crossing loops, dBA		Railway noise – level crossings, dBA		Overall night-time railway noise levels[2], dBA	
	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax
256637	**60**	**83**	52	73	**61**	**83**
256650[1]	**62**	**94**	**71**	**94**	**72**	**94**
256661	**57**	80	44	64	**57**	80
256662	**56**	78	45	65	**56**	78
256793	**56**	79	49	71	**57**	79
256797	**56**	80	<30	<50	**56**	80
256832	**56**	80	34	55	**56**	80
256848	**58**	**82**	<30	<50	**58**	**82**
256876	**58**	**81**	<30	<50	**58**	**81**
256908	**59**	**83**	31	51	**59**	**83**
256911	**58**	**82**	35	56	**58**	**82**
257380	**61**	**86**	**64**	**86**	**66**	**86**
257687	54	78	52	74	**56**	78
258288	**61**	**85**	50	71	**61**	**85**
259276	**64**	**88**	**60**	**82**	**65**	**88**
259451	54	77	51	73	**56**	77
259541	**58**	**81**	55	76	**59**	**81**
259806	**60**	**84**	48	69	**60**	**84**
259959	**70**	**94**	48	69	**70**	**94**
260751	**61**	**85**	<30	<50	**61**	**85**
260785	**64**	**88**	<30	<50	**64**	**88**
260863	**56**	79	<30	<50	**56**	79
260950	**57**	**81**	<30	<50	**57**	**81**
260994	**66**	**90**	<30	<50	**66**	**90**
261010	**56**	79	<30	<50	**56**	79
261041	**60**	**84**	<30	<50	**60**	**84**
261048	**56**	80	<30	<50	**56**	80
261951	**60**	**84**	<30	<50	**60**	**84**
262146	**59**	**83**	<30	<50	**59**	**83**
262240	**61**	**85**	<30	<50	**61**	**85**
262746	**58**	**81**	<30	<50	**58**	**81**
262785	**60**	**84**	<30	<50	**60**	**84**
262909	**58**	**82**	<30	<50	**58**	**82**
263433	**56**	79	45	66	**56**	79
263538	54	77	**56**	76	**58**	77
263606	53	76	55	75	**57**	76

SLR ID	Railway noise levels – main line and crossing loops, dBA		Railway noise – level crossings, dBA		Overall night-time railway noise levels[2], dBA	
	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax	LAeq(9hour)	LAmax
263634	53	78	**57**	78	**58**	78
263798	54	80	**59**	80	**60**	80
264005	**66**	**93**	**70**	**93**	**71**	**93**
264159	**59**	**84**	**64**	**84**	**65**	**84**
264269	**57**	80	**60**	80	**62**	80
264283	53	77	55	76	**57**	77
264340	55	78	**56**	76	**59**	78
264366	**63**	**87**	55	76	**64**	**87**
264487	**65**	**89**	**56**	76	**66**	**89**
264543	**56**	79	53	74	**58**	79
264650	**62**	**85**	**63**	**85**	**65**	**85**
264801	**64**	**87**	**65**	**85**	**67**	**87**
265011	**58**	**81**	**58**	79	**61**	**81**
265035	**56**	79	**57**	78	**60**	79
266281	**56**	79	<30	<50	**56**	79
266502	54	76	52	72	**56**	76
266696	55	78	**56**	76	**59**	78
268183	**64**	**89**	44	65	**64**	**89**
268538	**60**	**83**	47	68	**60**	**83**
268681	**58**	80	41	62	**58**	80
268808	55	78	55	76	**58**	78
269156	**56**	78	38	58	**56**	78
269645	**57**	79	39	59	**57**	79
270651	**60**	**83**	35	56	**60**	**83**
271173	**61**	**84**	40	60	**61**	**84**
273122	**65**	**88**	**58**	79	**66**	**88**
273695	**58**	**82**	**61**	**82**	**63**	**82**
274584	**67**	**90**	**64**	**86**	**69**	**90**
324070	**67**	**96**	**73**	**96**	**74**	**96**

Note 1 SLR ID is a sensitive receptor within the assessment area where the Project is the upgrade of existing railway infrastructure.

Note 2 Whilst overall noise levels are presented as integers, the noise levels were assessed to one decimal place.



CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 1 of 30

100Metres

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Date: 16-Mar-2020
Author: JG

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

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FIGURE 28 - Map 2 of 30

100 Metres

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 3 of 30

100 Metres

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FIGURE 28 - Map 4 of 30

100Metres

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FIGURE 28 - Map 5 of 30

100 Metres

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FIGURE 28 - Map 6 of 30

100 Metres

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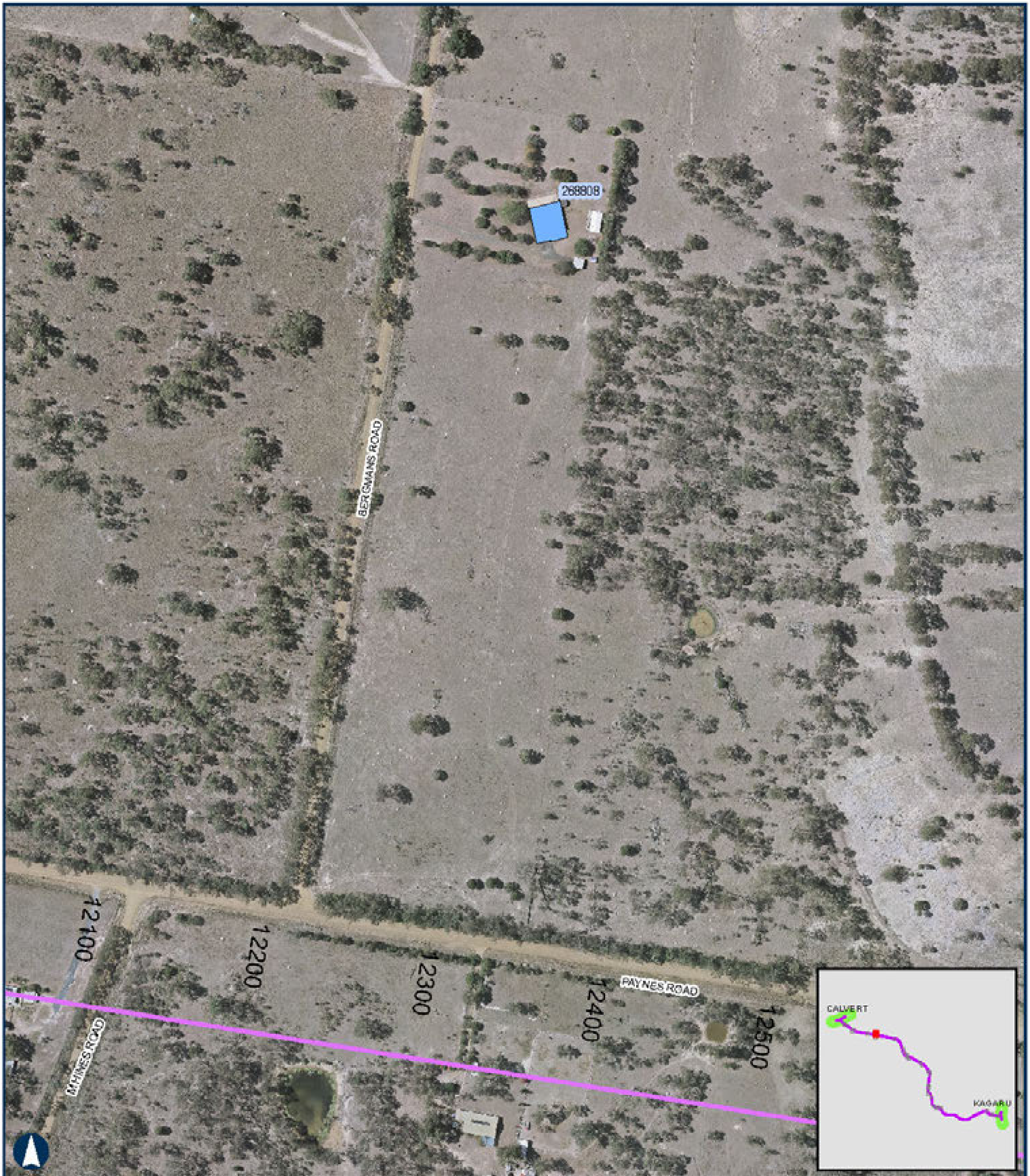

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FIGURE 28 - Map 7 of 30

100 Metres

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FIGURE 28 - Map 8 of 30

100 Metres

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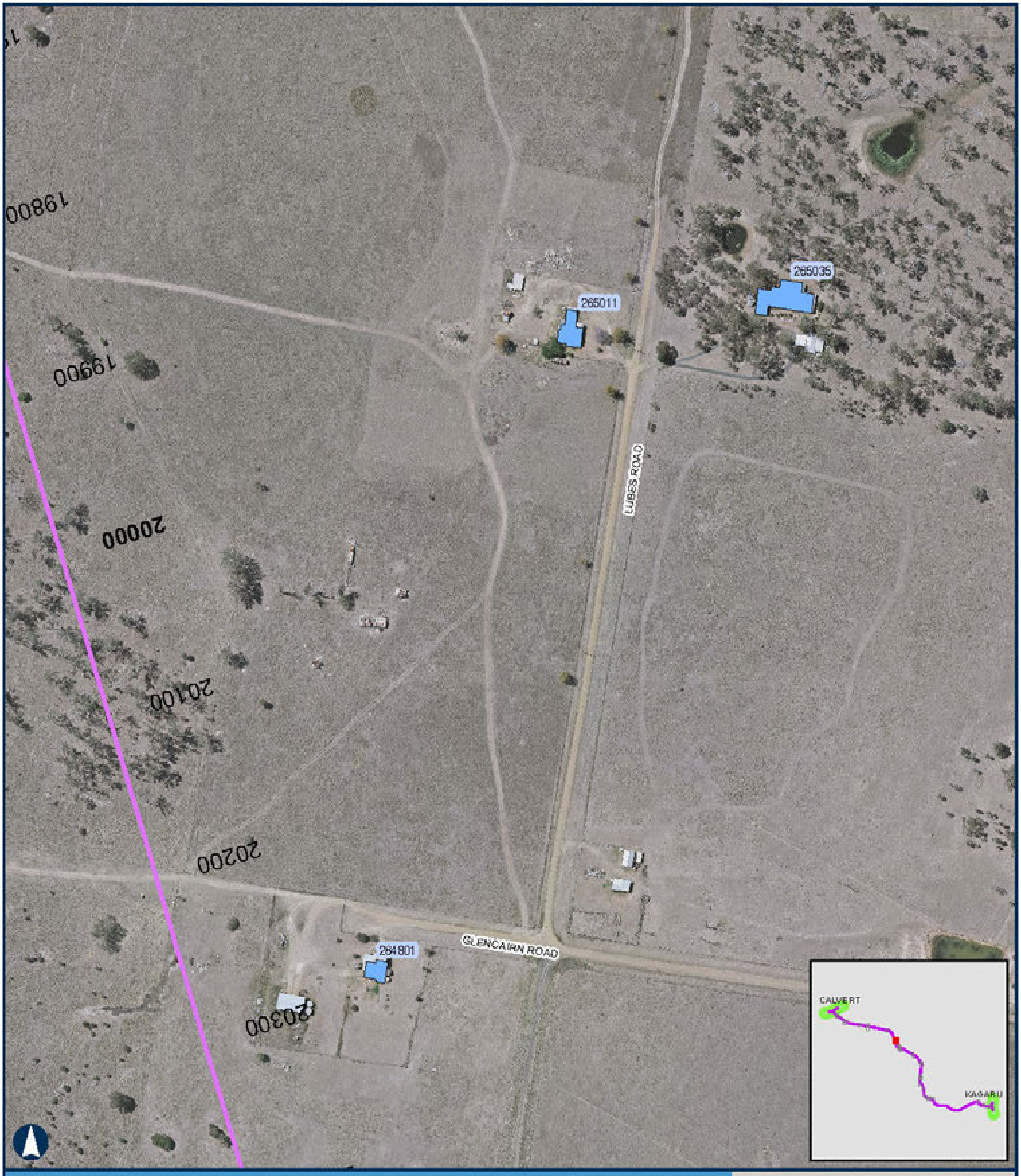

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FIGURE 28 - Map 9 of 30

100 Metres

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Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 10 of 30

100Metres

Coordinate System: GDA 1994 MGA Zone 56

Project Extent

Crossing Loops

Rail Alignment/Centreline

Bridges and Viaducts

Teviot Range Tunnel

Sensitive receptors triggering a review of mitigation

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FIGURE 28 - Map 11 of 30

100Metres

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FIGURE 28 - Map 12 of 30

100 Metres

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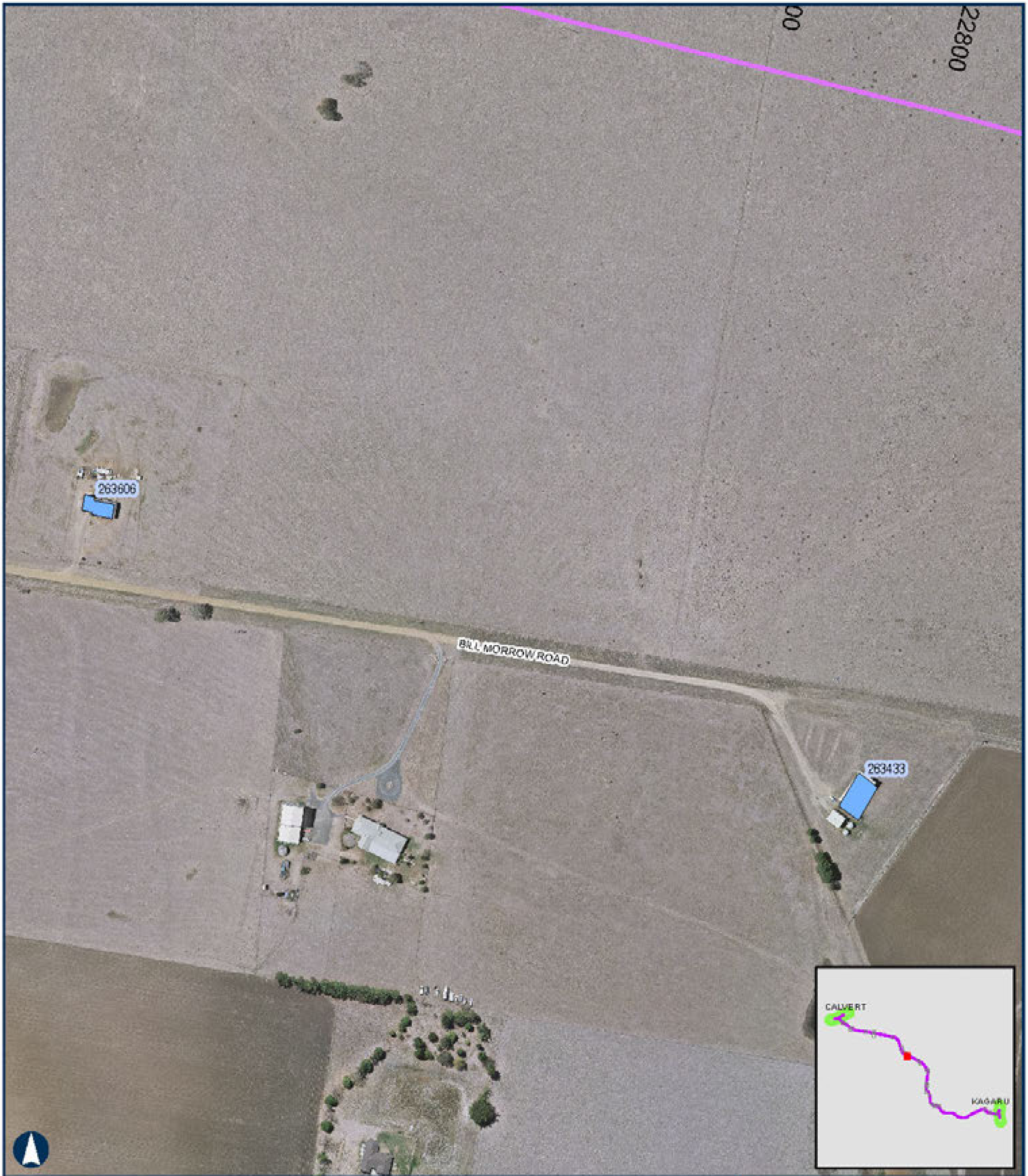

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FIGURE 28 - Map 13 of 30

100 Metres

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FIGURE 28 - Map 14 of 30

100 Metres

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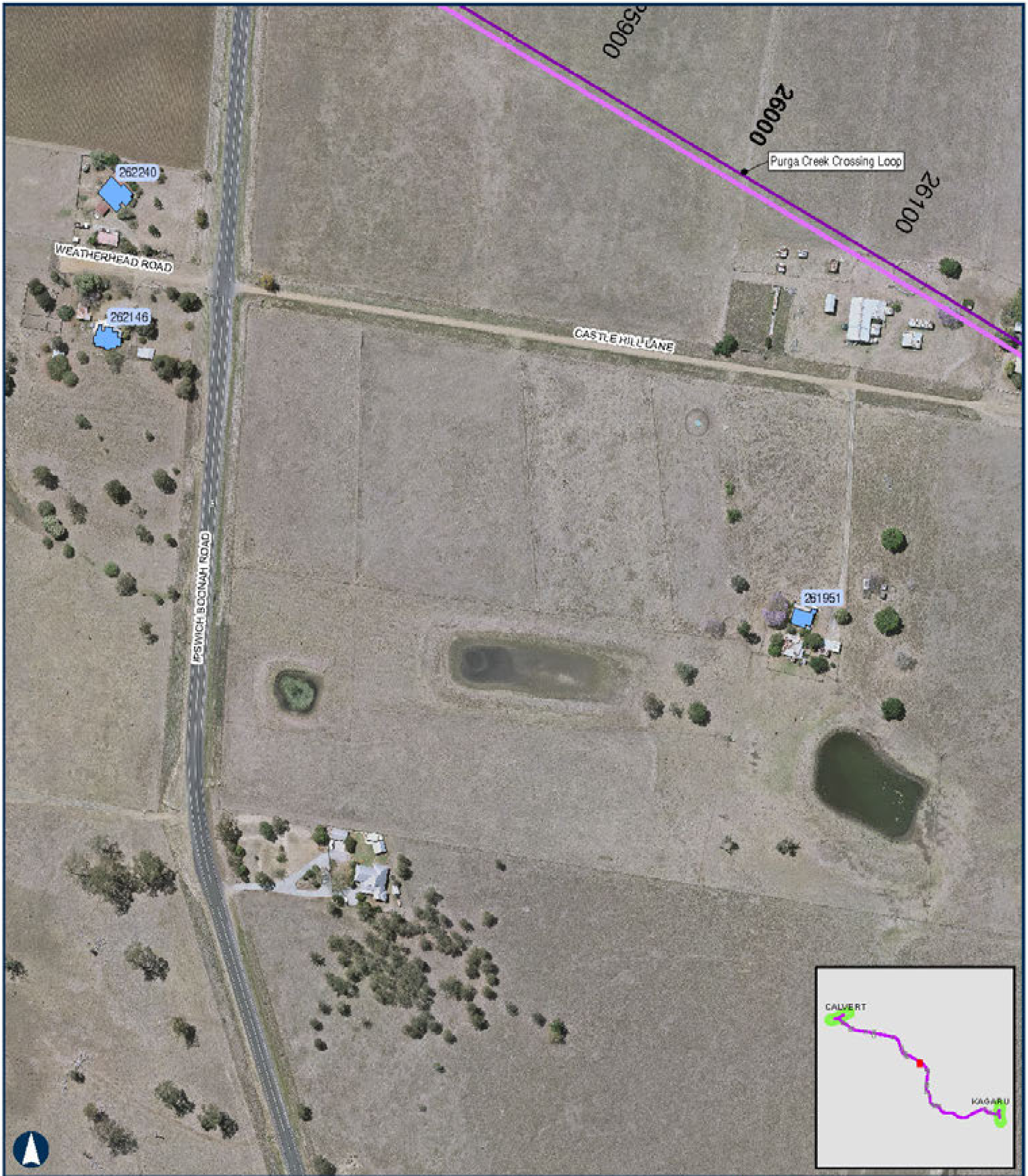

CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 15 of 30

100 Metres

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- Project Extent
- Crossing Loops
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- Bridges and Viaducts
- Teviot Range Tunnel
- Sensitive receptors triggering a review of mitigation

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 16 of 30

100 Metres

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 17 of 30

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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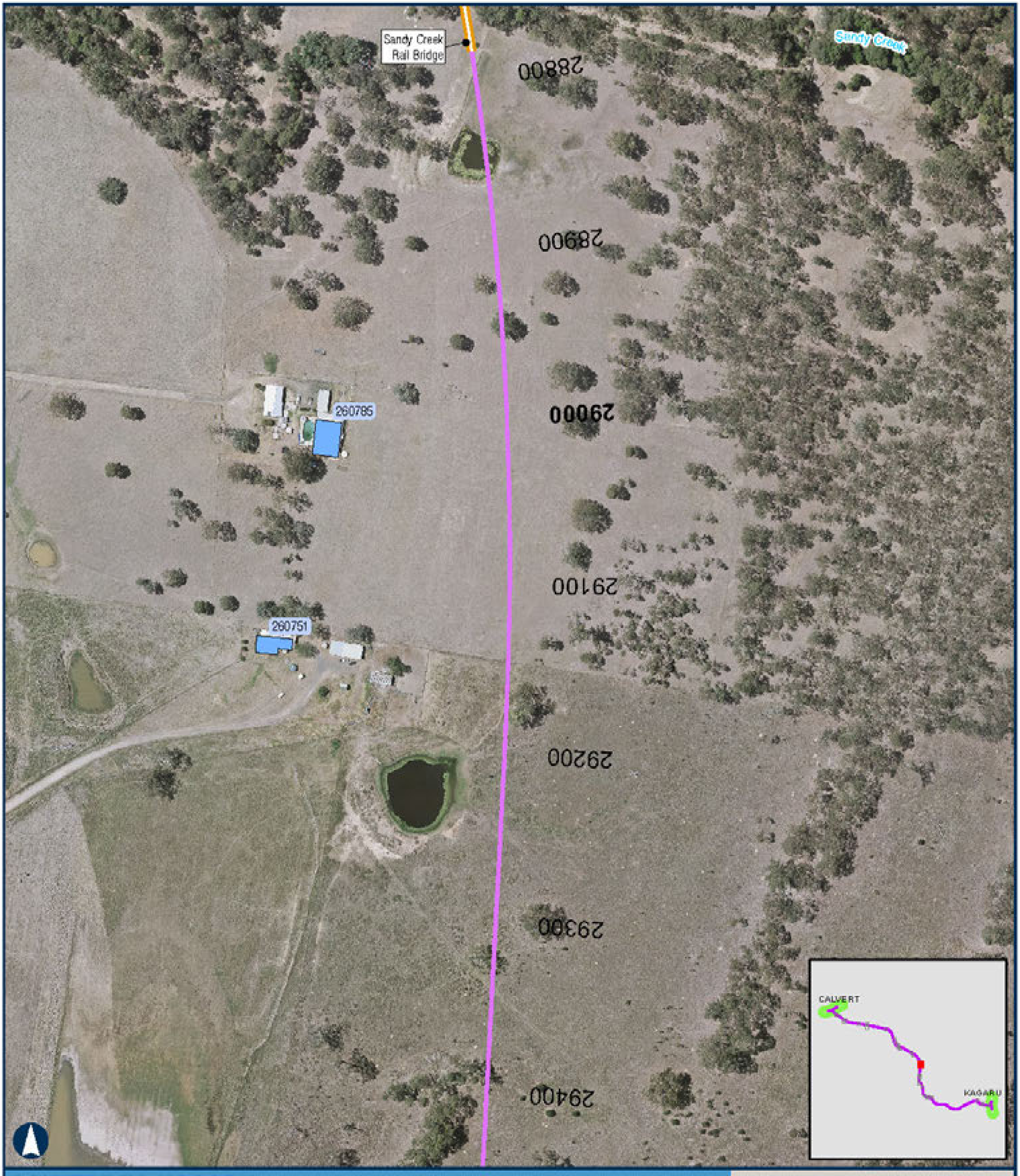

CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 18 of 30

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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- Project Extent
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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 19 of 30

100Metres

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- Crossing Loops
- Rail Alignment/Centreline
- Bridges and Viaducts
- Teviot Range Tunnel
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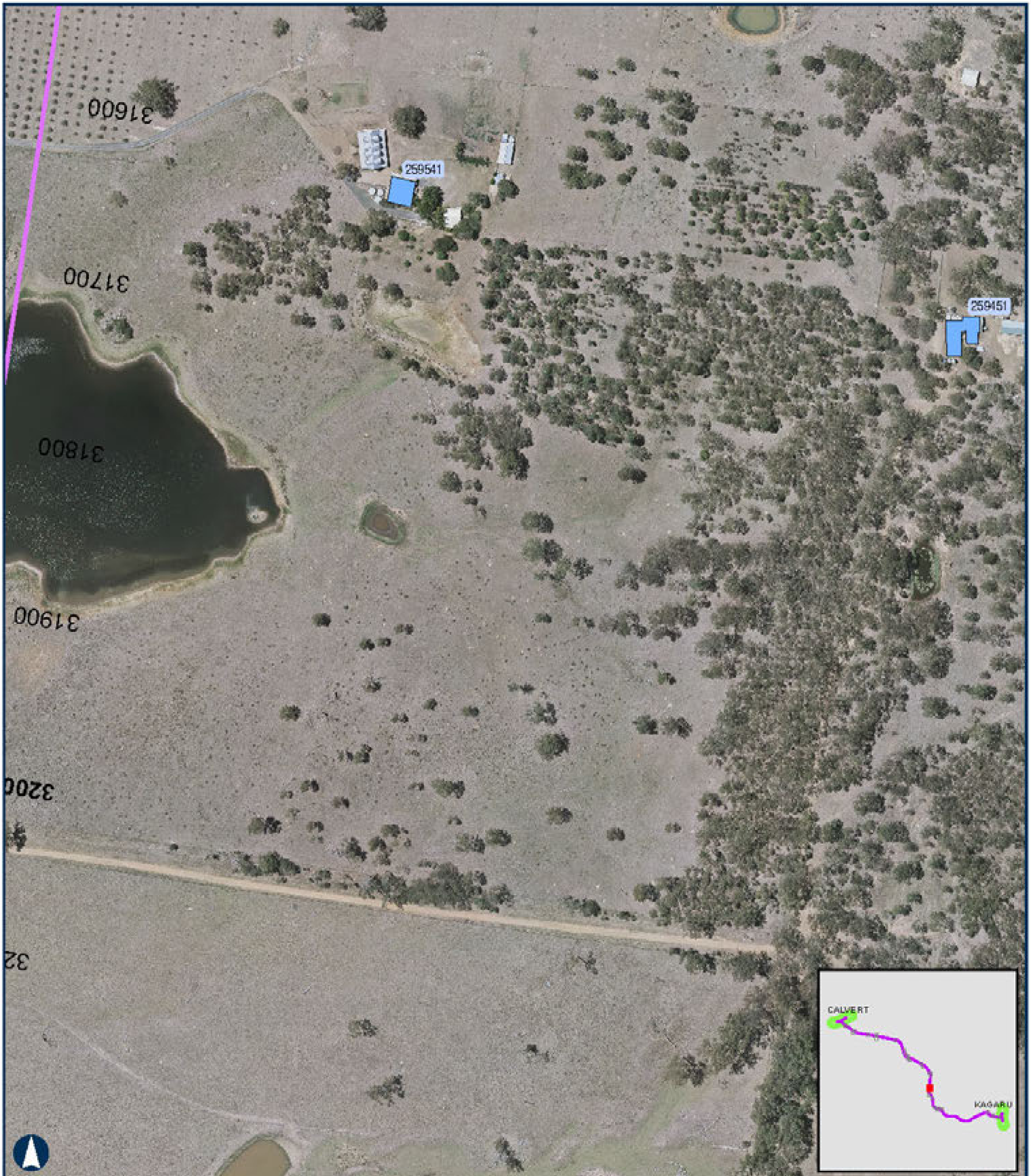

CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 20 of 30

100 Metres

Coordinate System: GDA 1994 MGA Zone 56

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Date: 16-Mar-2020
Author: JG

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

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 21 of 30

100 Metres

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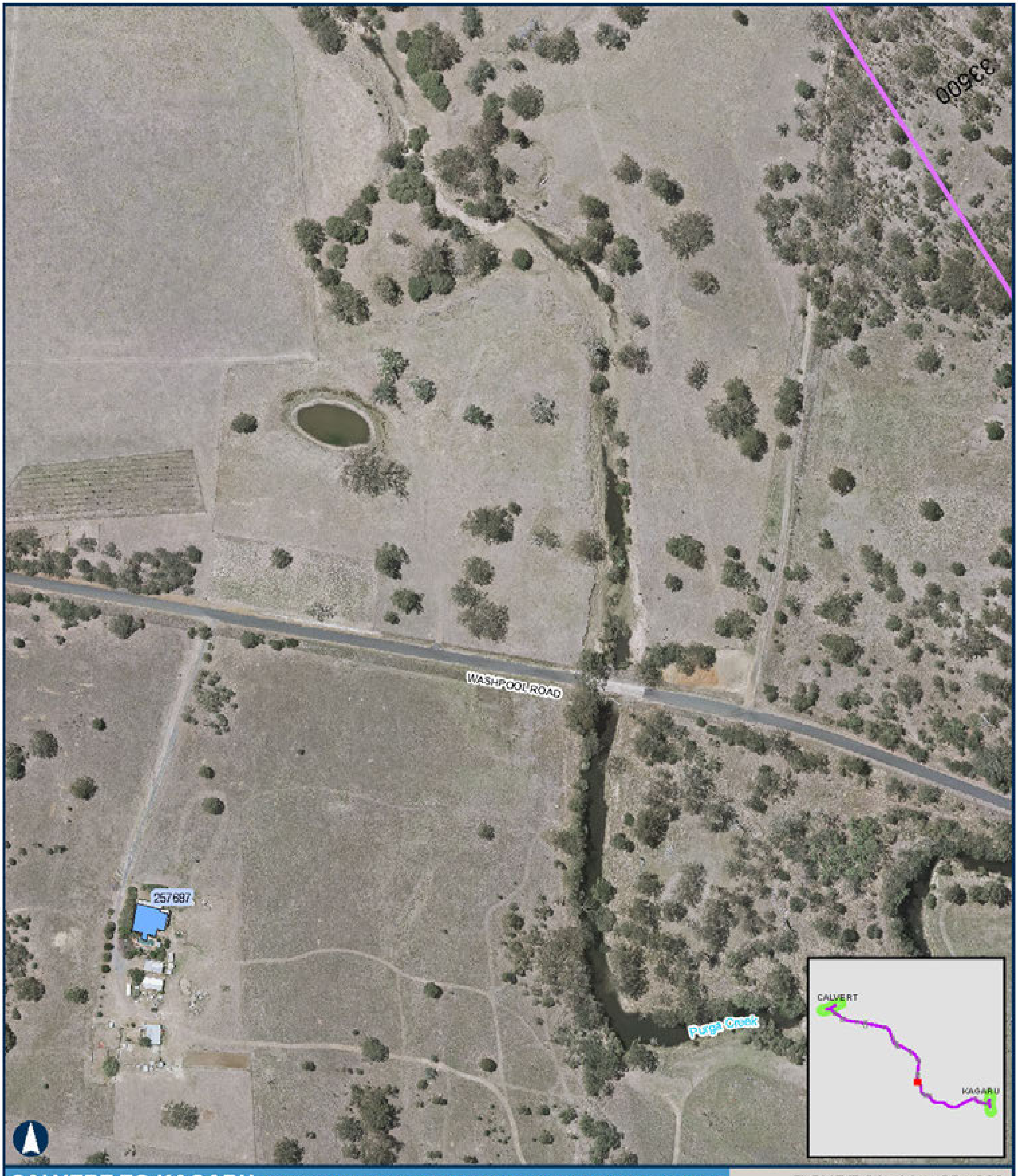

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Sensitive Receptors Triggering the Investigation of Noise Mitigation

100Metres

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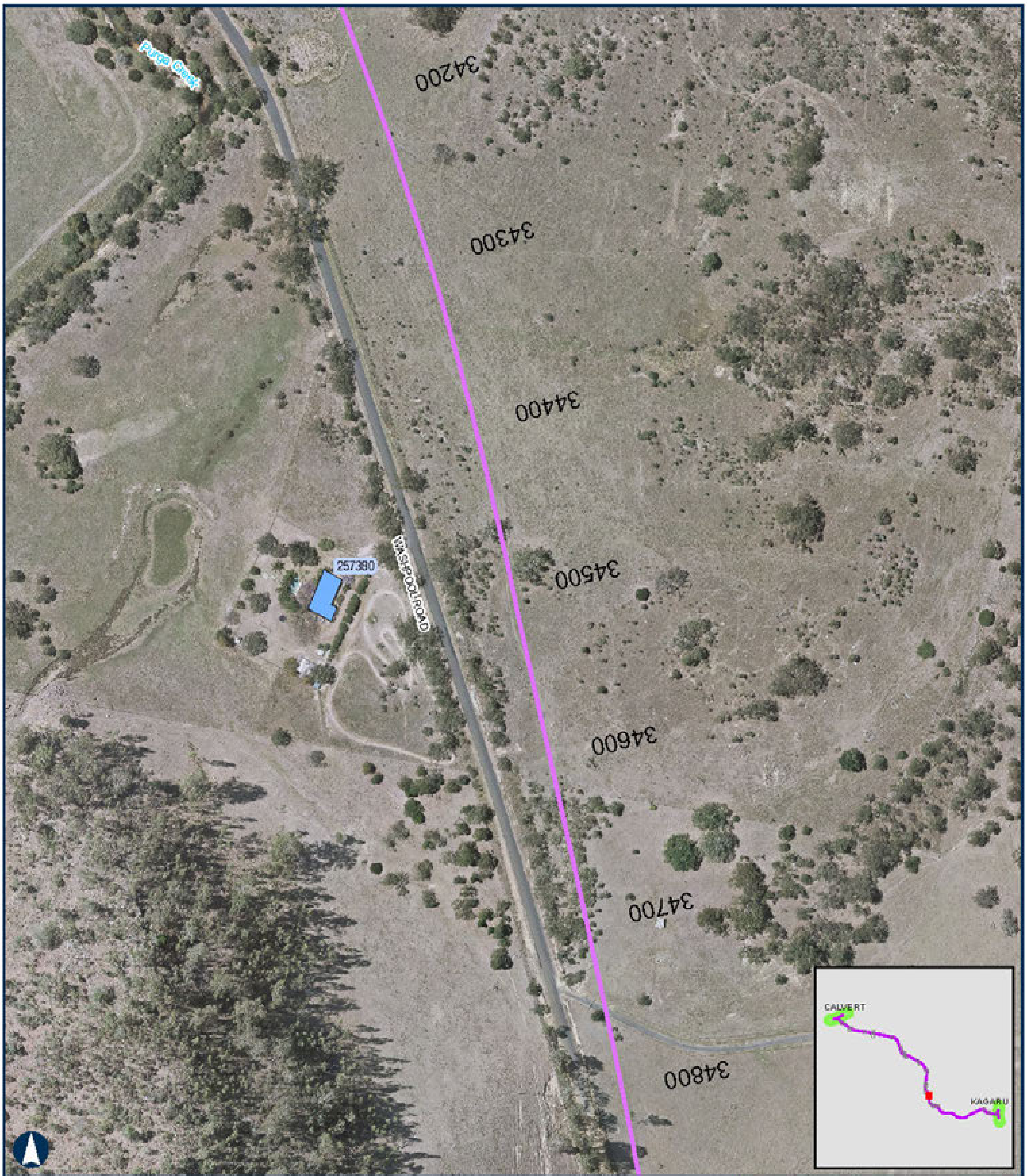

CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 23 of 30

100 Metres

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 24 of 30

100Metres

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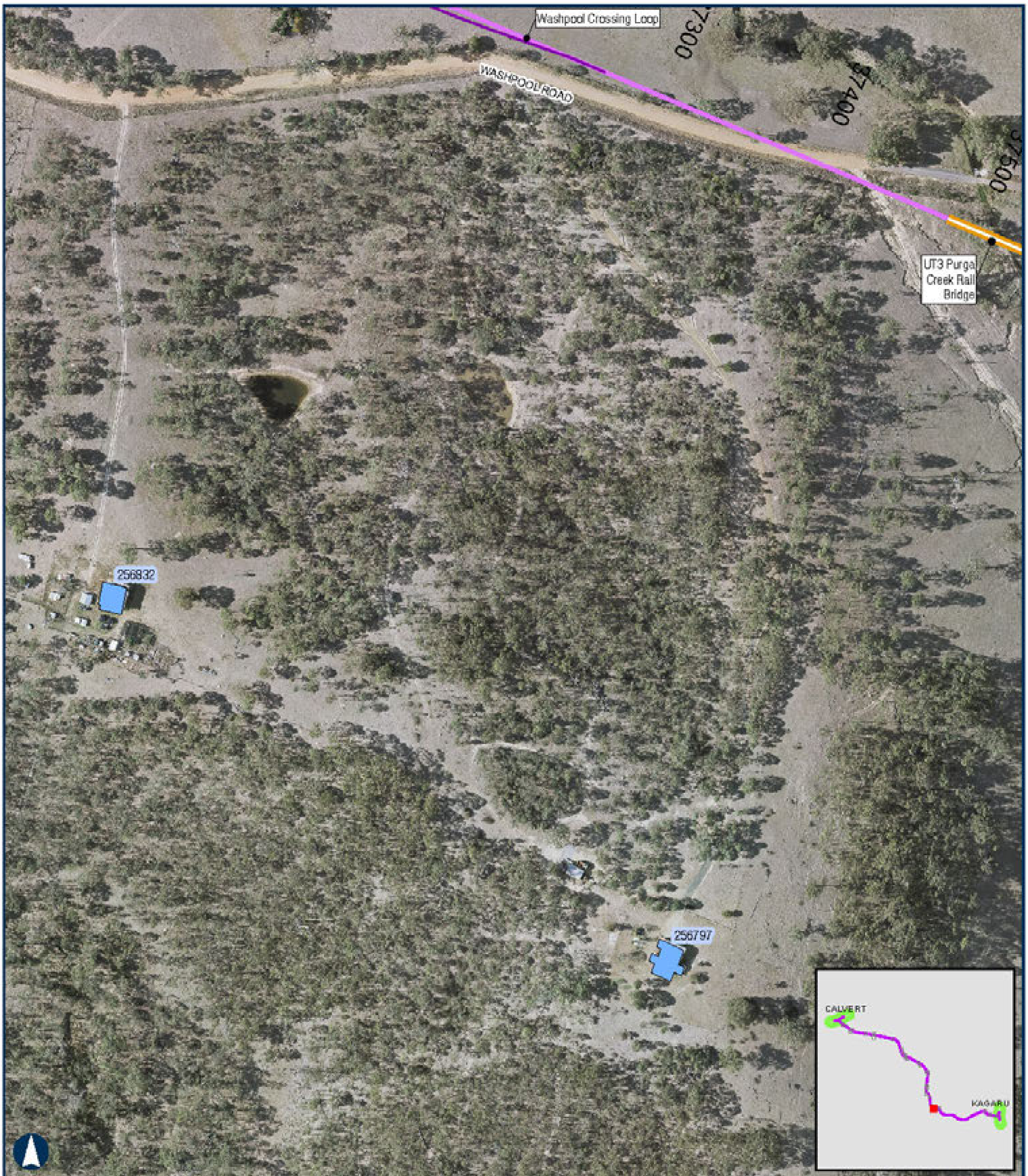

CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 25 of 30

100 Metres

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 26 of 30

100 Metres

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CALVERT TO KAGARU Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 27 of 30

100Metres

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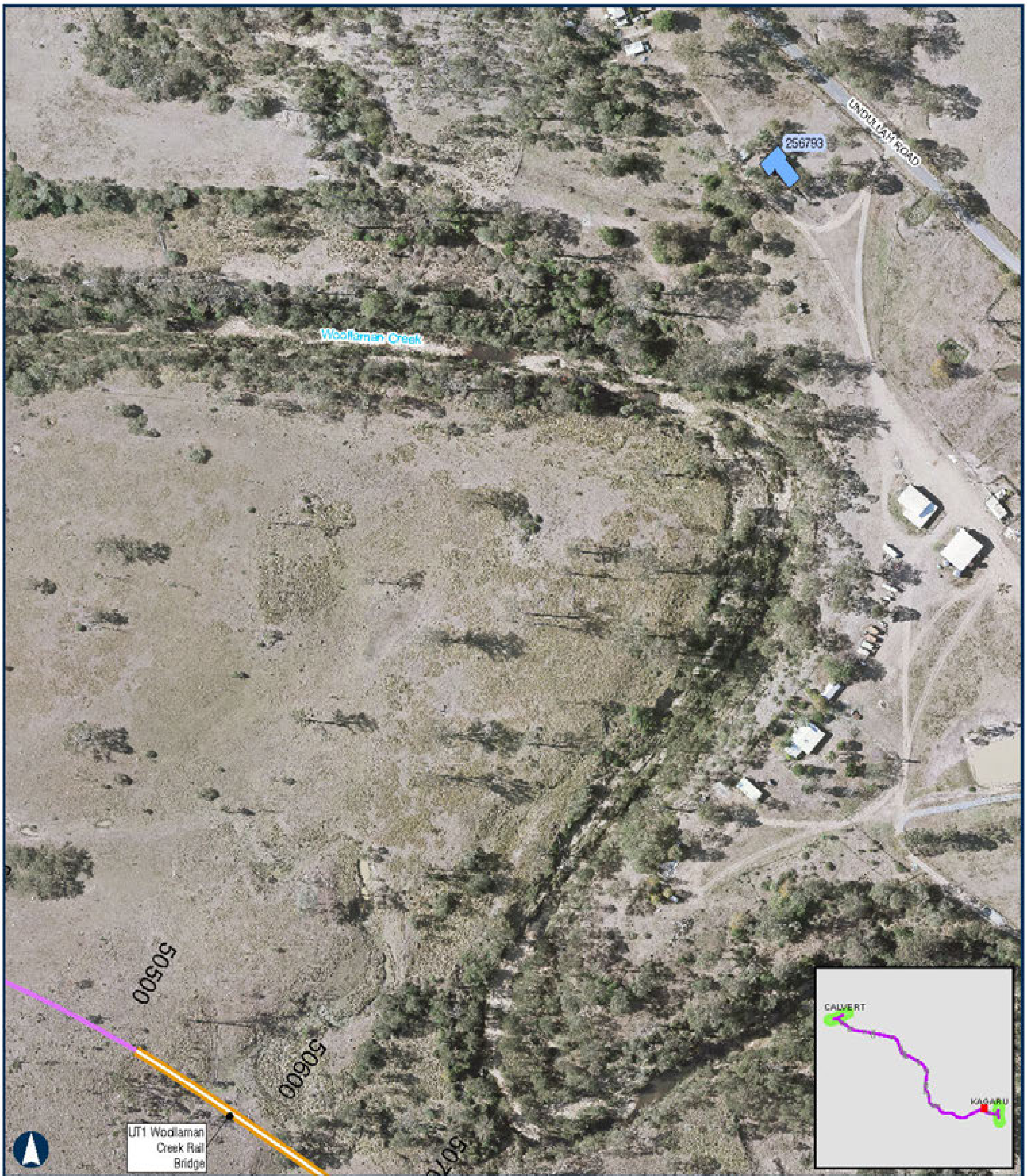

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Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 28 of 30

100 Metres

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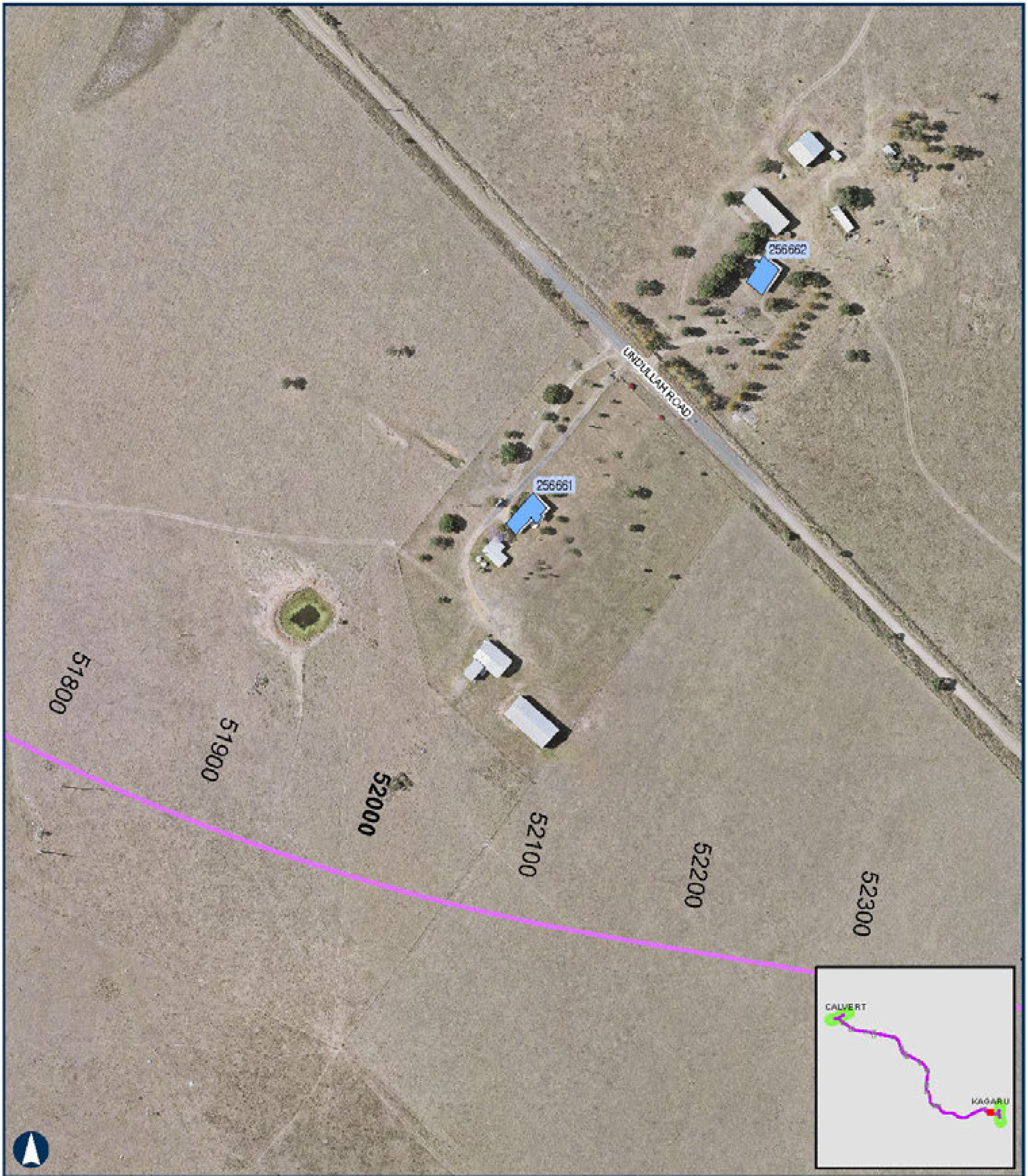

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Sensitive Receptors Triggering the Investigation of Noise Mitigation

FIGURE 28 - Map 29 of 30

100Metres

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FIGURE 28 - Map 30 of 30

100 Metres

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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 $L_{Aeq(15hour)}$ 40 dBA daytime, $L_{Aeq(9hour)}$ 41 dBA night-time and L_{Amax} 55 dBA for both the daytime and night-time periods.

The predicted noise levels from the crossing loops were within the ARTC noise assessment criteria and are lower than the railway noise levels from the daily train passby events on the main line. Because the crossing loops are within 4.5 m of the main line tracks, they are 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.

The number of sensitive receptors where the level crossing events are triggering the L_{Amax} railway noise criteria are summarised in **Table 31**. The train horns are sounded on approach to the level crossing and it is the maximum (L_{Amax}) noise from the train horns that is the principal source of the noise criteria triggers.

Based on this analysis, the Project is to review reasonable and practicable noise mitigation options for the level crossings and train horns, with the sensitive receptors triggering the noise criteria detailed in **Table 31**.

Table 31 Summary of level crossing noise

Level crossing	Number of receptors triggering noise criteria
Hayes Road	1
Mount Hines Road	0
Glencairn Road	2
Middle Road	4
Dwyers Road	1
Washpool Road	1
Wild Pig Creek Road	0
Wild Pig Creek Road	0
Private road	1

10.4 Potential for sleep disturbance

The night-time L_{Amax} (maximum) rail noise assessment criteria have been adopted by ARTC across Inland Rail 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 assessment criteria account for the highest level of noise during train passbys and the number of passby events in the night-time.

The assessment of railway noise determined that L_{Amax} noise assessment criteria for new railways and upgrading existing railways were met at the majority of sensitive receptors.

There were up to 38 sensitive receptors where the predicted noise levels were above the L_{Amax} noise assessment criteria by up to 19 dBA within the night-time period. The noise predictions identified the L_{Amax} criteria was generally met where receptors were further than 500 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 assessment criteria are met. 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[13] recommends that internal (indoor) noise levels are not above L_{Amax} 42 dBA to preserve sleep quality. Further advice from the WHO also acknowledges the establishment of relationships between single event noise indicators, such as L_{Amax}, and long-term health outcomes remains tentative.

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.

Noise modelling indicates that predicted 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 impacts.

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. In such circumstances the building construction would assist in managing noise intrusion and the guideline values for internal noise amenity would be more readily achieved.

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 effect causes a layer of cool, still air being trapped below the warmer air.

Temperature inversion conditions are most likely to occur during the early morning and night-time periods during the winter months. The stable conditions, with 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 over large distances.

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.

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

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. 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.

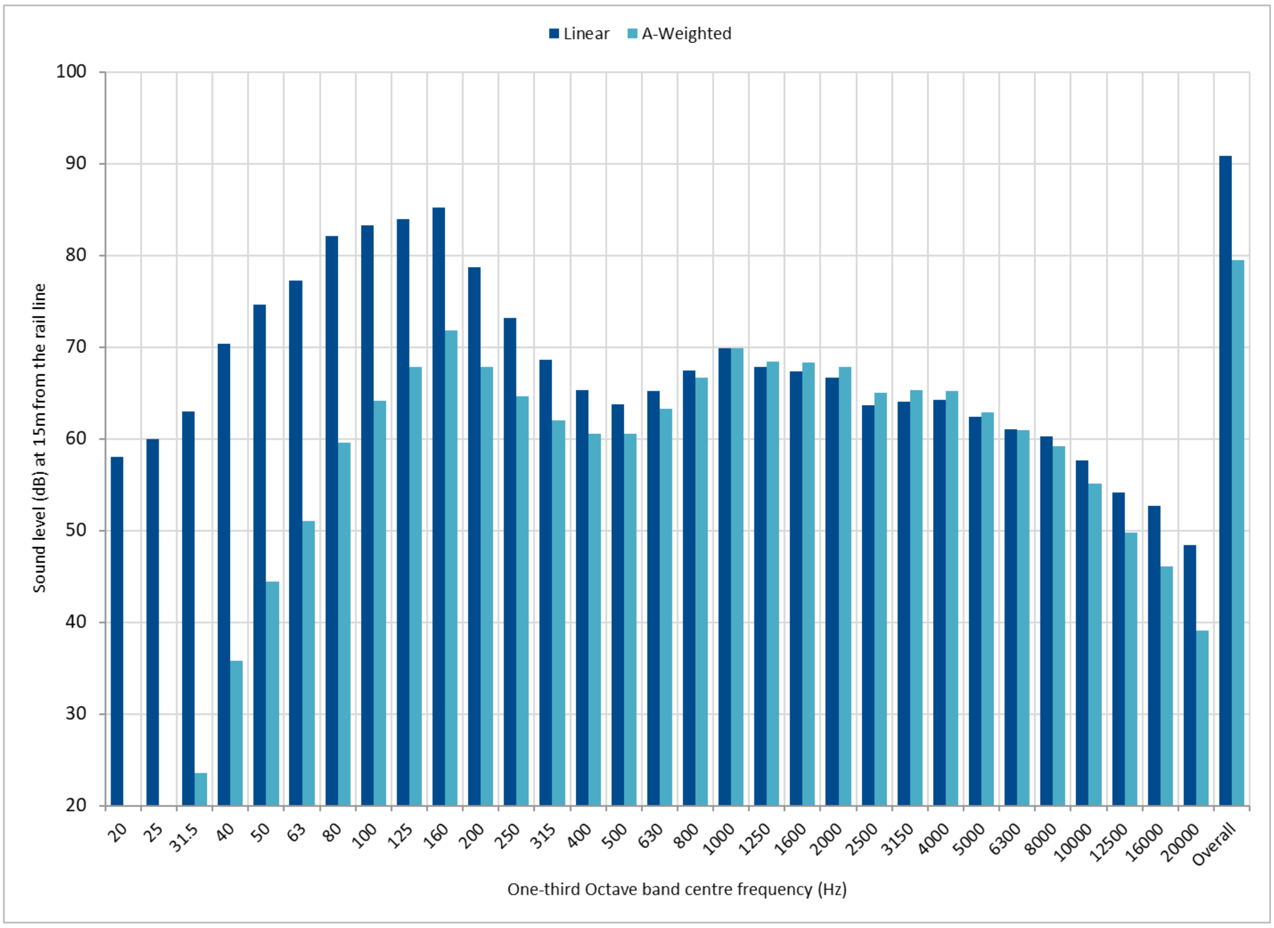
10.6 Characteristics of railway noise

The potential impacts of noise from railway operations can be influenced by the characteristics of source noise emitted 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 29**. The noise spectrum was derived from noise measurements of 149 rail freight movements on the QR West Moreton System rail corridor in March 2019. The noise levels were measured at 15 m from the single 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 were the primary source of the low frequency noise content during the measured train passby events.

Where locomotives noise emissions have a low frequency noise content in proximity to the rail line (200 m for example) 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 29 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 (Kilde 130) 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 is reasonable to assume that where railway noise would be clearly audible above the ambient noise environment there may 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 as follows:

- 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 loops proposed on the Project.
- Short-lived 'booming' noise with potential low frequency characteristics can be caused by empty containers and wagons resonating. The occurrence of noise events of this nature is not readily forecast and have not been specifically accounted for in the noise modelling at this EIS stage.
- When trains depart from the crossing loops the locomotives may be required to initially operate under a high notch setting to accelerate from a standing position. This can cause increased noise emissions from the locomotives which may result in a perceptible increase in railway noise for a short time interval nearby to the crossing loops. Given the short duration, the event would not be expected to influence the noise levels over the 15-hour daytime and 9-hour night-time assessment periods.
- Curving noise, such as wheel-squeal, can result in prominent tonal noise emissions. The Project includes a relatively short section of a tight-radius curve where the Project ties into the existing rail corridors. Corrections for potential curving noise were included in the noise prediction modelling at these locations.
- 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 designed for freight rail 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 Overview

To assess ground-borne vibration from railway operations, guidance was referenced from ISO 14837[14]. It defines three levels of modelling according to the level of project detail available, as

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

[14] International Standards Organisation, 2005. ISO 14837-1 2005 "*Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General guidance*

This assessment adopted a Scoping Model with elements of an Environmental Assessment Model to predict the likely range of ground-borne vibration levels and the benefits (or otherwise) of different design and mitigation options.

The approach used in this assessment considers source vibration levels, losses between the source and nearby building foundations, and the propagation of vibration into and within the building elements. The effects of vibration in buildings can be divided into two broad categories, where the:

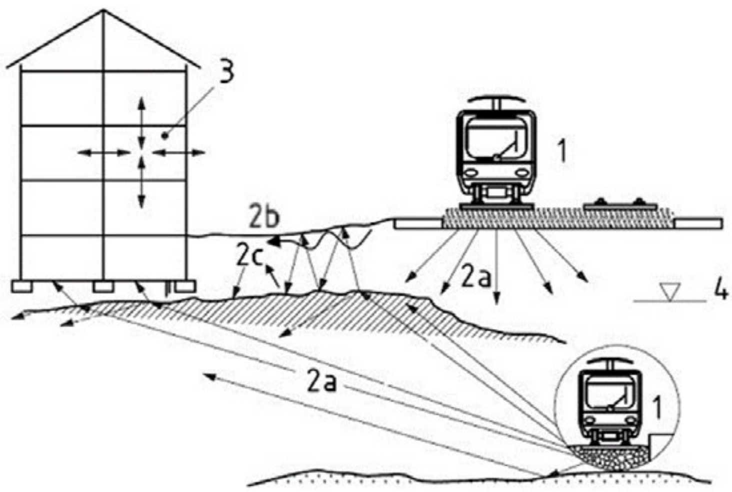
- occupants or users of the building are inconvenienced or possibly disturbed either from tactile vibration or audible noise generated from the building vibration ('comfort risk'); and,
- building contents or internal linings may be noticeably affected or where the integrity of the building or the structure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

These effects are estimated using a combination of published theoretical and empirical relationships, which includes some conservatism to cover the likely variation expected in practice. Conservatively, the modelling also assumes:

- Attenuation rates vs distance are estimated in terms of overall values only;
- No adjustment for buildings of substantially greater mass or size than those used to inform published data (conservative);
- No coupling losses between the building and adjacent soil; and,
- a crest factor[15] of 4.

A diagram of how vibration propagates from track to a structure is illustrated in **Figure 30**.

Figure 30 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.

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

More complex factors shown in **Figure 30**, such as how rail vibration might interact with different ground soils and media, are not directly modelled at the EIS stage given the level of detail that would be required in order to effectively do so, and the field data applied in this assessment includes these effects.

11.2 Source vibration levels

The Project is primarily a new railway and does not have existing comparable rail freight operations or speeds as those proposed. Consequently, it was not possible to measure local vibration levels directly and a vibration prediction model was used to estimate potential impacts.

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 Inland Rail 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. The calculated VDV (W_b weighted) 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 typical differences in rollingstock, wheel conditions and train consist (set of wagons).

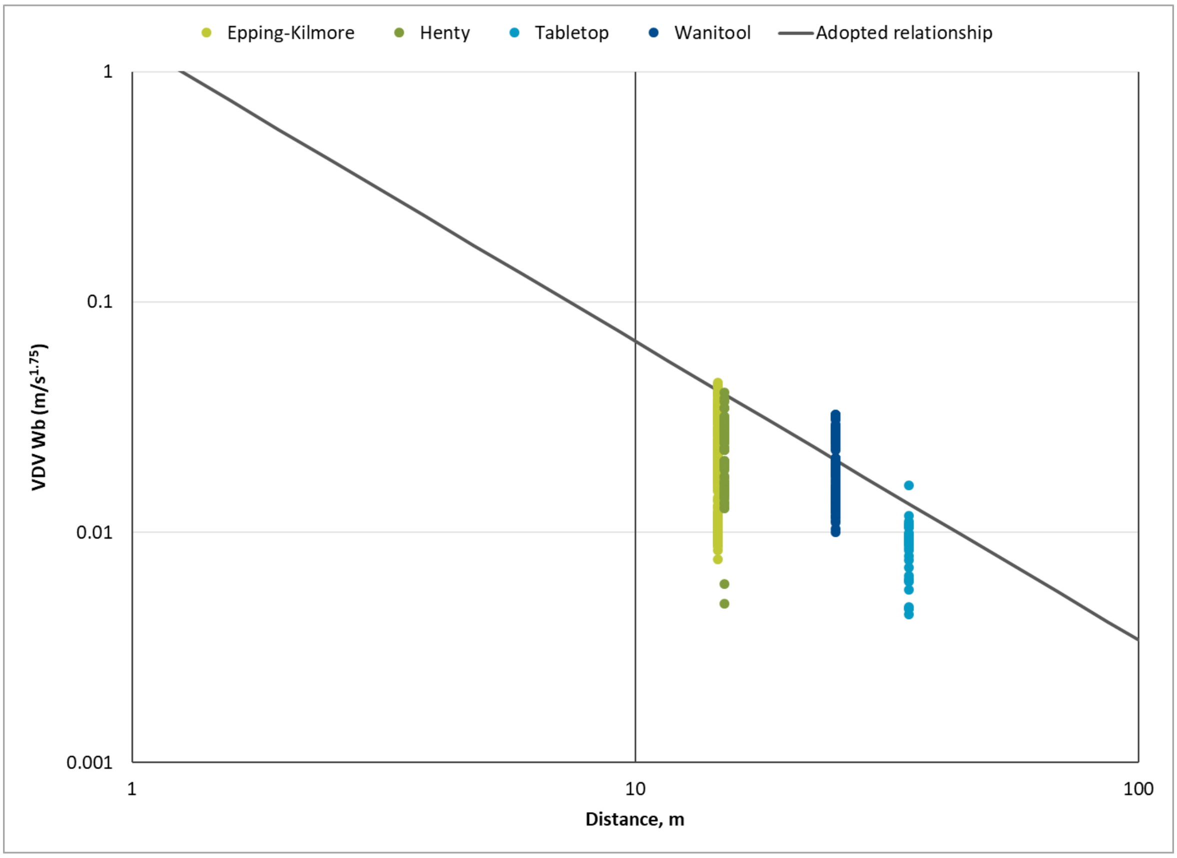
The adopted VDV (W_b weighted) of 0.04 $m/s^{1.75}$ at a setback of 15 m for a single train passby was based on the maximum derived VDVs. Accordingly, the assessment inherently assumes that each train is a worst-case vibration generating event and is therefore conservative.

The change in VDV for a single train passby event with distance from the track is shown in **Figure 31**. 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 32** 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.

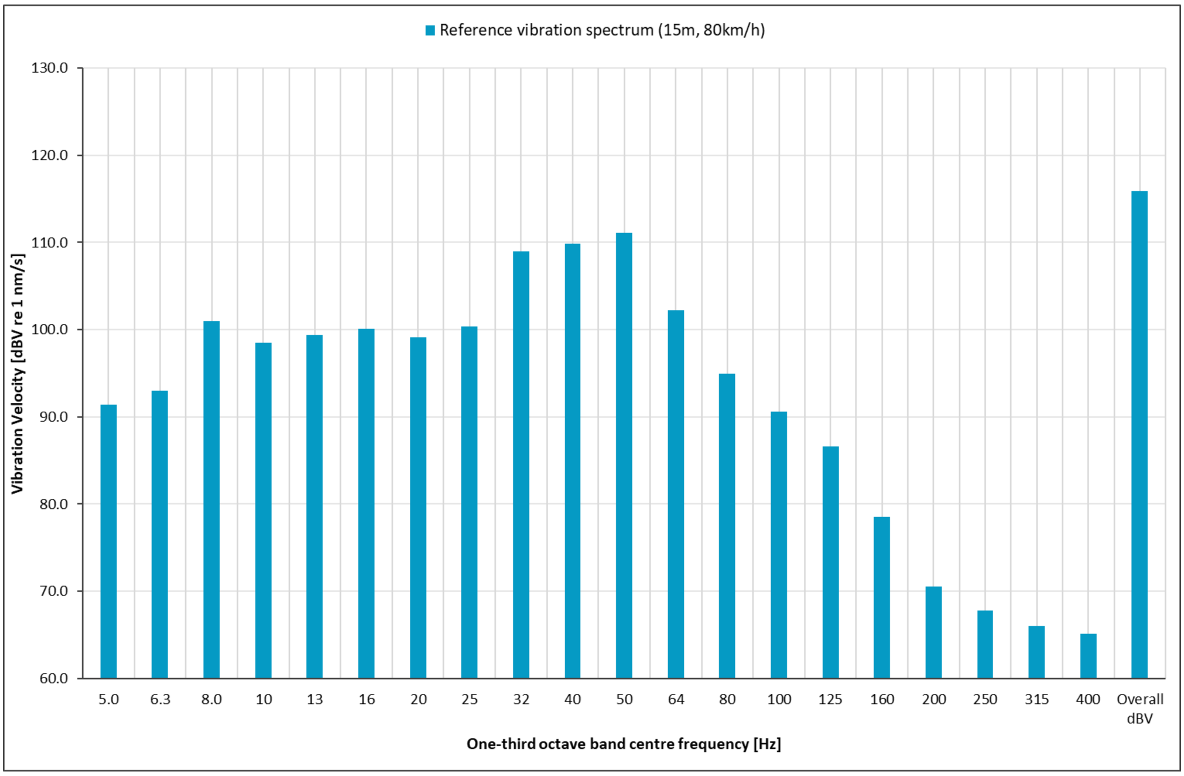
The variation in actual vibration spectra is affected by various local factors such as wheel and rail roughness conditions and track speed.

Figure 31 Logarithmic relationship between VDV and distance



Note Reference VDV for a single freight train passby.

Figure 32 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 impacts from surface track

11.3.1 Assessment approach

Previous measurement and assessment of ground-borne vibration from existing rail freight corridors with similar geotechnical considerations indicates that tactile vibration impacts would be limited to sensitive receptors located within 100 m of the proposed rail alignment.

Vibration levels at properties beyond this distance are routinely expected to be within recommended assessment criteria for comfort and where the comfort goals are met, criteria relating to the integrity of building structures are also considered to be achieved given they are typically an order of magnitude higher.

Bridge and viaduct structures are expected to be constructed from reinforced concrete and a ballasted track system. These structures are considered to have resilient matting for ballast retention (at least in the vicinity of residents), and this also provides benefits in terms of vibration isolation.

Based on the location of the nearest sensitive receptors, expected source vibration spectra and typical losses through the structure, the ground-borne vibration criteria is expected to be met at ground level assessment positions near bridges and viaducts. On this basis, the following sections consider properties within 100 m of the alignment excluding bridges and viaducts.

11.3.2 Residential and other occupied buildings

The VDV results were estimated based on daily train movements at the project opening in 2026 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.

Recommended off-set distances to achieve the daytime and night-time rail vibration criteria are shown in **Table 32**.

Table 32 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 $m/s^{1.75}$)	
2026 opening year	11 m (23 trains)	15 m (19 trains)	None
2040 design year	12 m (29 trains)	16 m (22 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 16 m from the outer rail would be required to meet ground-borne vibration criteria. This is based on the conservative assessment approach and the number of train movements in each time period.

A review of the Project alignment identified that all sensitive receptors, excluding those expected to be acquired by the Constructing Authority, would be outside of the 16 m off-set distance from the outer rail of the track. On this basis, the railway operations on the Project rail tracks are expected to meet the ground-borne vibration assessment criteria at all sensitive receptors.

Where ground-borne vibration levels meet the criteria for managing vibration disturbance, consequently the less stringent vibration criteria for managing risk of cosmetic damage to buildings would also be met.

Where ground-borne vibration from railway operations are within the assessment criteria, there may still be potential for rail operations to generate perceptible levels of ground-borne vibration at sensitive receptors in the form of regenerated noise (refer **Section 12**).

11.3.3 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 value. 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 that 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.
- That 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 32**), 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:

- depending on location, some assets may already be exposed to similar vibration levels, as the Project shall be co-locating within an existing corridor that is primarily used by coal and freight trains; and,
- ground-borne vibration levels may still be within guideline values at closer distances, depending on local factors and the spectral nature of criteria used to estimate cosmetic damage risk.

The screening assessment of vibration impacts at sites with potential heritage significance is provided in **Table 33**. The assessment determined that the heritage sites with identified structures are considered not at potential risk from railway induced ground-borne vibration.

Table 33 Screening assessment of ground-borne vibration at heritage sites

Site ID	Site name	Site description	Proximity to the Project	Expectation
C2K-19-H1	Brooklands Homestead SLR ID265560,	Original homestead was demolished in the mid-20th century, other original elements remain.	Approximately 90 m from the rail spurs connecting to the Interstate Line	No significant vibration impacts
C2K-19-H2	Kagaru Station	Former Kagaru Station, some elements remain such as timber road bridge, water standpipes and plantings.	Approximately 150 m from the Project alignment and 60 m of the Interstate Line.	No significant vibration impacts

Site ID	Site name	Site description	Proximity to the Project	Expectation
C2K-19-H9	House SLR ID 259884	House and out-buildings identified.	Approximately 68 m from the rail centreline	No significant vibration impacts
C2K-19-H10	House SLR ID260785	House and out-buildings identified	Approximately 95 m from the rail centreline	No significant vibration impacts

11.4 Ground-borne vibration impacts from the Teviot Range Tunnel

The movement of the trains through the Teviot Range Tunnel will induce vibration of the track system and the tunnel structure. This vibration will then propagate into the surrounding ground soil towards sensitive receptors. The passby emissions may be sufficient to impact the amenity of the receptors through perceptible vibration within properties.

A Scoping Model approach recommended by the ISO 14837 was adopted to identify whether ground-borne vibration could be a potential source of impact and should be considered in more detail. This model was adopted because the majority of the nearest sensitive receptors are greater than 200 m from the rail track within the Teviot Range Tunnel.

A ground vibration model was developed to account for the:

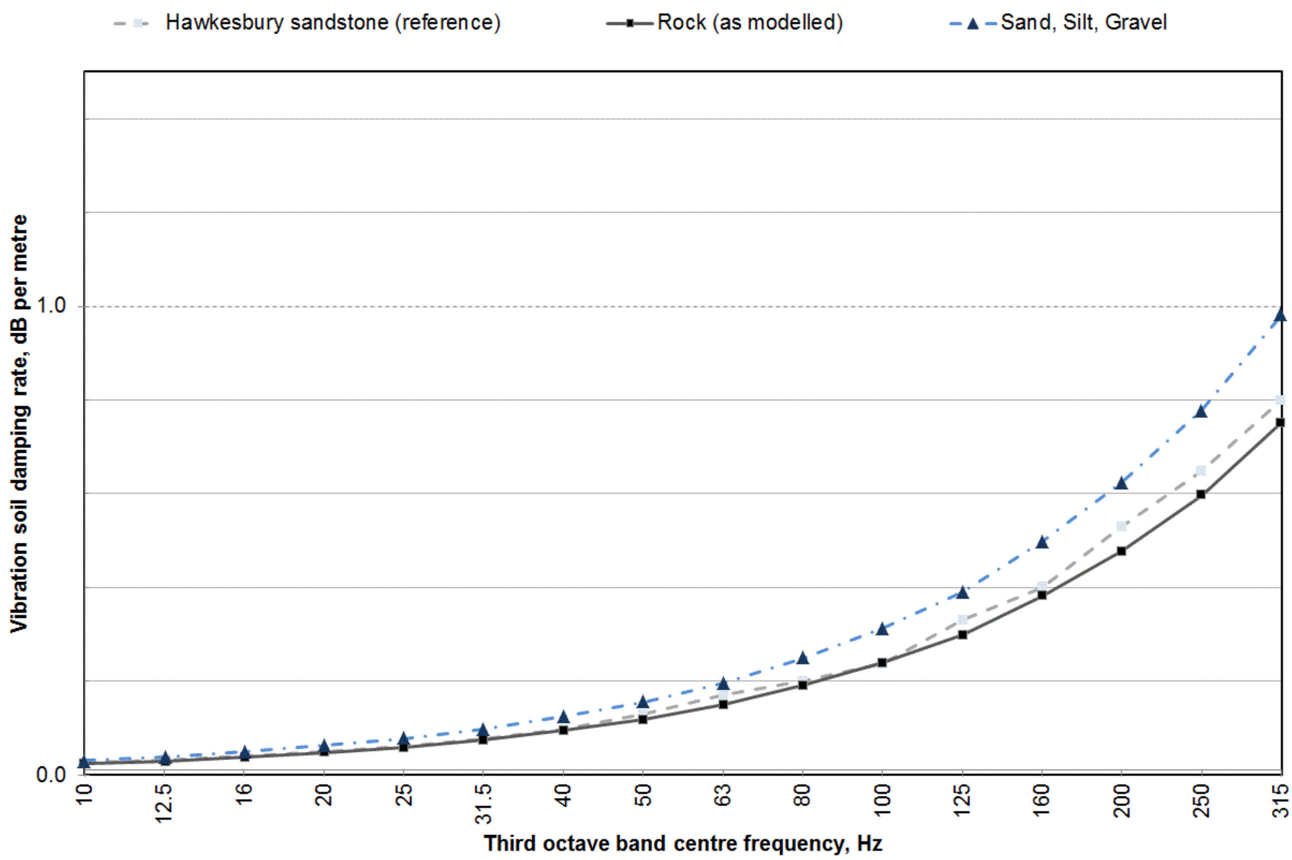
- concrete slab track form (including rail supports) within the tunnel;
- vertical profile of the tunnel alignment (depth);
- speed profiles of the trains operating within the tunnel;
- daily train numbers and train types; and,
- principal geology surrounding the tunnel alignment.

A theoretical approach is used for the tunnel compared to surface track, as field measurements of a similar arrangement have not yet been undertaken. Adopting the above information, the model accounted for geometric spreading of the vibration wave front and propagation losses which include a ground attenuation or ‘damping’ rate.

Specifically, the modelling considered the following parameters which are provided in detail in **Appendix F**:

- The tunnel track sections use the Rheda2000 system with a Vossloh 300NG series highly resilient rail fastener (cellentic intermediate plate with 17 MN/m (mega Newton per metre) static stiffness, 1.1 dynamic to static stiffness ratio).
- The trains were modelled as a line source with the vibration levels in **Section 11.2**, adjusted for distance to represent the designed tunnel internal surfaces.
- No coupling loss (or amplification) between the designed tunnel structure and surrounding media, which is a conservative assessment approach.
- The ground attenuation rates described in **Figure 33** which references historical measurements by SLR of various soil classifications. Lower dampening rates mean less loss per metre and local strata competencies (i.e. presence of different material pockets or voids) or stratification (layering of different soil types) were not modelled to provide a conservative assessment.

Figure 33 Ground attenuation rate modelled for tunnel vibration



Higher vibration levels are predicted from the tunnel compared to the proposed ground-level track over similar distances in the study area, based on the conservative assessment approach.

The ground-borne vibration criteria are predicted to be met at approximately 90 m from the tunnel track alignment. These results are forecast to be controlled by vibration energy in the third octave bands with centre frequencies 31.5 Hz to 63 Hz.

The nearest identified sensitive receptors were over 400 m from the tunnel alignment and the predicted ground-borne vibration levels would be well within the assessment criteria. The potential ground-borne vibration levels at nearest sensitive receptors would be very low and likely to not be perceptible within receptor buildings.

On the basis of the above, no additional measures to mitigate source ground-borne vibration from the rail passbys in the tunnel are considered to be required.

12 Assessment of ground-borne noise

12.1 Overview

The ground-borne vibration from train passbys can be sufficient to cause floors or walls of the structure to vibrate and this can result in an audible low frequency rumble inside buildings, referred to here as ground borne noise or regenerated noise.

The potential for ground-borne noise is highly dependent on the arrangement, construction and condition of a property. The specific 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 assessment applied the following key assumptions:

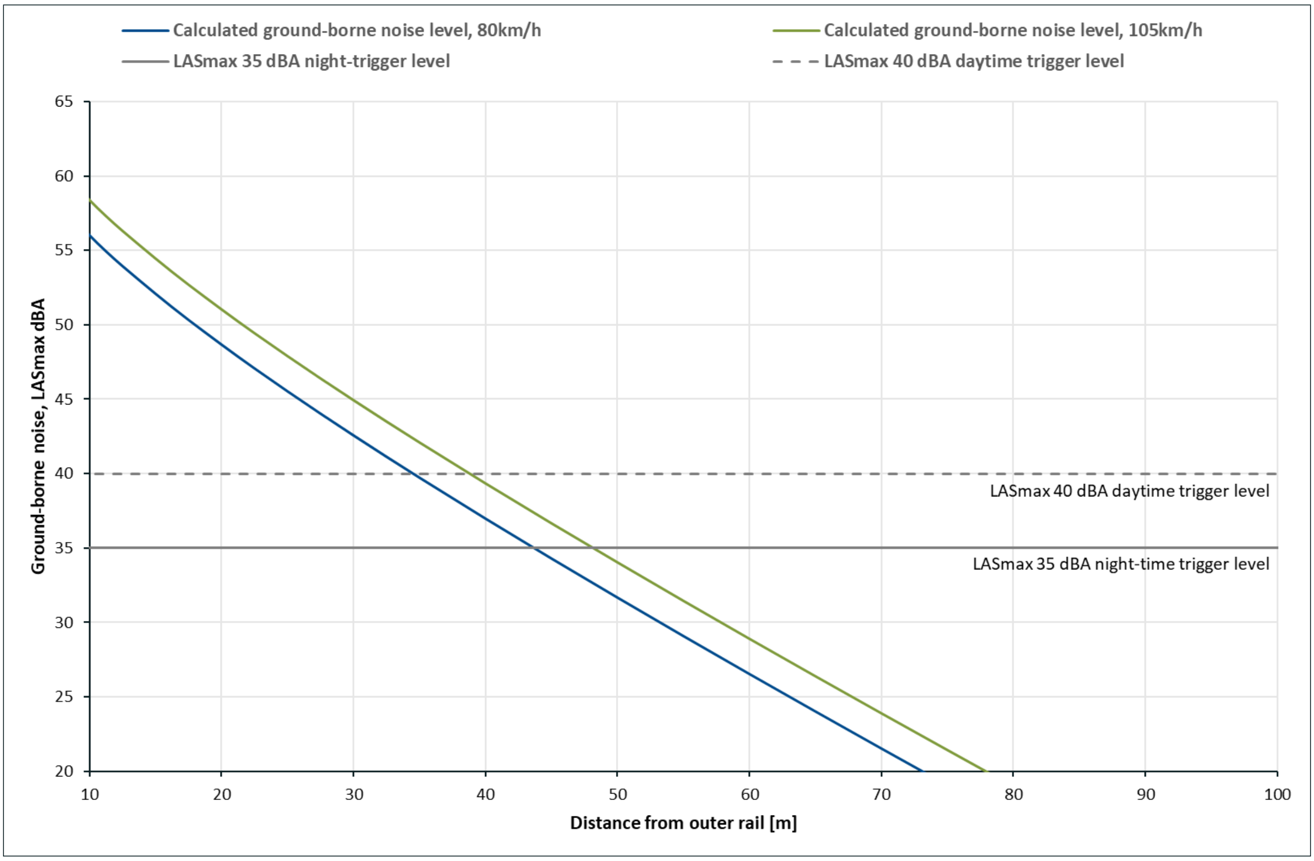
- No coupling loss between the ground and the receptor building structures to account for loss of energy as vibration enters the building footings.
- No floor amplification effects or floor-to-floor losses within the receptor structures.
- Use of a vibration to sound pressure (noise) conversion factor of -32 dB[16].
- Application of a 0.05 per metre damping loss estimated from the rail vibration measures described in **Section 11**.

12.2 Ground-borne noise impacts from surface track

12.2.1 Assessment approach

The calculated ground-borne noise levels in decibels, at increasing distance from the outer rail, of the Project are detailed in **Figure 34**. The ground-borne noise levels are presented for a train speed of up to 105 km/h. Calculated ground-borne noise levels at a distance of greater than 50 m from the outer rail are less than or equal to the L_{ASmax} 40 dBA daytime and L_{ASmax} 35 dBA night-time ground-borne noise assessment criteria.

Figure 34 Calculated ground-borne noise levels from train passbys



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

Based on the 50 m off-set distance and a review of aerial imagery, there are three sensitive receptors identified to be within 50 m of the outer rail of the Project (excluding the Teviot Range Tunnel). The nearest facades of the three receptor buildings are at the boundary of the 50 m off-set distance where the outdoor noise environment would be dominated by the airborne railway noise.

At this distance from the rail alignment, the airborne noise levels 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.

Whilst ground-borne noise levels calculated at most sensitive receptors were principally 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. Furthermore, 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 predict with greater 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 detailed design of the Project to confirm the assessment outcomes.

12.3 Teviot Range Tunnel

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 and from train passbys within the Teviot Range Tunnel. Following the same procedures and basis stated in **Section 11** and **Appendix F**, the ground-borne noise levels were forecast to achieve the more stringent L_{ASmax} 35 dBA night-time ground-borne noise criterion at greater than 160 m from the Teviot Range Tunnel alignment.

The nearest identified sensitive receptors were over 400 m from the tunnel alignment and the potential ground-borne noise levels would be well within the assessment criteria. The potential ground-borne noise levels at nearest sensitive receptors would be very low and not likely to be perceptible.

Consistent with the assessment of ground-borne vibration, no additional measures to mitigate source ground-borne noise from the rail passbys in the tunnel would be required.

13 Cumulative impacts

The Project directly links to the west with the adjoining Helidon to Calvert project section and links directly to the Kagaru to Acacia Ridge and Bromelton project section to the east. At the sensitive receptors within the Project area, the primary source of rail noise will be the Inland Rail trains as they travel on the Project alignment.

Rail noise from the arrival and departure of the trains from the adjacent Helidon to Calvert and Kagaru to Acacia Ridge and Bromelton project sections will occur further from the 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 study area.

Whilst Inland Rail 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.

On the Project, the Inland Rail trains and existing rail operations at each project extent will be collocated within the same rail corridor. The overall railway noise levels from all train operations within the new and upgraded rail corridors have been assessed in this report.

Where required by the noise criteria and assessment methodologies, the potential cumulative noise from the existing rail traffic and the future additional rail traffic introduced with the Project was included in the noise and vibration modelling predictions and the assessment of noise and vibration levels and associated related impacts.

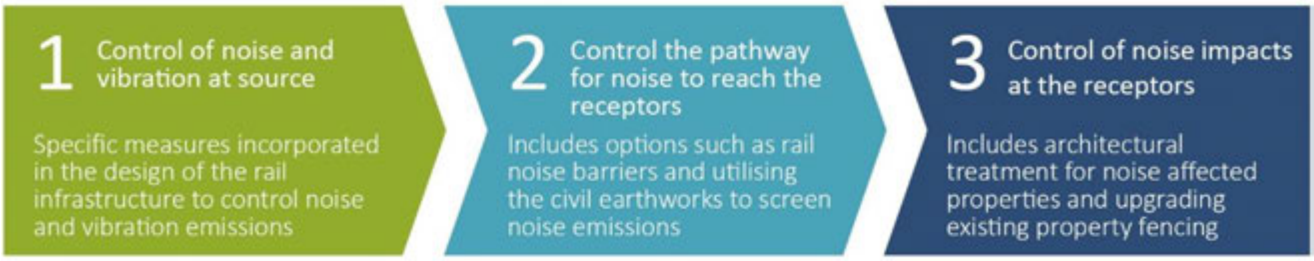
14 Recommendations

14.1 Reasonable and practicable 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 relevant criteria.

The investigation of noise and vibration mitigation for the Project follows a hierarchy of control options, as summarised in **Figure 35**.

Figure 35 Hierarchy of noise and vibration mitigation measures



On Inland Rail, ARTC is applying the following strategy as the basis for selecting reasonable and practicable 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 (operations, maintenance), community (preferences, amenity), engineering (constructability, feasibility), environmental (noise levels, hydrology, visual) and social factors (land-use, connectivity). Whole of life cost and total benefits achieved are also key factors adopted in the final selection, design and implementation of any proposed mitigation option.

The terms 'reasonable' and 'practicable', with respect to noise mitigation, are outlined in **Table 34**.

Table 34 Evaluation of reasonable and practicable for noise mitigation

Term	Description	
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 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 on-going maintenance. 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 reasonable and practicable mitigation options to reduce and control noise and/ or vibration levels, and related impacts at sensitive receptors, is discussed in **Table 35**.

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

The mitigation measures are specific to the sources of noise and vibration, for example wheel-rail (rolling) noise, curving noise on sections of tight-radius track or potential ground-borne noise from train passbys within the Teviot Range Tunnel.

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

Table 35 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, crossings, utilities, waterways and drainage culverts. Adjacent infrastructure can constrain the location, extent and performance 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 suitable land between the rail line and sensitive receptors may constrain the construction of the base/ foundations of the noise wall or barrier (this includes existing/ proposed embankments or sub-surface conditions present). • The design of the noise walls or barriers would need to achieve; a minimum noise reduction performance, control reflected sound and edge diffraction effects and meet specifications for earthworks, cross drainage, flooding, surface water run-off, stabilisation, wind loading, erosion and durability. • Social and environmental factors include; loss of open aspect and breezes, connectivity, cohesion, severance, potential for vandalism, safety in design, collapse consequence, reduction in visual amenity of the landscape, loss of views and vistas and lighting/ shadow effects.
	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 may 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, earth mounds would need to be a comparable height and length to potential rail noise walls or barriers.
		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 mounds 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 that 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 meet environmental and design 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.
	Rail dampers	Rail dampers may provide localised benefit for the control of rolling noise where the contribution from the rail is a primary factor. International experience suggests a reduction in rolling noise of 3 dBA could be achieved and there is limited evidence that suggests rail dampers provide modest capability for 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, that are highly susceptible to prominent or regular wear, would be most suited for the consideration of rail dampers.
	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. 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, defects can be repaired to address factors contributing to higher noise levels or discrete annoying noise characteristics. This measure is not readily implementable by ARTC without appropriate commitments from rail operators. It is likely the overall reduction to L_{Aeq} and average L_{Amax} noise levels would be minor but would assist in managing noise events that could cause disturbance.

Noise source	Aspect	Commentary
Managing curving noise	Track lubrication systems	Diagnosis and control of curving noise can require detailed investigation of the track systems and rollingstock. Track lubrication systems are an effective control measure to reduce, and even eliminate, curving noise. Wayside lubrication systems include gauge-face lubrication and top of rail friction modifiers. The Project reference design includes section of curved track with a radius less than 500 m where the Project connects with the QR West Moreton System near Calvert. On this basis, track lubrication systems should be considered for the rail spur to control potential curving noise.
	Other measures	Depending on the specific source of the rail noise, other measures can include wheel dampers to control aspects such as curving noise (wheel squeal). Because such measures require specifications for the rollingstock they will not be readily implementable by ARTC without appropriate commitments from rail operators.
Locomotives and engine shrouds	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 noise impacts.
Safety warning devices	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 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 are to 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.
	Turning off audible alarms at night	Subject to appropriate review of safety and operational requirements, the audible alarms on level crossings could potentially be turned off during the night-time period, for example between 10.00 pm to 7.00 am.
Ground-borne noise & vibration from the tunnel	Highly resilient trackform	The trackform in the Teviot Range Tunnel is to be an effective high vibration attenuation class trackform, such as Vossloh 300 NG with the 17 MN/m static stiffness 'Cellentic' pad.

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 and 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 the individual property. Suitability will be confirmed prior to the implementation of at-property noise control treatments.
	Property construction	The age and construction of residential properties can influence the practical implementation of modern architectural treatments. The review of architectural treatments will require further review of eligible properties and advice from suitably qualified professionals.
	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 be reduced by approximately 3 dB to 6 dB .
	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. The approach applied would need 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[17]. This curve should be considered as a design target for architectural treatments where measured external rail noise levels at sensitive receptors are above the assessment criteria and prominent low frequency noise identified.

[17] 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.
	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

This noise assessment identified railway noise levels triggered the review of noise mitigation at up to 59 sensitive receptors for rail operations at project opening (2026), with an additional six sensitive receptors triggering the criteria, for a total of 65 sensitive receptors triggering investigation of noise mitigation at the design year 2040).

A review of the location of these sensitive receptors determined the majority of properties were 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 reasonable and practicable 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 triggered; the reasonable and practicable 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.

During the detailed 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.

A review of the noise mitigation triggers, based on the margin the noise levels are above the criteria, is provided in **Table 36**. The noise levels at the majority of sensitive receptors are within 5 dBA of the criteria.

Table 36 Summary of noise mitigation triggers

Assessment criteria margin	Sensitive receptors triggering the assessment criteria
Year 2026 – project opening	
1 dBA to 3 dBA	27
>3 dBA to 5 dBA	13
>5 dBA to 10 dBA	14
>10 dBA	5
Total receptors triggering noise mitigation - project opening	**59**
Year 2040 – design year	
1 dBA to 3 dBA	28
>3 dBA to 5 dBA	13
>5 dBA to 10 dBA	14
>10 dBA	10
Total receptors triggering noise mitigation - design year	**65 (includes the 59 receptors triggering in 2026)**

14.4 Mitigation for ground-borne vibration and ground-borne noise

The assessment identified the potential ground-borne vibration and ground-borne noise levels would meet the assessment criteria at the majority of sensitive receptors and airborne noise levels would likely mask ground-borne noise impacts.

Notwithstanding, there may still be potential for perceptible ground-borne noise and vibration even where the respective criteria are met. Accordingly, the following recommendations are provided to inform the detailed design of the Teviot Range Tunnel.

A key component will be verifying the outcomes of this assessment and managing the potential for disturbance impacts from perceptible ground-borne noise and vibration during train passbys.

- The prediction of ground-borne noise and vibration levels from the train movements in the Teviot Range Tunnel will need to be assessed during detailed design phase once additional information on the tunnel structure, track form, pad stiffness and geotechnical conditions is available.
- Within tunnel slab track areas, the trackform should utilise an effective high vibration attenuation class trackform such as Vossloh 300NG with the 17 MN/m static stiffness (1.1 dynamic to static ratio) 'Cellentic' pad (or performance equivalent). The systems will need to be installed and maintained in accordance with manufacturer specifications.
- Where ground-borne noise is required to be managed, it is common to apply softer rail pad systems to those proposed. There are a range of engineering and maintenance implications with the application of softer rail pad systems for rail freight. The implementation of such measures to control ground-borne noise from train movements in the Teviot Range Tunnel will need to be investigated.
- The effectiveness of alternative or supplementary measures, such as rail dampers or rail pads, may be significantly limited by the stiffness of the track and concrete sleepers, the forces exerted by heavy rail freight and the long-term durability and maintenance of such measures.

14.5 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 and does not allow for more advanced prediction and analysis of railway noise.

It is recommended that during the detailed design of the Project, when aspects such as noise mitigation will be confirmed, the rail noise prediction modelling is updated for the detailed 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.

14.6 Validation of noise and vibration levels during operation

A program 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 assessment 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 and cover a period of consecutive days to be representative of typical operations.
  - Monitoring locations being 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 and climate 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 and reassess noise 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 reasonable and practicable 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 on the surface track and in the tunnel. 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 reasonable and practicable mitigation measures.

15 Residual impacts

The rail noise and vibration assessment criteria implemented by both DTMR and ARTC are designed to manage aspects such as environmental harm and nuisance. The intent of the criteria is to identify where reasonable and practicable mitigations should be implemented to manage the potential for impacts.

The railway noise criteria do not require noise from railway operations, including where noise mitigation is implemented, to be inaudible 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 reasonable and practicable 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 the 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 specifications 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.

The assessment has identified the ground-borne noise and vibration assessment criteria would be met at the majority of sensitive receptors. 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 sensitive receptors.

16 Conclusion

The operation of the Calvert to Kagaru project section of Inland Rail has the potential to be a source of airborne noise, ground-borne noise and ground-borne vibration within the environment surrounding the Project. This assessment has identified where the predicted levels of noise and vibration from the railway operations would meet the adopted criteria and where the noise and vibration levels trigger an investigation of reasonable and practicable 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 met at the majority of the identified sensitive receptors. There are up to 65 sensitive receptors where noise levels trigger a review of mitigation.

The location of the sensitive receptors, the predicted noise levels at each receptor and the principles of ARTC's assessment of noise on Inland Rail were reviewed recommend noise mitigation options were also evaluated. 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 may 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 detailed design of the Project.

This will include consultation with the property owners, further railway noise and vibration assessments, 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, including within the Teviot Range Tunnel, determined that predicted levels would meet the criteria for ground-borne noise and ground-borne vibration at the majority of sensitive receptors. The airborne railway noise levels are likely be sufficient to mask the ground-borne noise levels. On this basis, the assessment did not identify a need for specific vibration treatments beyond the highly resilient trackform proposed for slab track in the tunnel. Resilient matting for retention of ballast on bridge and viaduct structures would also be considered.

Where the Project meets the noise and vibration criteria there may still be potential for noise and vibration from railway operations to be audible within the environment. It is not uncommon 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 detailed design and construction of the Project. It is recommended that the predicted noise and vibration levels and assessment outcomes presented in this report are validated as part of the on-going assessments.

Where the detailed design remains consistent with this assessment and allowing for the implementation of recommended noise and vibration mitigation measures, the Project is expected to achieve the objectives of the ToR for the management of noise and vibration from railway operations.

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APPENDIX Q

Operational Noise and Vibration Technical Report

Appendix A Sensitive receptors

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

IR_1381

CALVERT TO KAGARU

Sensitive Receptors

APPENDIX A - Map 1 of 34

300 m

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- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
- Bridges & Viaducts
- Teviot Range Tunnel
- Sensitive Receptors (Residential)

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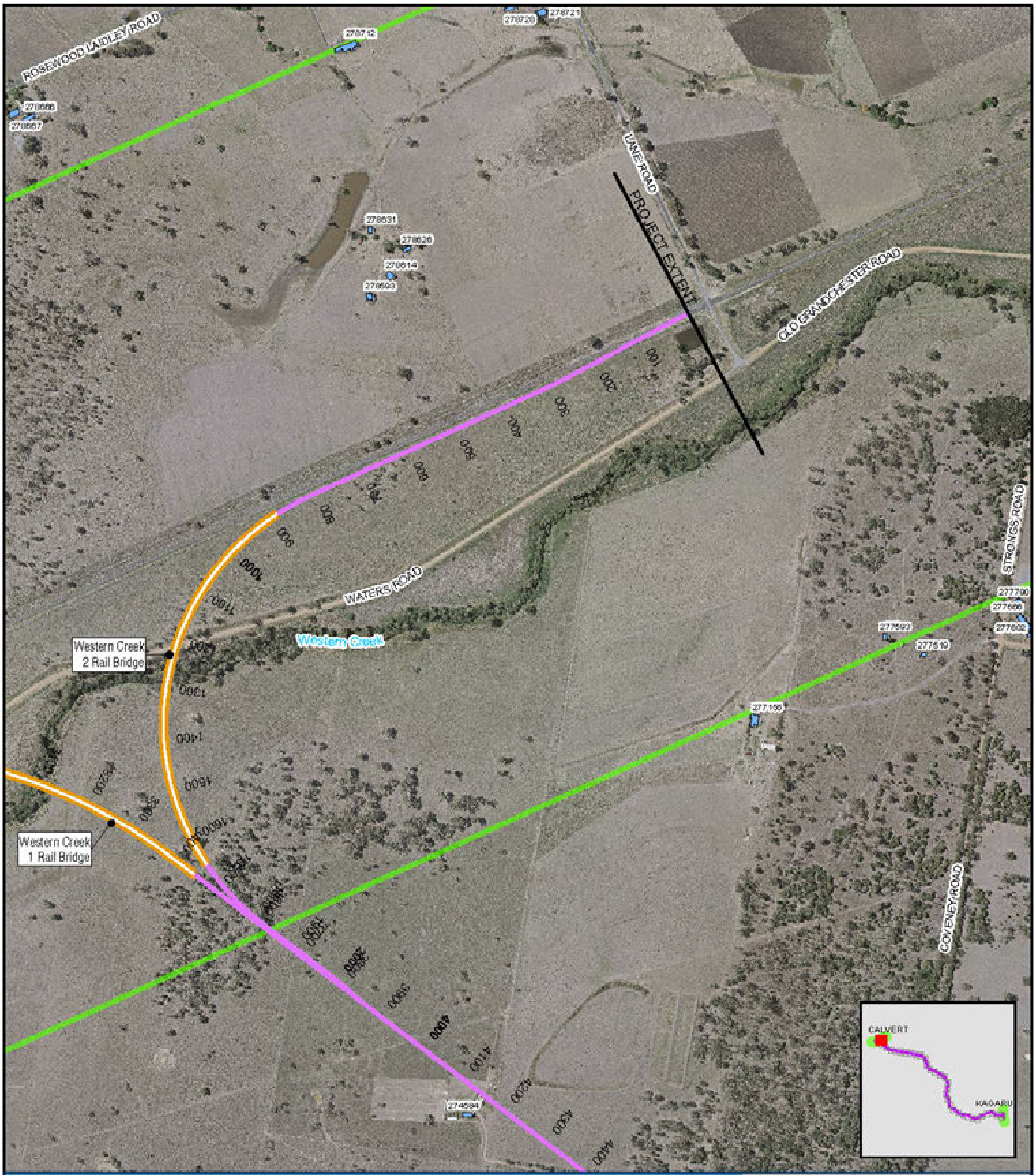

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Sensitive Receptors

APPENDIX A - Map 2 of 34

300 m

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- Rail Alignment/Centreline
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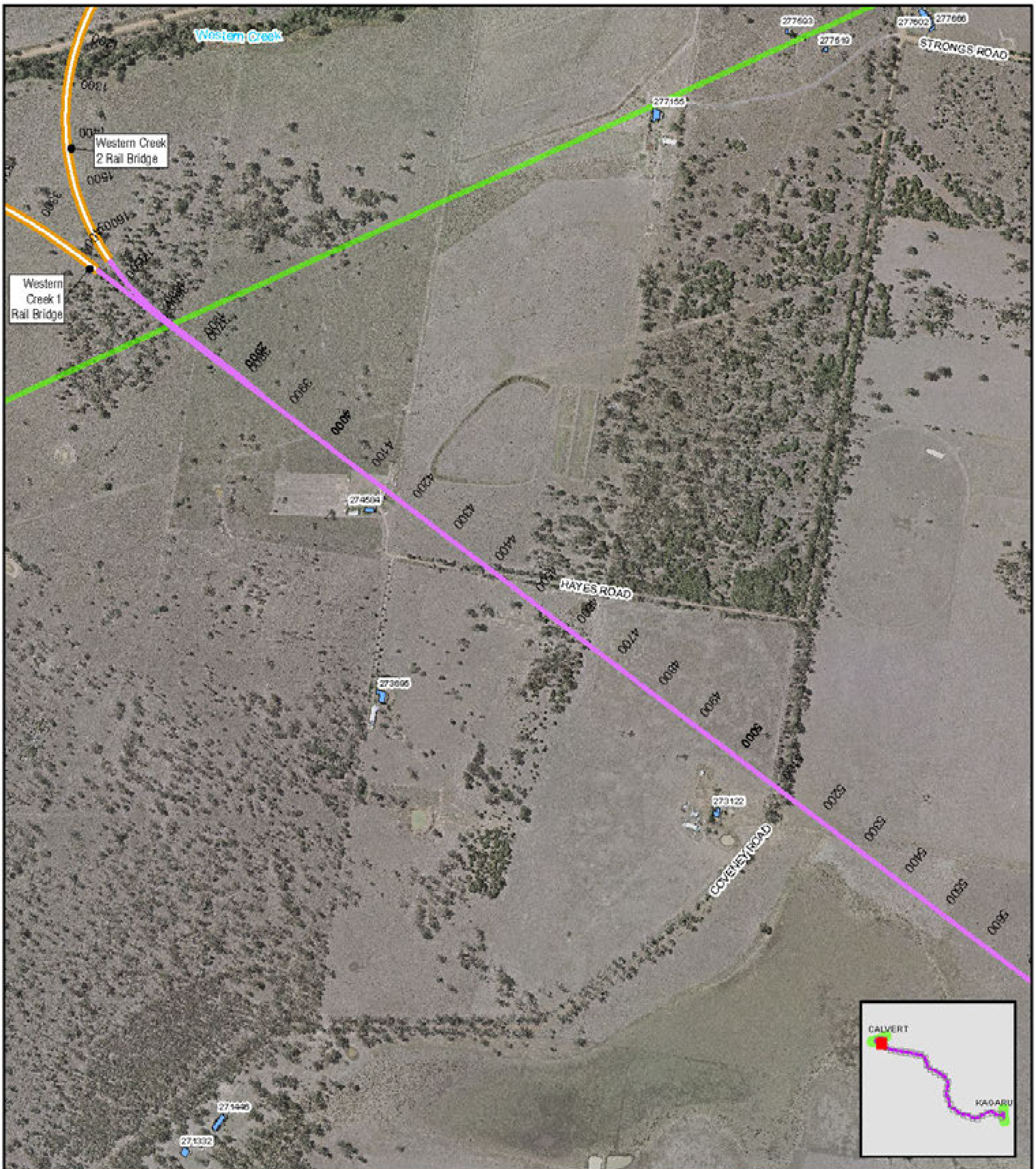

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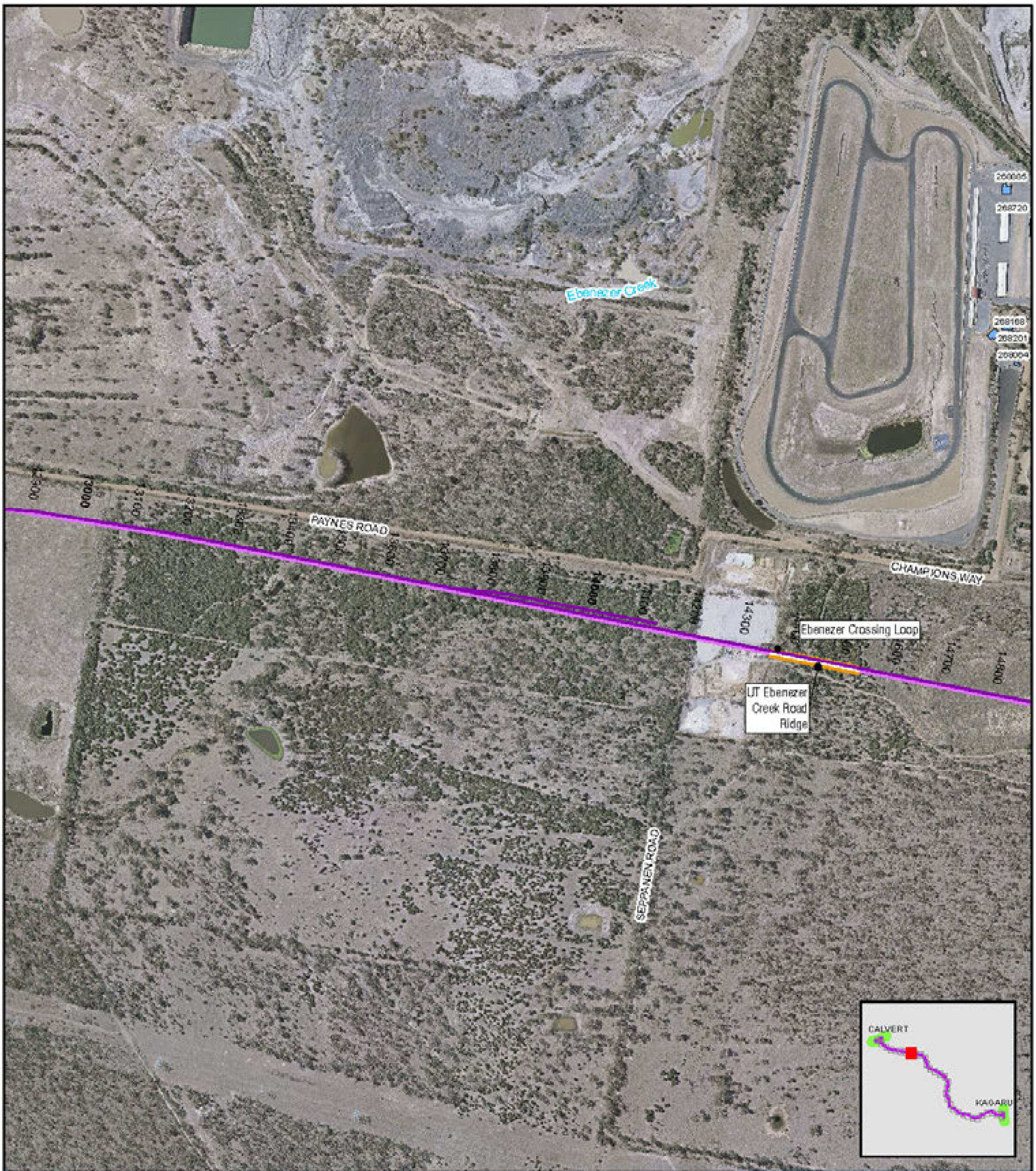

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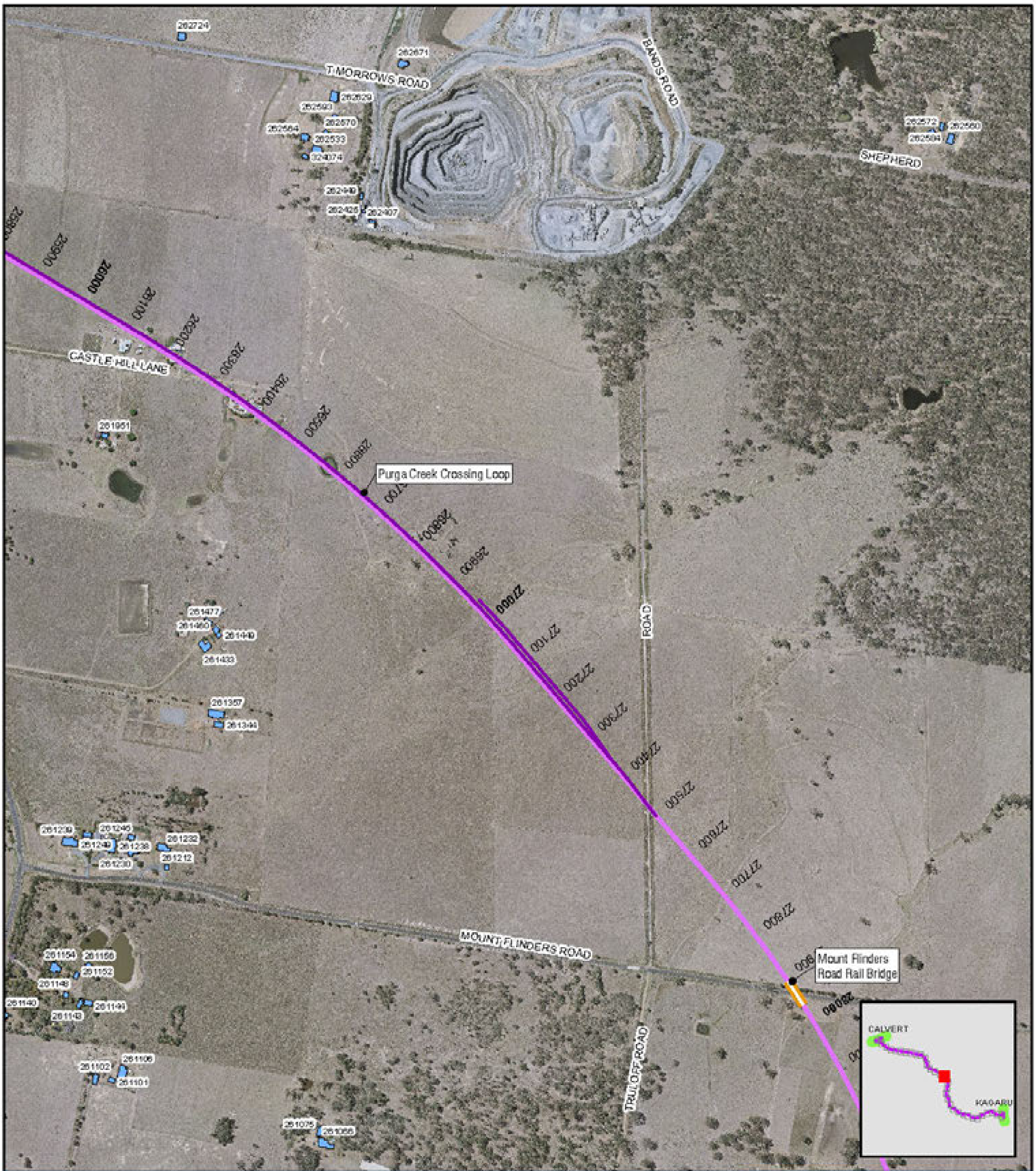

CALVERT TO KAGARU

Sensitive Receptors

APPENDIX A - Map 17 of 34

300 m

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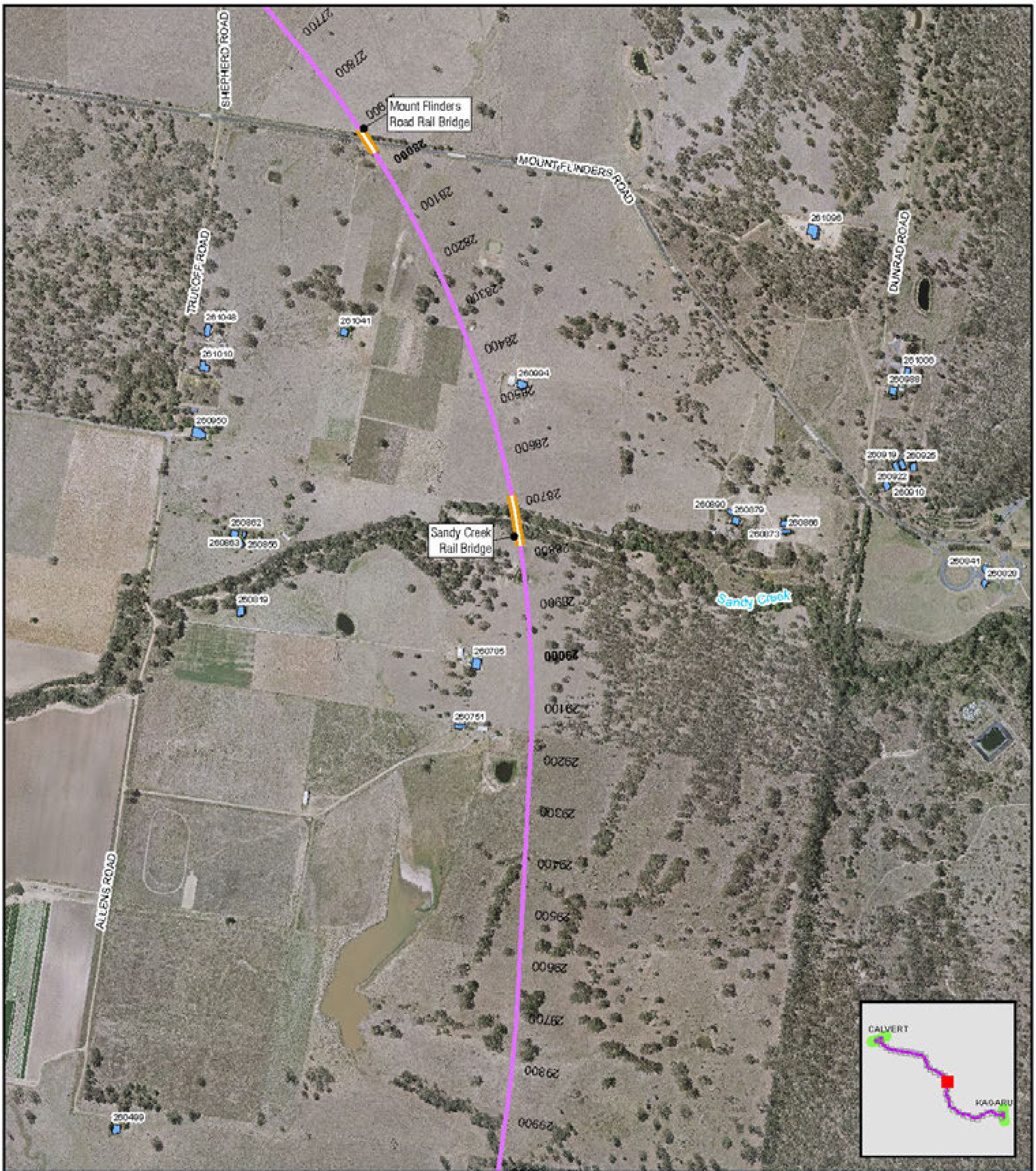

CALVERT TO KAGARU

Sensitive Receptors

APPENDIX A - Map 18 of 34

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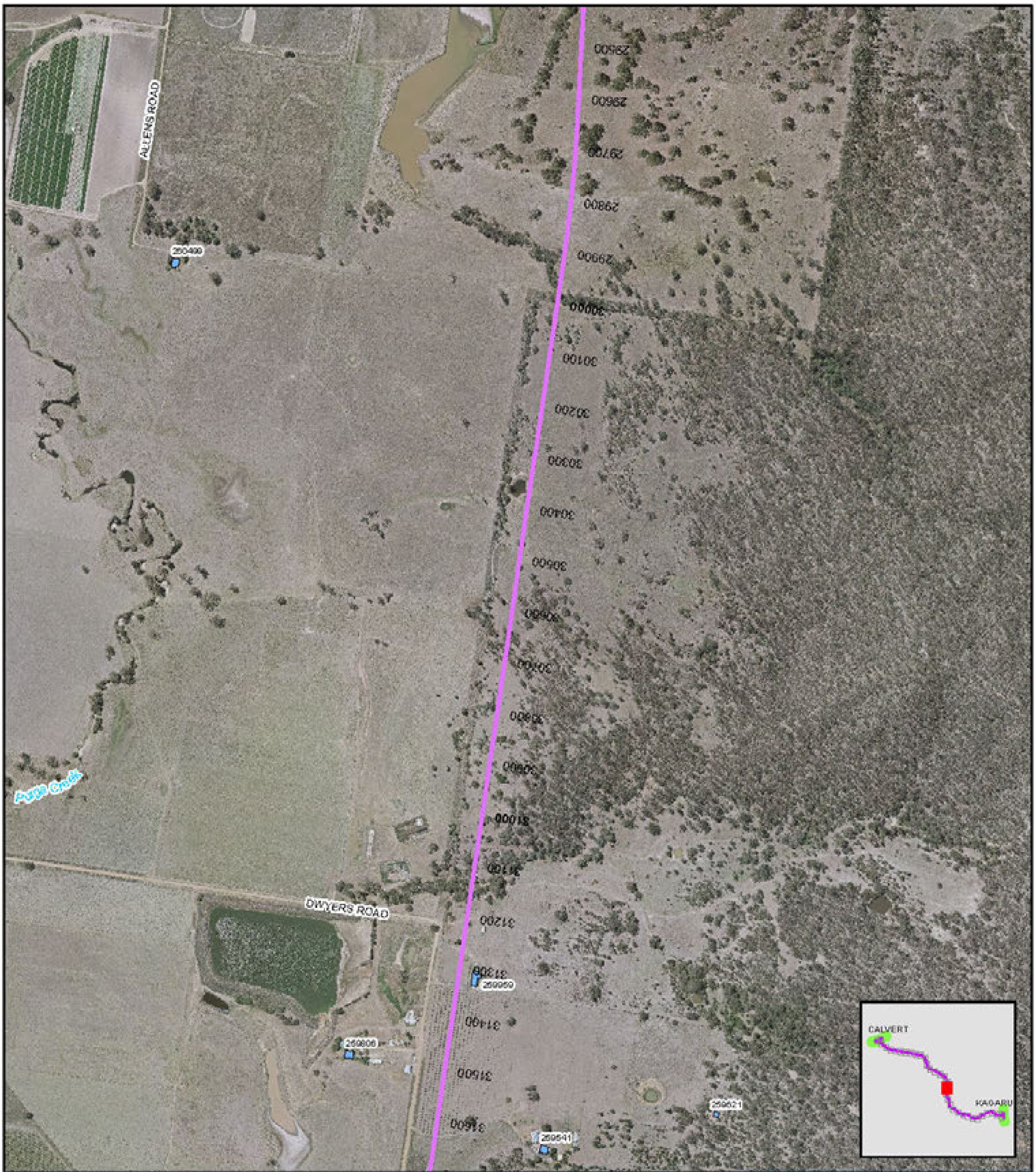

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APPENDIX A - Map 19 of 34

300 m

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- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
- Bridges & Viaducts
- Teviot Range Tunnel
- Sensitive Receptors (Residential)

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Scale: 1:10,000
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APPENDIX A - Map 20 of 34

300 m

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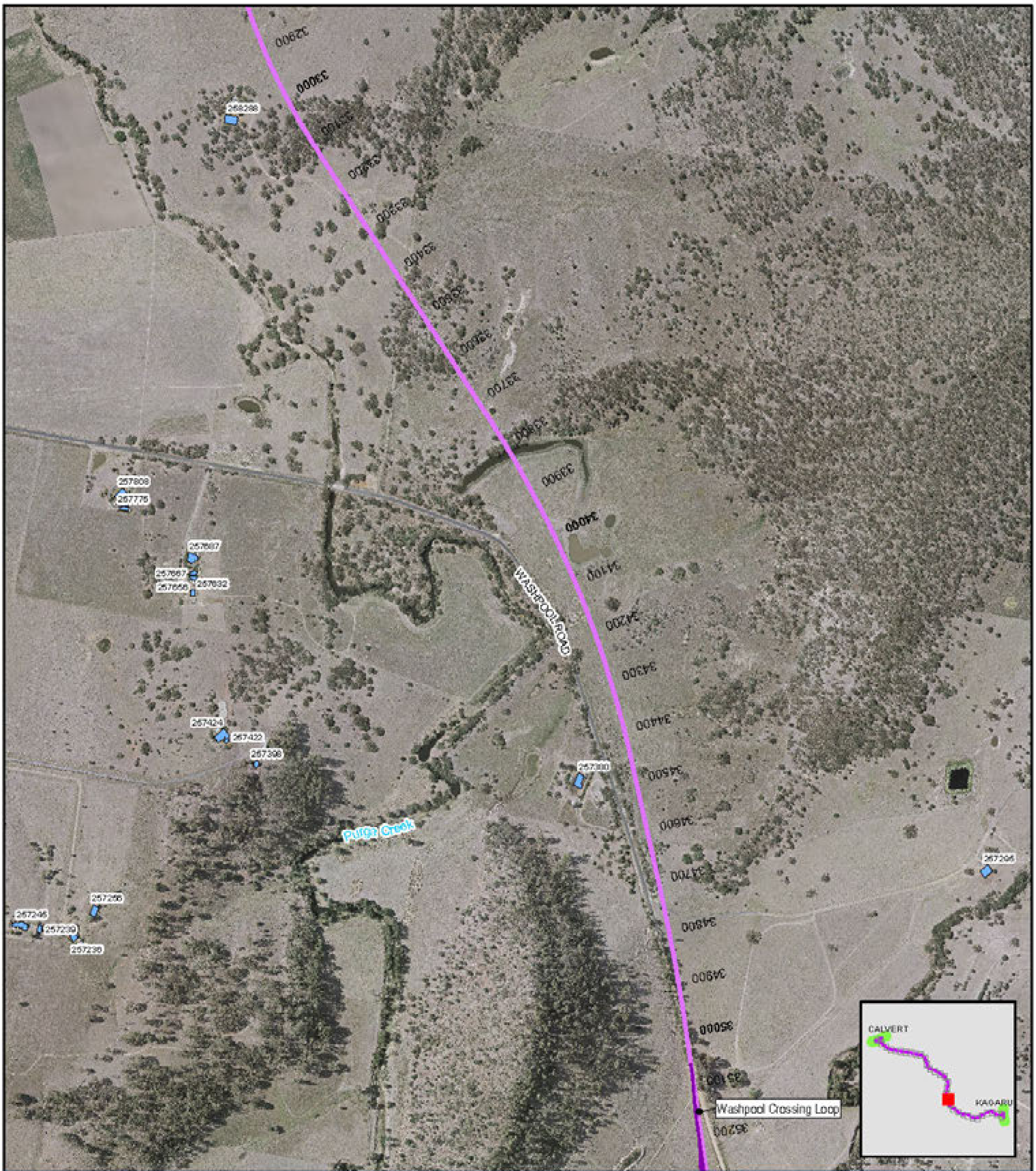

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300 m

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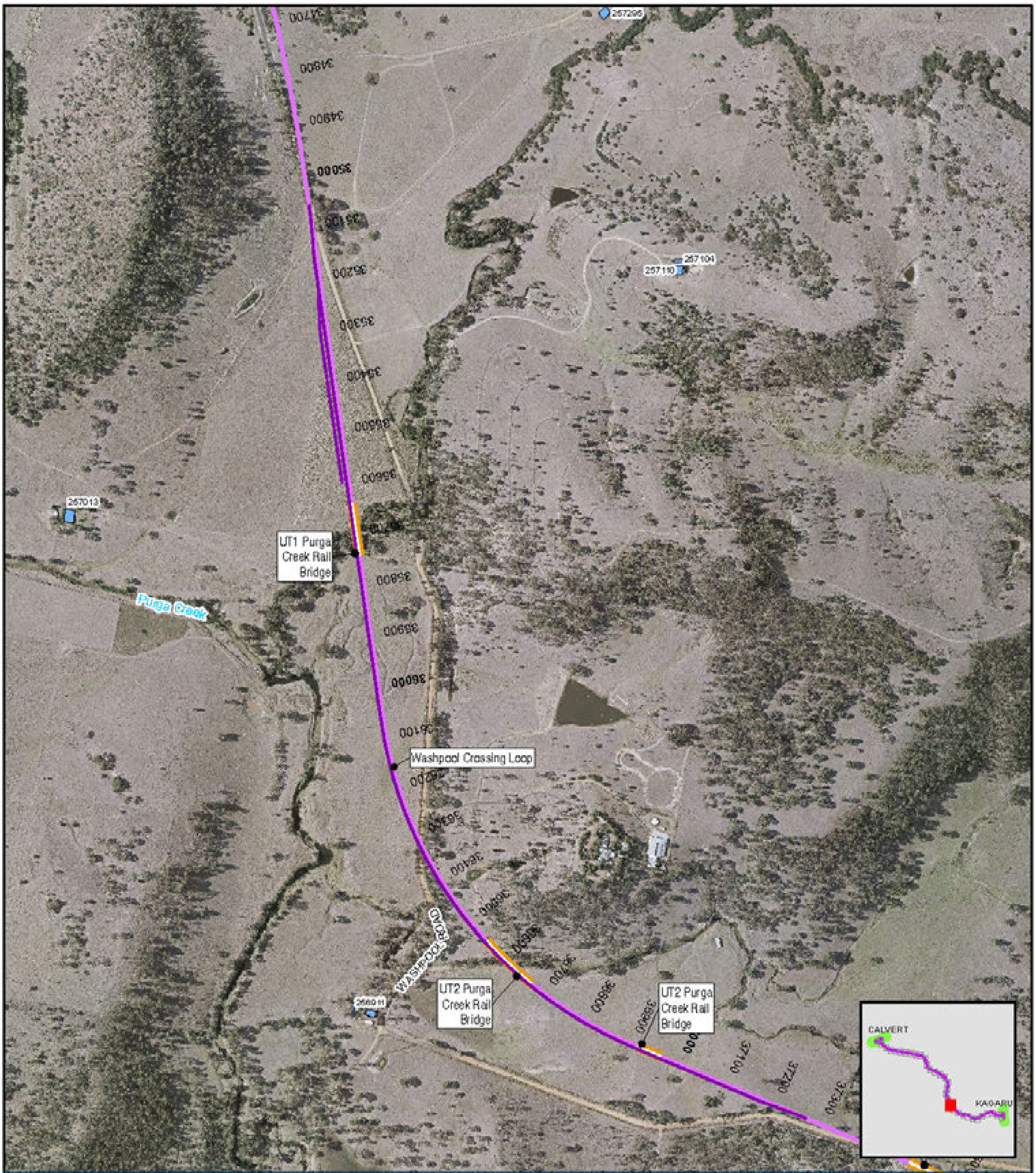

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300 m

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300 m

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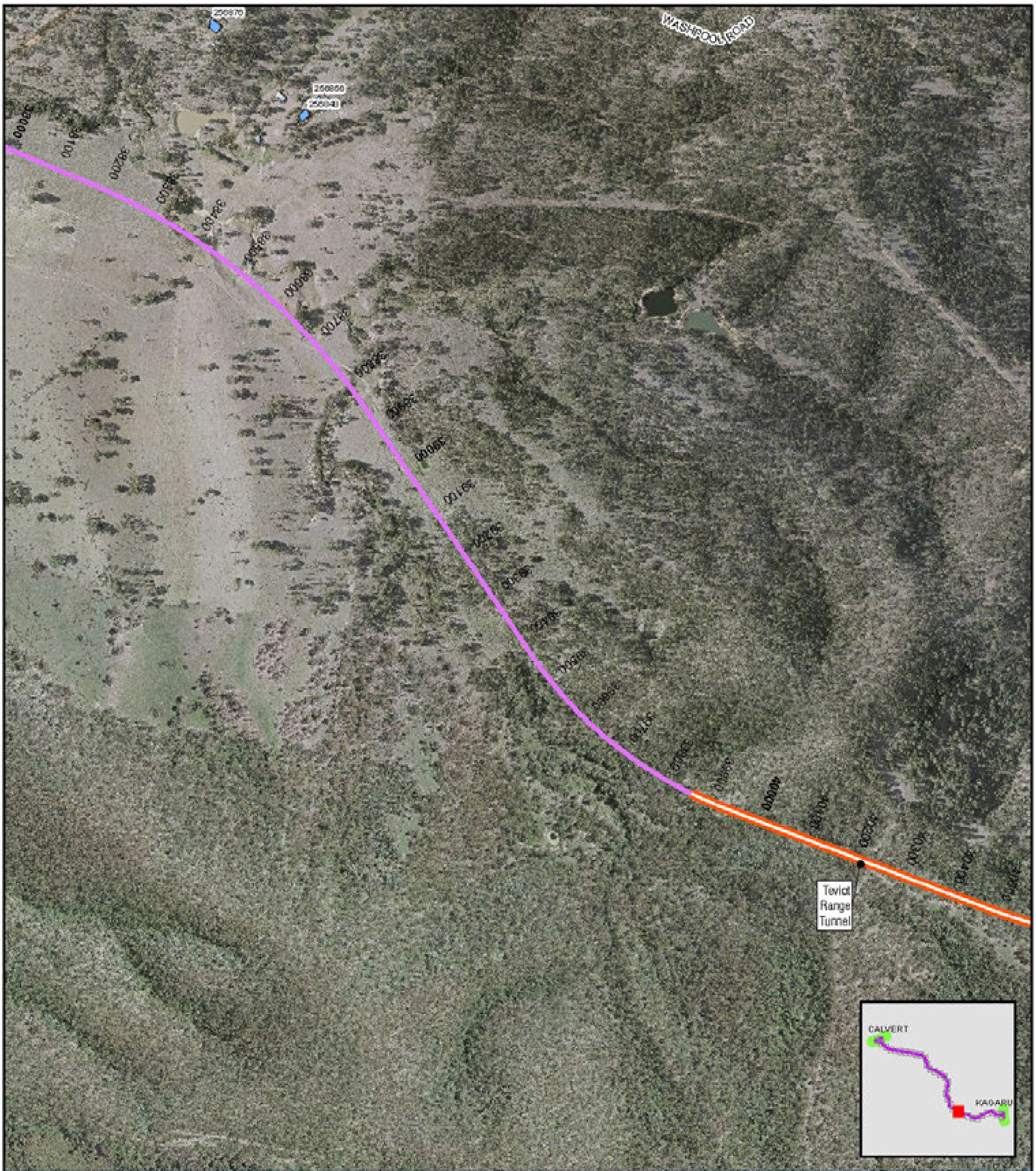

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APPENDIX A - Map 24 of 34

300 m

Coordinate System: GDA 1994 MGA Zone 56

- Project Extent
- Crossing Loops
- Rail Alignment/Centreline
- Bridges & Viaducts
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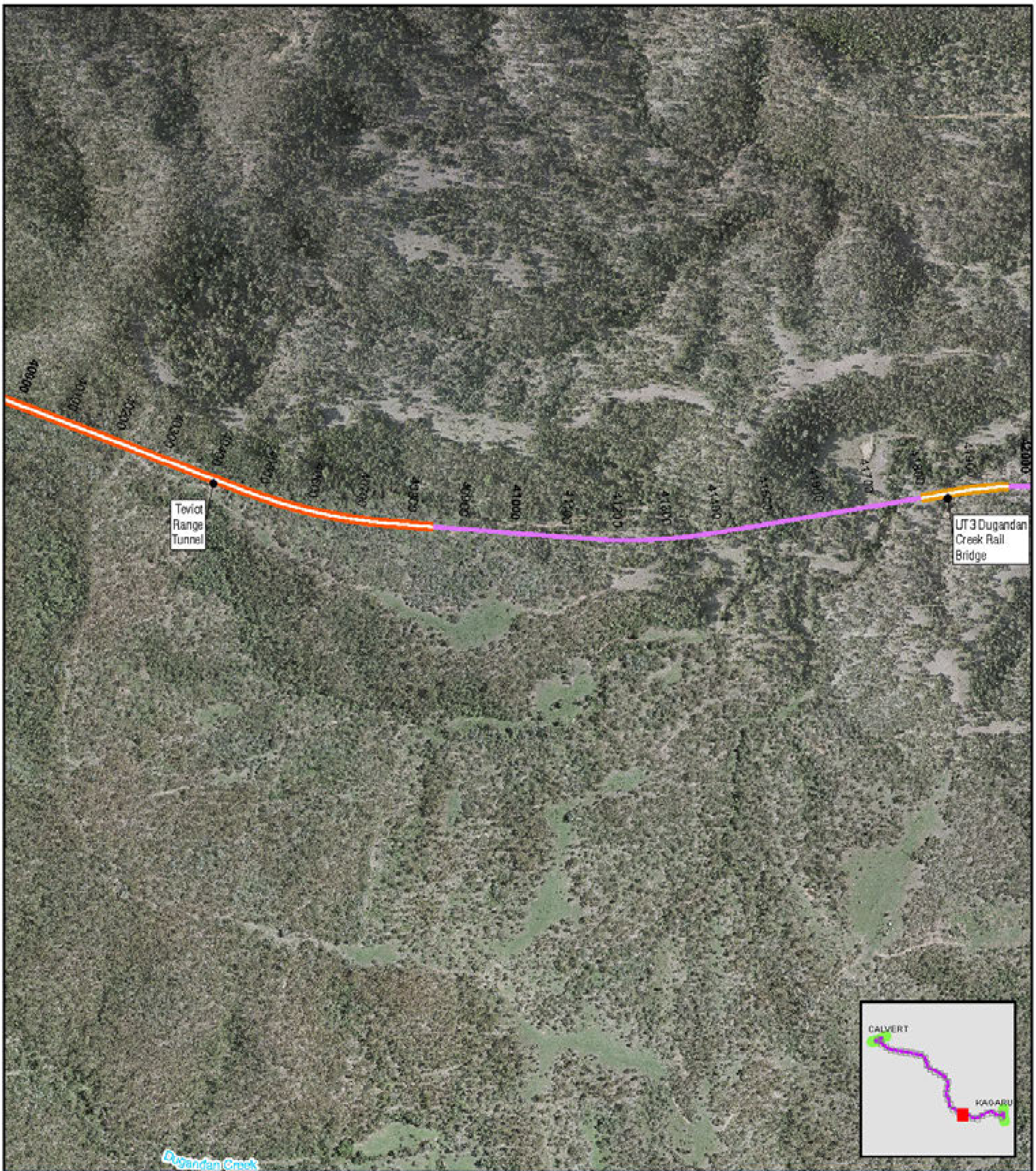

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APPENDIX A - Map 25 of 34

300 m

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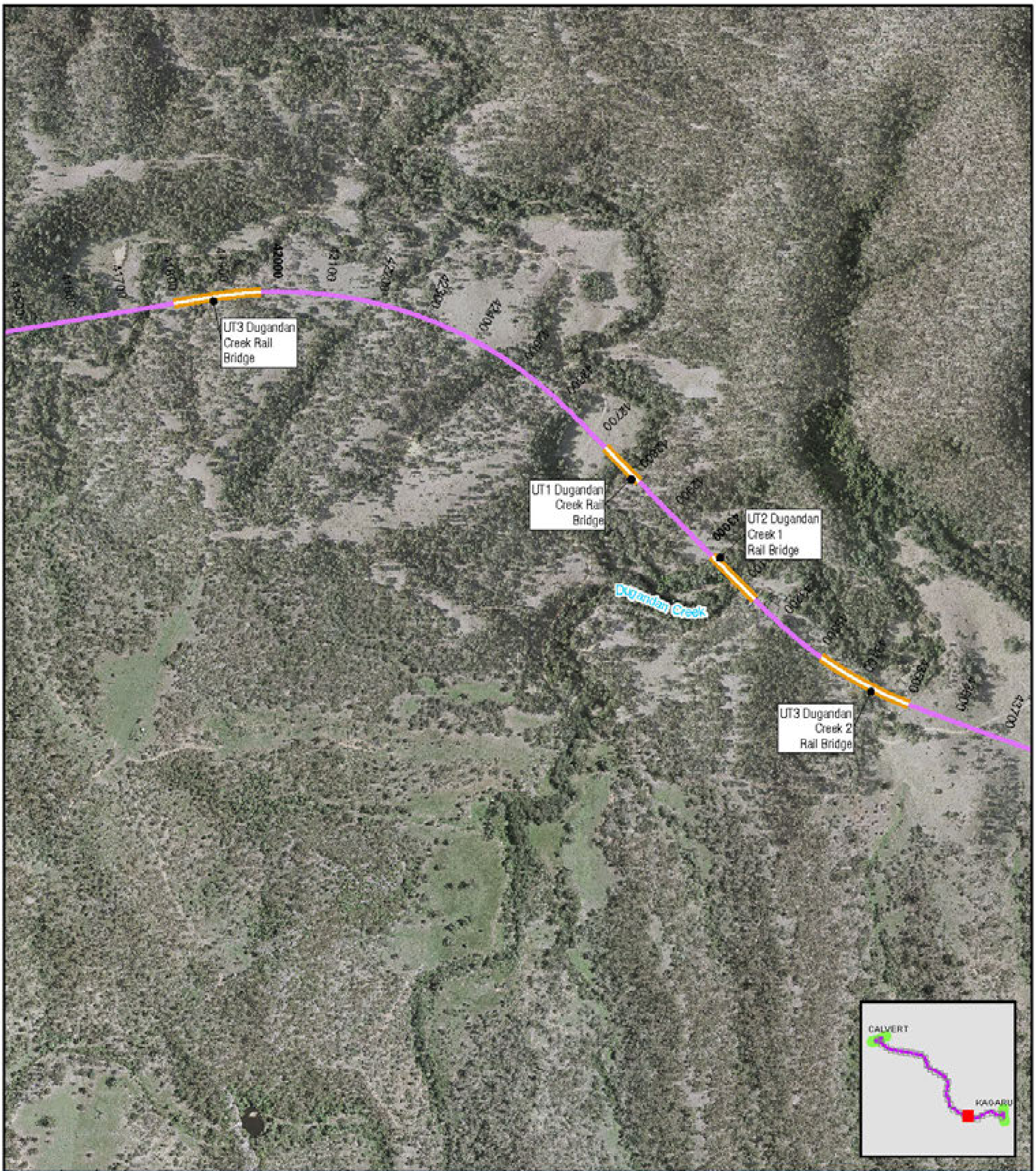

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Sensitive Receptors

APPENDIX A - Map 26 of 34

300 m

Coordinate System: GDA 1994 MGA Zone 56

- Project Extent
- Crossing Loops
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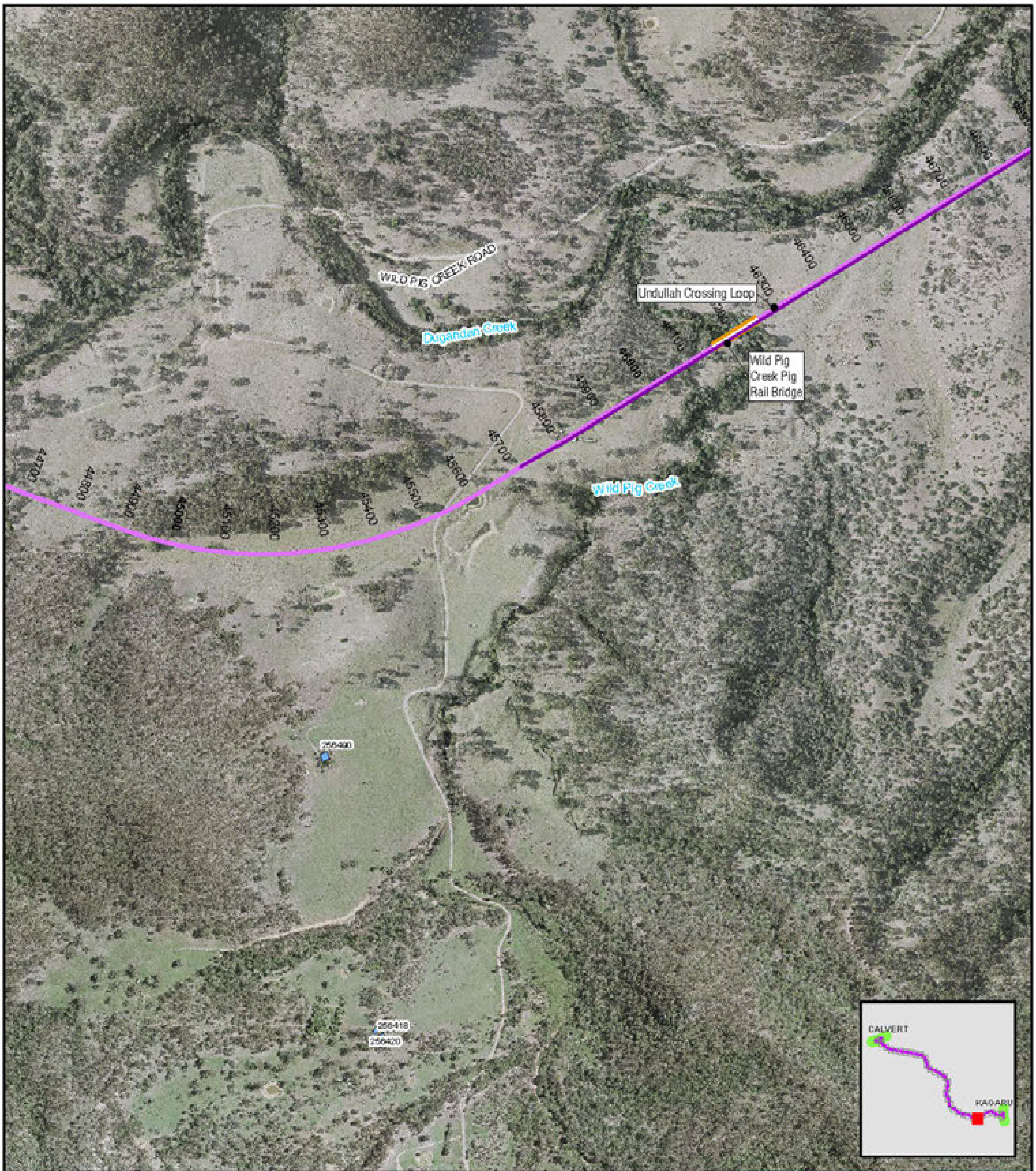

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300 m

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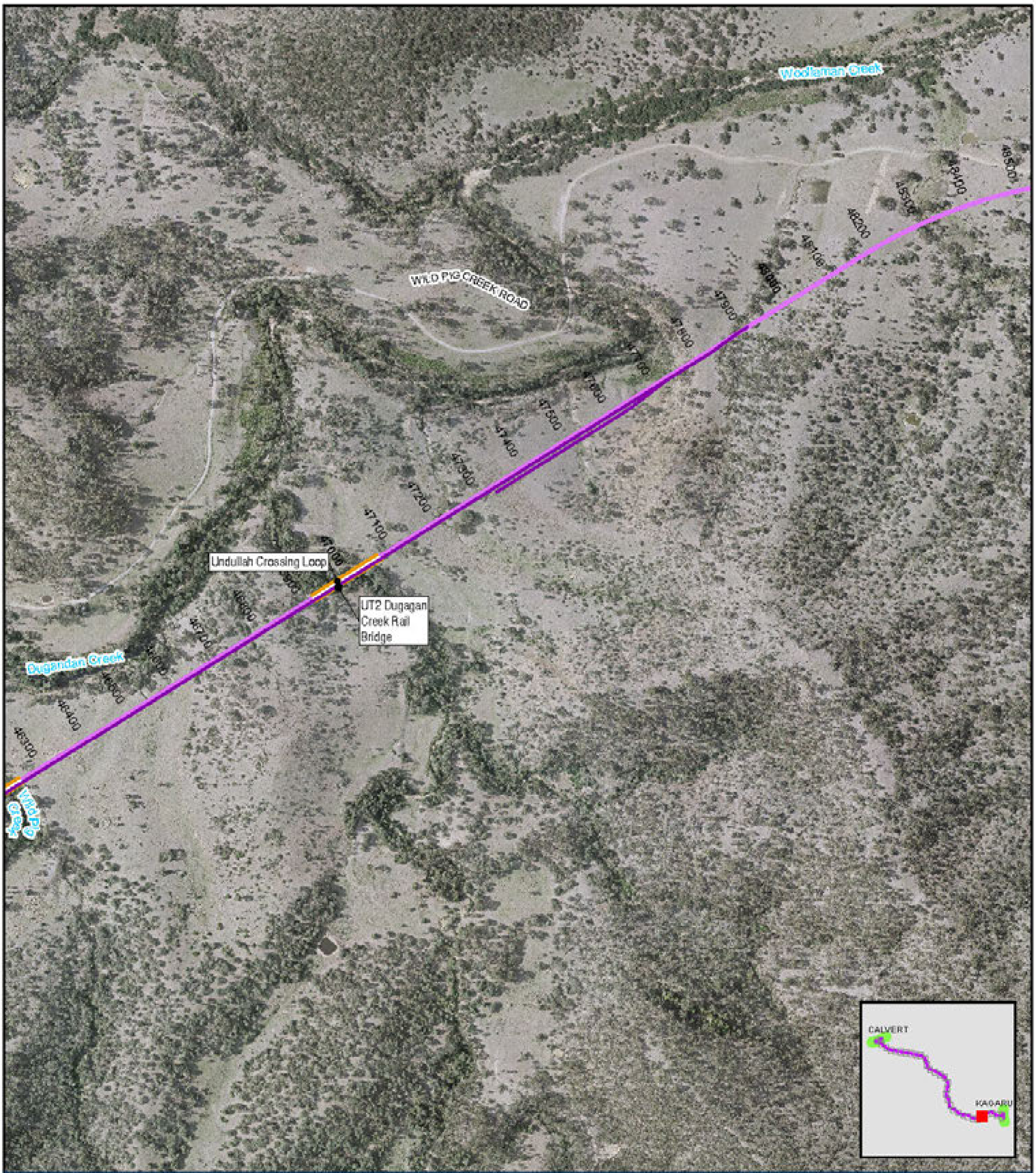

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Sensitive Receptors

APPENDIX A - Map 29 of 34

300 m

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Sensitive Receptors

APPENDIX A - Map 30 of 34

300 m

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Sensitive Receptors

APPENDIX A - Map 31 of 34

300 m

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Sensitive Receptors

APPENDIX A - Map 32 of 34

300 m

Coordinate System: GDA 1994 MGA Zone 56

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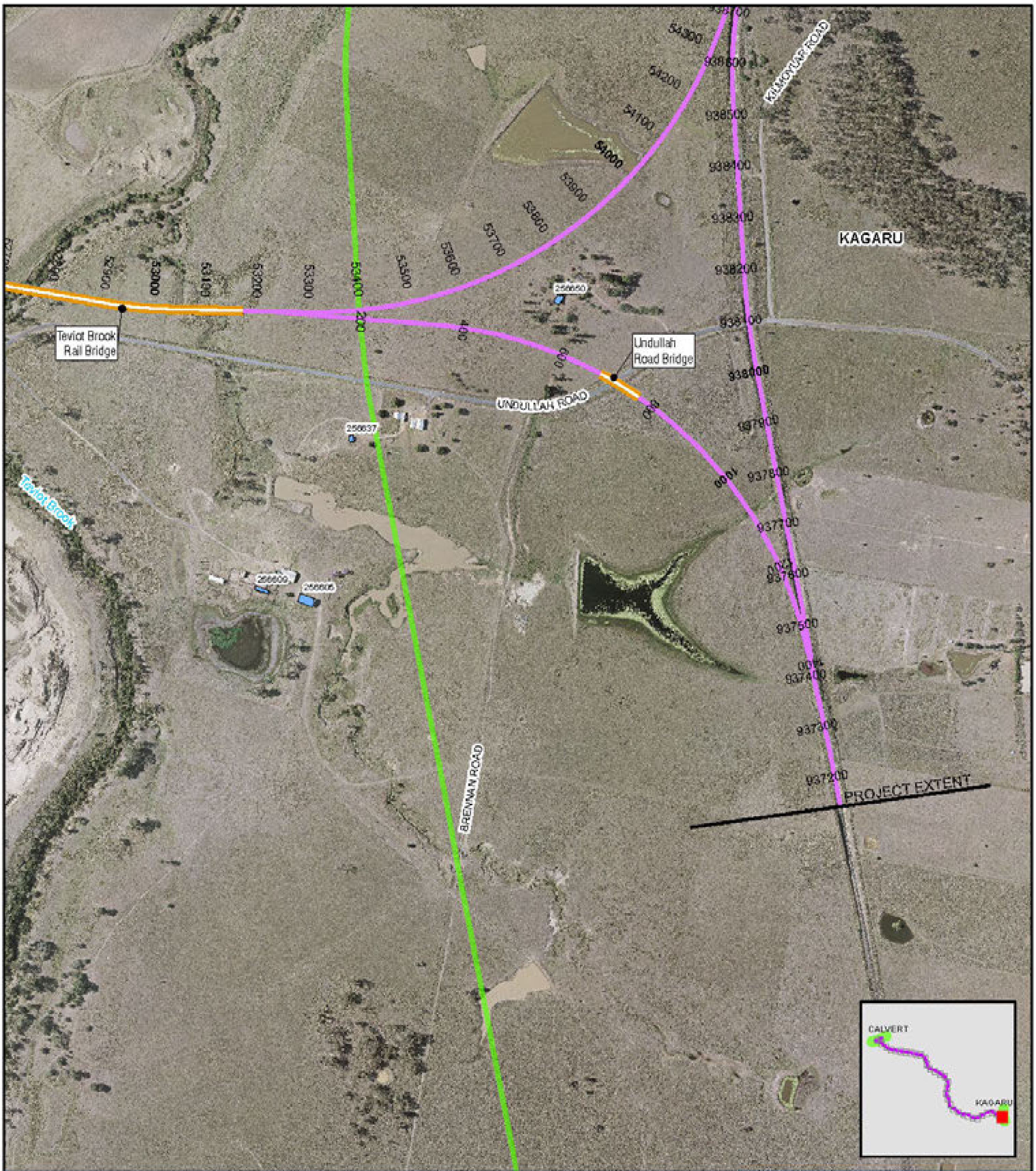

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APPENDIX A - Map 33 of 34

300 m

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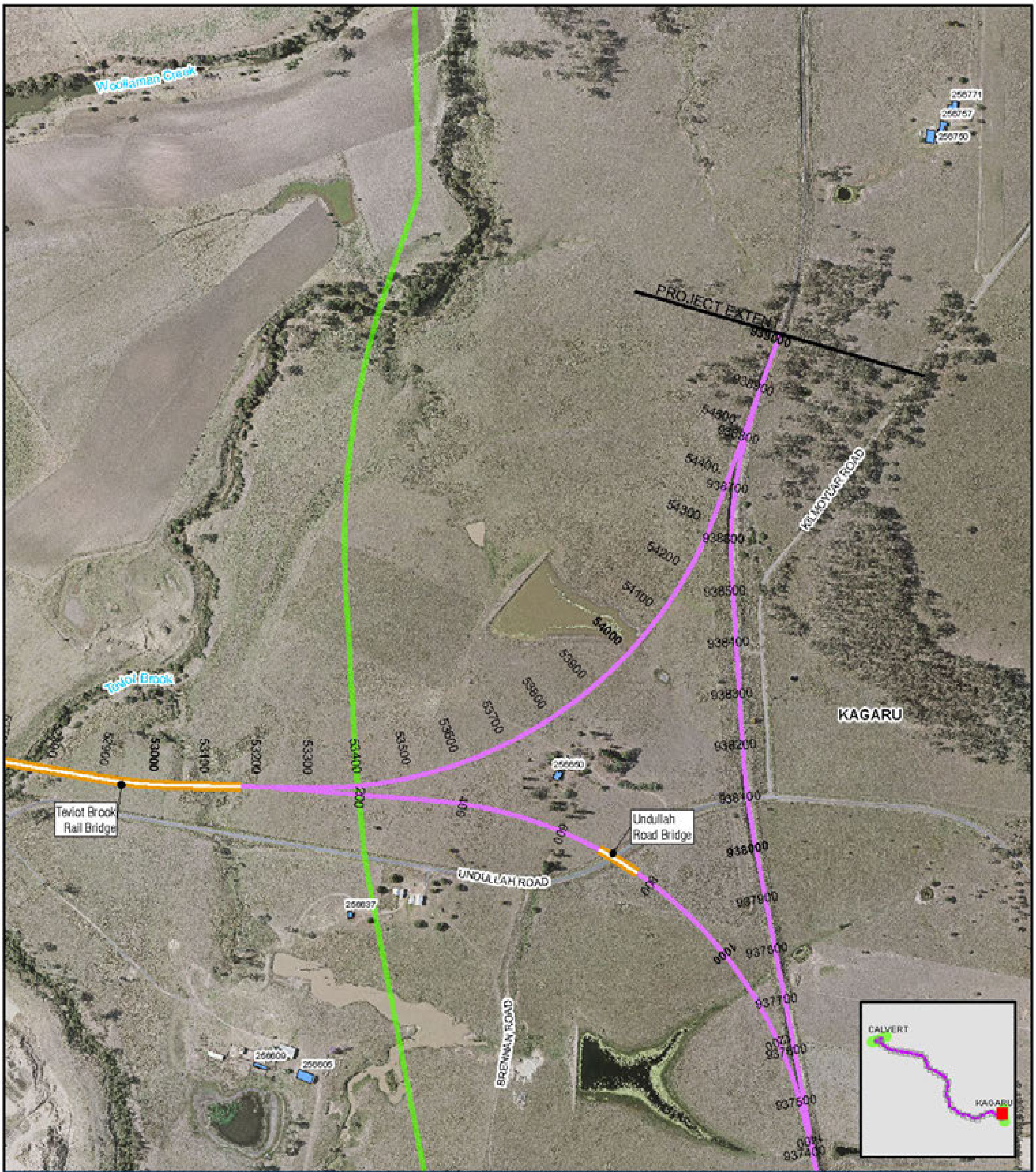

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Sensitive Receptors

APPENDIX A - Map 34 of 34

300 m

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APPENDIX

Q

Operational Noise and Vibration Technical Report

Appendix B Noise prediction model verification (Queensland)

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

IR_1381

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 and QR provide 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 24** 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 QR West Moreton System rail corridor.

The details of the railway noise monitoring and noise model verification in three townships in Queensland are provided in the following sections. Whilst the specific verification sites are outside the Project study area, the outcomes of the verification are reliable for the verification of the noise model and modelling methodology.

Noise monitoring locations and methodology

The noise monitoring locations were selected based on the following criteria, designed to provide a consistent approach 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, locations were within 50 m of the rail corridor to be representative of the nearest sensitive receptors that align the rail corridor 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 on Inland Rail.
- Railway operations were predominately heavy rail traffic (coal and freight 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).

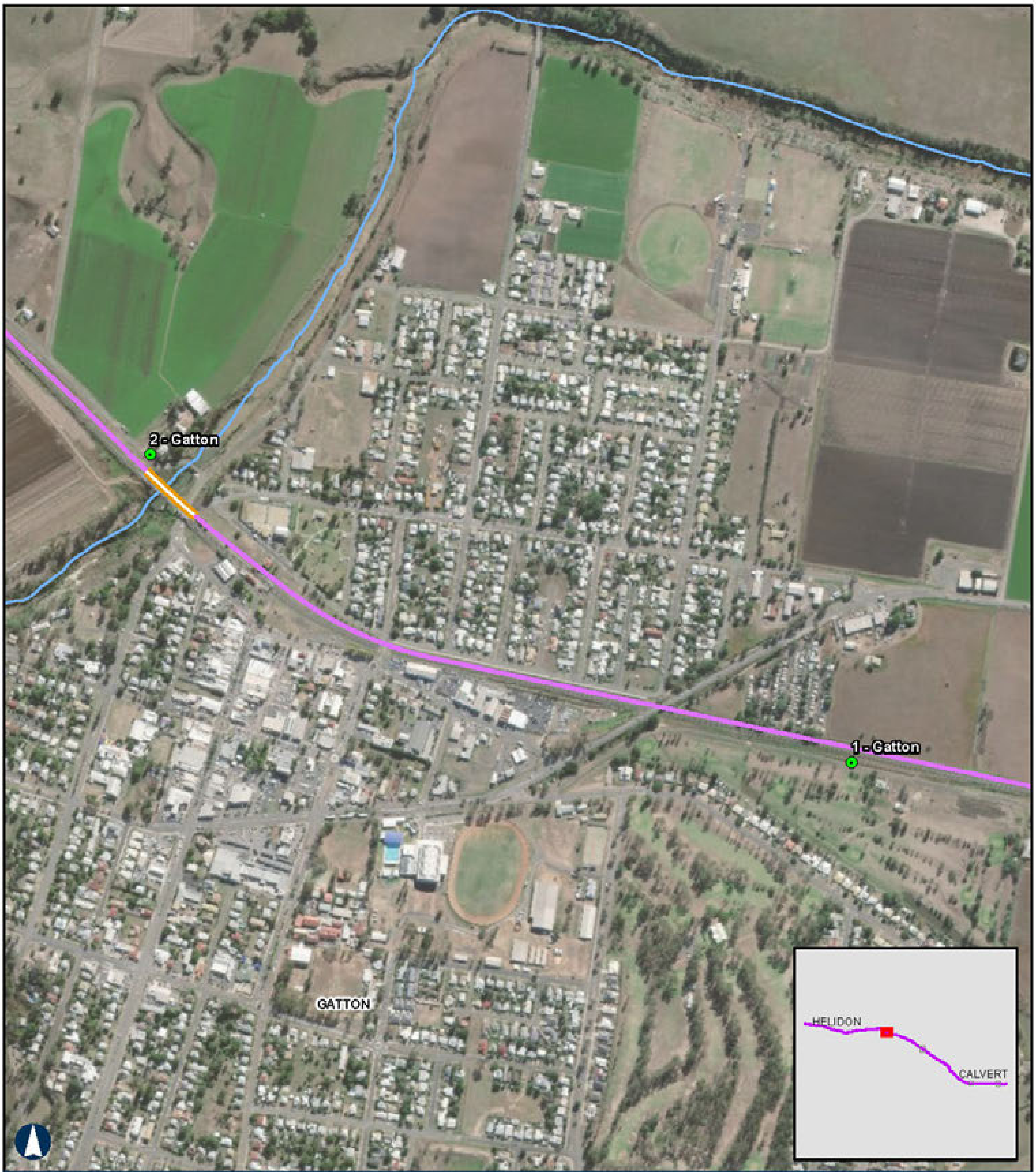
Railway noise levels for the daily existing trains movements were monitored at five individual locations at the townships of Gatton, Forest Hill and Calvert, as summarised in **Table B1** and presented in **Figure B1**.

Table B1 Noise monitoring locations in Queensland

SLR ID	Location	Monitoring dates	Equipment[1,2]
1	Smithfield Road, Gatton 40 m from the outer rail	20 to 27 March 2019	SVAN 957 noise logger (27580)
2	Chadwick Road, Gatton 17 m from the outer rail	20 to 27 March 2019	SVAN 957 noise logger (23241)
3	Railway Street, Forest Hill 15 m from the outer rail	20 to 27 March 2019	NGARA noise logger (8781A5)
4	Gordon Street, Forest Hill 18 m from the outer rail	20 to 27 March 2019	NGARA noise logger (8780FF)
5	Newcastle Street, Calvert 78 m from the outer rail	21 to 27 March 2019	NGARA noise logger (8780AF)

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.



QLD NOISE MODEL VERIFICATION

FIGURE B1 - Map 1 of 3

200 metres

Coordinate System: GDA 1994 MGA Zone 56

- Noise Monitoring Locations
- Rail Alignment/Centreline
- Bridges and Viaducts
- Watercourses

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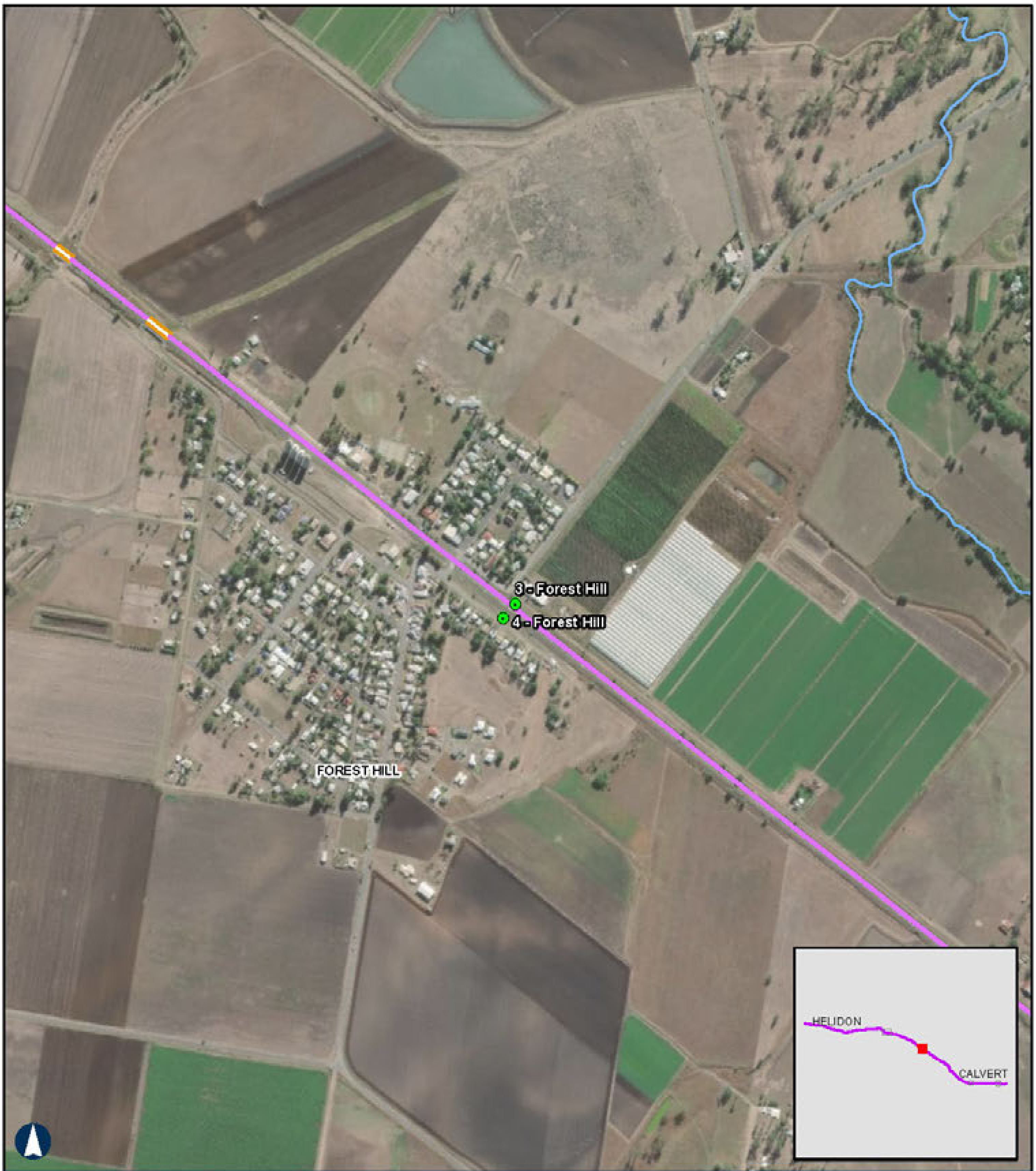

QLD NOISE MODEL VERIFICATION

FIGURE B1 - Map 2 of 3

200 metres

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- Noise Monitoring Locations
- Rail Alignment/Centreline
- Bridges and Viaducts
- Watercourses

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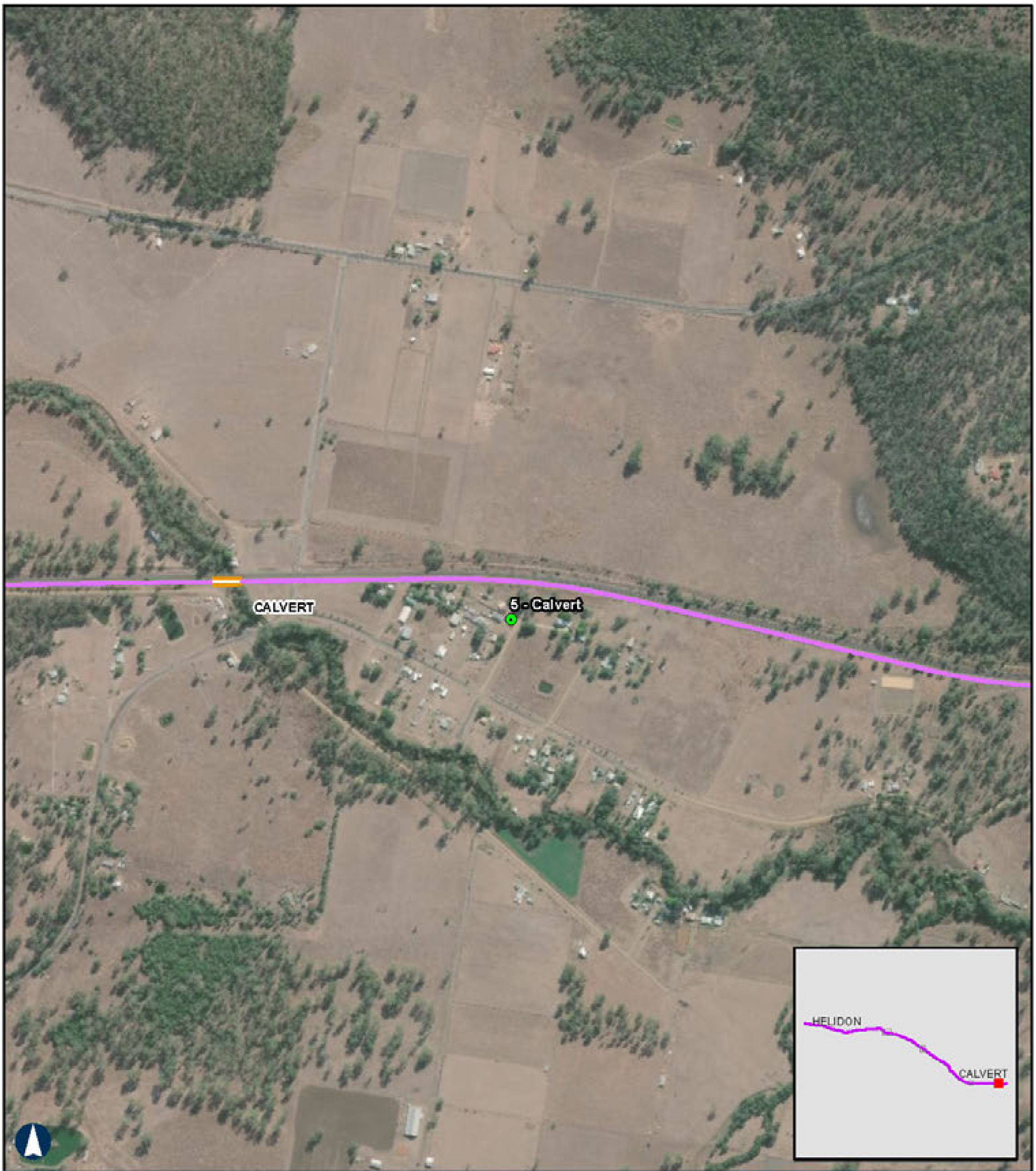

QLD NOISE MODEL VERIFICATION

FIGURE B1 - Map 3 of 3

200 metres

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Noise Monitoring Locations
Rail Alignment/Centreline
Bridges and Viaducts
Watercourses

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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 were within 10 dBA of the ambient noise level.
- 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 no other, erroneous, activity nearby to the monitoring location.

Monitored daily rail noise levels

The highest daily L_{Aeq} and L_{Amax} railway noise levels at each monitoring location are detailed in the following table. The L_{Aeq} and L_{Amax} noise levels are the highest noise levels reported over a 24-hour period.

The L_{Amax} railway noise levels have been determined as the 95th percentile in line with ARTC's noise assessment criteria for Inland Rail. The 24-hour L_{Amax} noise level has been reported as the Single Event Maximum (SEM), which is the arithmetic average of the 15 highest L_{Amax} passby noise levels in a 24-hour period or the arithmetic average of all L_{Amax} noise levels where there were fewer than 15 train passbys in a 24-hour period. The L_{Amax} noise levels exclude the influence from train horns and level crossing alarm bells.

Weather data was referenced from the nearest Bureau of Meteorology weather station at Gatton, station number 94562. 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 monitored railway noise levels at the locations in Gatton, Forest Hill and Calvert are detailed in **Table B2**.

Table B2 Monitored daily railway noise levels

Monitoring location	Monitored railway noise levels, dBA				
	Daytime	Night-time	Daytime	Night-time	24-hour
	$L_{Aeq,15hr}$	$L_{Aeq,9hr}$	L_{Amax}[1]	L_{Amax}[1]	SEM[2]
ID 1 Gatton	56.0	56.7	88.6	85.7	83.6
ID 2 Gatton	55.4	56.0	85.9	87.6	83.7
ID 3 Forest Hill	61.2	59.2	88.1	88.1	86.4
ID 4 Forest Hill	59.7	61.1	88.9	89.7	86.3
ID 5 Calvert	47.0	47.8	77.4	78.3	71.6

Note 1 Maximum railway noise levels determined as the 95th percentile LAmax noise level per period.

Note 2 SEM as defined by Section 3.1.3 of the DTMR Interim Guideline, Operational Railway Noise and Vibration, March 2019.

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

- At ID 1 in Gatton, the nearby steel framed railway bridge did not substantially influence the rolling noise, when compared to the adjacent surface track sections. The trains speed of approximately 50 km/h in Gatton may not have been sufficient for the bridge structure to be a source of elevated rolling noise.
- The L_{Amax} noise levels in Gatton were, at times, influenced by trains accelerating using short-lived higher notch settings as the train departed the centre of Gatton. The specific notch settings and acceleration was dependent on the driver and varied for each train.
- The monitored noise levels vary by 1 dBA to 2 dBA between the two monitoring locations at Forest Hill and demonstrate rail noise levels are generally consistent either side of the immediate rail corridor.
- At Calvert, whilst the train passbys were clearly audible, the ambient noise levels and local environment (buildings and vegetation) had an influence on the ability to isolate the complete duration, and L_{Aeq} noise level, of some train passbys events. The L_{Amax} noise levels were clearly defined.
- At all monitoring locations the SEM was in the order of 1 dBA to 6 dBA lower than the daytime or night-time 95th percentile L_{Amax} noise levels.

Noise modelling

To enable verification of the monitored noise levels, the SoundPLAN noise modelling developed for the Inland Rail project, as discussed in **Section 6** of this report, was applied to calculate railway noise levels at each noise monitoring location.

A summary of the key noise modelling data and methodologies for the existing railway noise levels is provided in **Table B3**.

Table B3 Noise modelling inputs

Noise model attribute	Source data/ modelling approach
Daily train movements	Refer to Table B1 for the QR West Moreton System
Rail line speeds	Referencing the monitored data the train speeds were estimated as 50 km/h in Gatton, 60 km/h in Forest Hill and Calvert.
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 with consist 850 m in length
Passenger rail traffic	There were no passenger rail movements on the QR West Moreton System
Local environment	3-dimensonal digital terrain models were developed for the existing environment at each monitoring location. Ground conditions were modelled as hard ground (ground absorption co-efficient of 0.0).

Noise model attribute	Source data/ modelling approach
Locomotive source noise emission levels	The rollingstock classes were determined from on-site observations and datasets of the rollingstock in use on each rail line. The following noise emission levels were assigned based on the Inland Rail noise emission database, with reference to comparable datasets developed by TfNSW and QR.

Rollingstock category	Reference length	Reference noise level, dBA	
		SEL	L_{Amax}
QR West Moreton System, Queensland			
82 Class locomotive (two per train) (representative of typical coal train locomotives)	22 m	83	89
NR Class locomotive (two per train) (representative of typical freight locomotives)	22 m	85	90

Note All noise levels are referenced at a distance of 15 m for a speed of 80 km/h.

Noise model verification

The predicted and monitored L_{Aeq} and L_{Amax} 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 noise levels were within ±2 dBA of the measured railway noise levels.

The modelled locomotive noise emissions at location ID 1 in Gatton included a +4 dBA adjustment to the modelled source levels to account for the intermittent localised increases in notch setting which were observed and monitored as trains had passed through the centre of Gatton.

Table B4 Modelled railway noise levels

Monitoring location	Railway noise levels, dBA			
	Daytime	Night-time	Daytime	Night-time
	$L_{Aeq,15hr}$	$L_{Aeq,9hr}$	L_{Amax}[1]	L_{Amax}[1]
QR West Moreton System, Queensland				
ID 1 Gatton	57.4	57.5	88.5	88.6
ID 2 Gatton	59.5	59.8	91.6	91.6
ID 3 Forest Hill	60.9	61.2	91.2	91.2
ID 4 Forest Hill	60.8	61.1	91.1	91.1
ID 5 Calvert	52.8	53.2	79.3	79.3

Note 1 Daytime and Night-time LAmax is the 95^{th} percentile LAmax rail noise level

The monitored and modelled L_{Aeq} and L_{Amax} noise levels at each location were compared, as detailed in **Table B5**. The noise model validation was determined for all five noise monitoring locations. Because the monitored L_{Aeq} noise levels at Calvert were at times influenced by the local environment the validation was also undertaken for the locations at Gatton and Forest Hill (total four 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 meets DTMR guidelines on transport noise model validation. The L_{Amax} noise levels are a relatively minor 0.5 to 1 dBA more than the desired 2 dBA verification and this is discussed further after **Table B5**. At the EIS stage it is satisfactory to 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	Noise model verification, dBA				
	Daytime	Night-time	Daytime	Night-time	24-hour
	$L_{Aeq,15hr}$	$L_{Aeq,9hr}$	L_{Amax}[1]	L_{Amax}[1]	SEM[2]
QR West Moreton System, Queensland					
ID 1 Gatton	1.4	0.8	-0.1	2.9	5.0
ID 2 Gatton	4.1	3.8	5.7	4.0	7.9
ID 3 Forest Hill	-0.3	2.0	3.1	3.1	4.8
ID 4 Forest Hill	1.1	0.0	2.2	1.4	4.8
ID 5 Calvert	5.8	5.4	1.9	1.0	7.7
Model validation all locations	2.4	2.4	2.6	2.5	6.0
Model validation locations ID 1,2,3 & 4	1.6	1.7	2.7	2.9	5.6

Note 1 Daytime and Night-time LAmax is the 95th percentile LAmax rail noise level

Note 2 Single Event Maximum level for the LAmax railway noise levels.

The following features of the existing railway operations and the noise modelling methodology are considered to have influenced the noise model validation.

- In Gatton the noise monitoring data and on-site observations identify potential for the speed of individual trains to vary depending on the time of day and driver behaviour. The monitored L_{Aeq} noise levels are sensitive to variations to factors such as train speed. The noise model assumes a consistent train speed of 50 km/h in Gatton and does not account for individual trains travelling at varying speeds.
- In Forest Hill the train speed was observed to be generally consistent and is suitably replicated by the consistent train speed applied in the noise model.
- The modelling of L_{Aeq} noise levels at Calvert does not account for the localised ambient noise which at times influenced the monitored L_{Aeq} railway noise levels.

The monitored 95th percentile L_{Amax} noise levels are less sensitive to outliers than the arithmetically averaged SEM noise levels. Consequently, the noise model, which adopted a consistent L_{Amax} noise emission, validates better to the 95th percentile L_{Amax} than the SEM.

APPENDIX

Q

Operational Noise and Vibration Technical Report

Appendix C Noise and vibration from double stacked freight wagons

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

IR_1381

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 top soil.
- 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 (three noise and three vibration) 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 dBV) are higher with the single stacked container wagons.

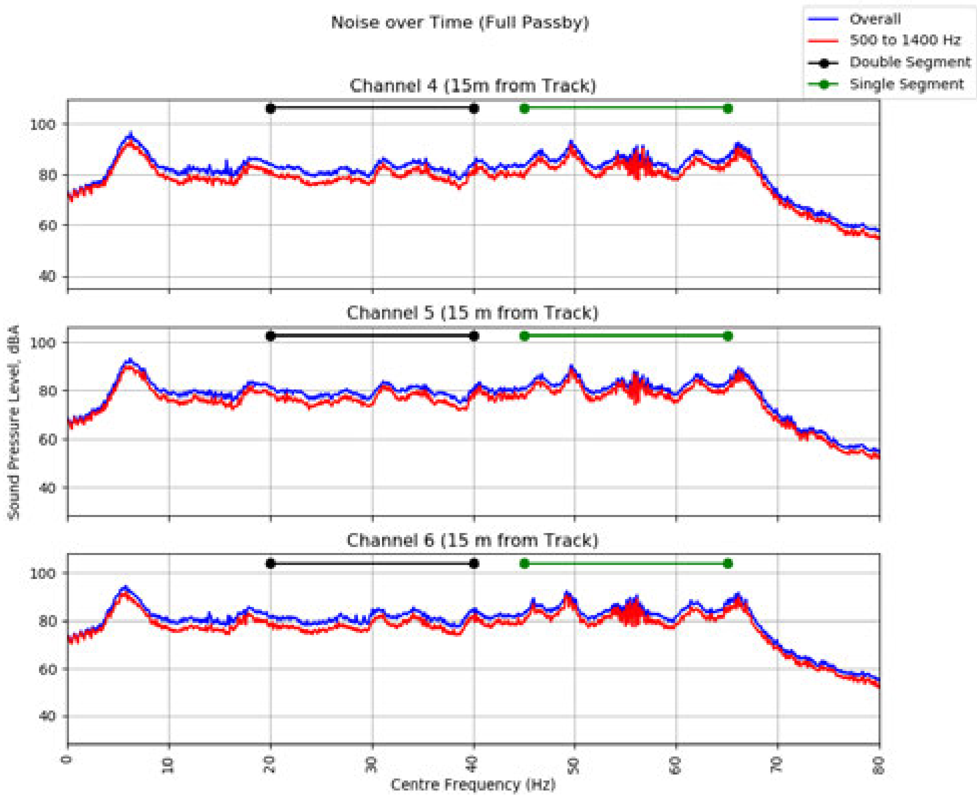
It is considered that if a noise emission correction factor were to be applied to the stacking configuration, this would be complicated by many factors in practice, particularly the:

- proportion of wagons with single and double stacked containers and where they are located,
- number and position of empty wagons (no containers); and,
- 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 have not be considered in the Inland Rail operational rail noise and vibration assessments at the EIS stage.

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