Epping to Thornleigh Third Track

Operational Noise and Vibration Review – Jan 2015 – PART 1

ETTT ALLIANCE

Australian Government

Transport for NSW

Table of Contents

ABOUT THE ONVR

The Epping to Thornleigh Third Track Project (ETTT) involves the construction of six kilometres of new and upgraded track within the rail corridor between Epping and Thornleigh Stations on the western side of the existing tracks.

The new (third) track will separate northbound freight from all-stops passenger train movements along the steep incline between Epping and Thornleigh. This will help provide additional capacity for northbound interstate container freight trains, particularly during the daytime when passenger trains currently have priority.

The Conditions of Approval of the ETTT Project require the preparation of an Operational Noise and Vibration Review (ONVR) – this document. This ONVR has been prepared by the Epping to Thornleigh Third Track Alliance (the ETTT Alliance). The ETTT Alliance's operational noise and vibration technical advisor – SLR Consulting – contributed the technical content for the document including carrying out the numerical modelling. The ONVR provides details of predicted operational noise and vibration impacts associated with the ETTT Project, and proposed mitigation measures.

The ONVR is divided into two parts:

This Part

PART 1

- Brief description of ONVR requirements, development, findings and next steps
- Maps showing proposed mitigation measures

PART 2

- Technical description of the noise modelling process
- Full details of ONVR development

Included within this Part 1 is a series of maps that show what measures are proposed in order to mitigate the predicted noise and vibration due to the project.

GUIDELINES

The Environmental Protection Agency's, Rail Infrastructure Noise Guideline (RING) have recently replaced the Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (IGANRIP). RING applies to heavy and light rail infrastructure projects including the construction of new rail lines and upgrades to existing lines. RING provides a procedure for the consideration of feasible and reasonable noise mitigation measures that form part of a noise impact assessment used by planning authorities to assess rail projects.

The ETTT Project's Conditions of Approval require the consideration of both the above guidelines, and for the more onerous one to be adopted.

During the development of the ONVR it was found that adhering to the RING guidelines would result in predictions of 26 properties exceeding the specified trigger levels in 2026 (10 years after operation), while under IGANRIP a total of 133 properties exceed trigger levels. Proposed mitigation measures are therefore based on IGANRIP requirements as that guideline is more onerous for the ETTT Project.

DEVELOPMENT

Development of the ONVR started with identification of impacts from various noise sources noise sources, topography, shielding effects, absorption effects and the project's detailed design.

An acoustic model was created to determine what the predicted impacts would be on nearby properties without any mitigation measures in place immediately prior to the project opening and 10 years after operations commence. These results were then compared against the IGANRIP trigger levels to determine which properties will trigger consideration of mitigation.

133 properties were identified as likely to exceed the noise trigger levels established in IGANRIP with the adoption of a safety factor on train numbers as required by the Conditions of Approval. An assessment was undertaken to determine how to mitigate these exceedances in the hierarchy of:

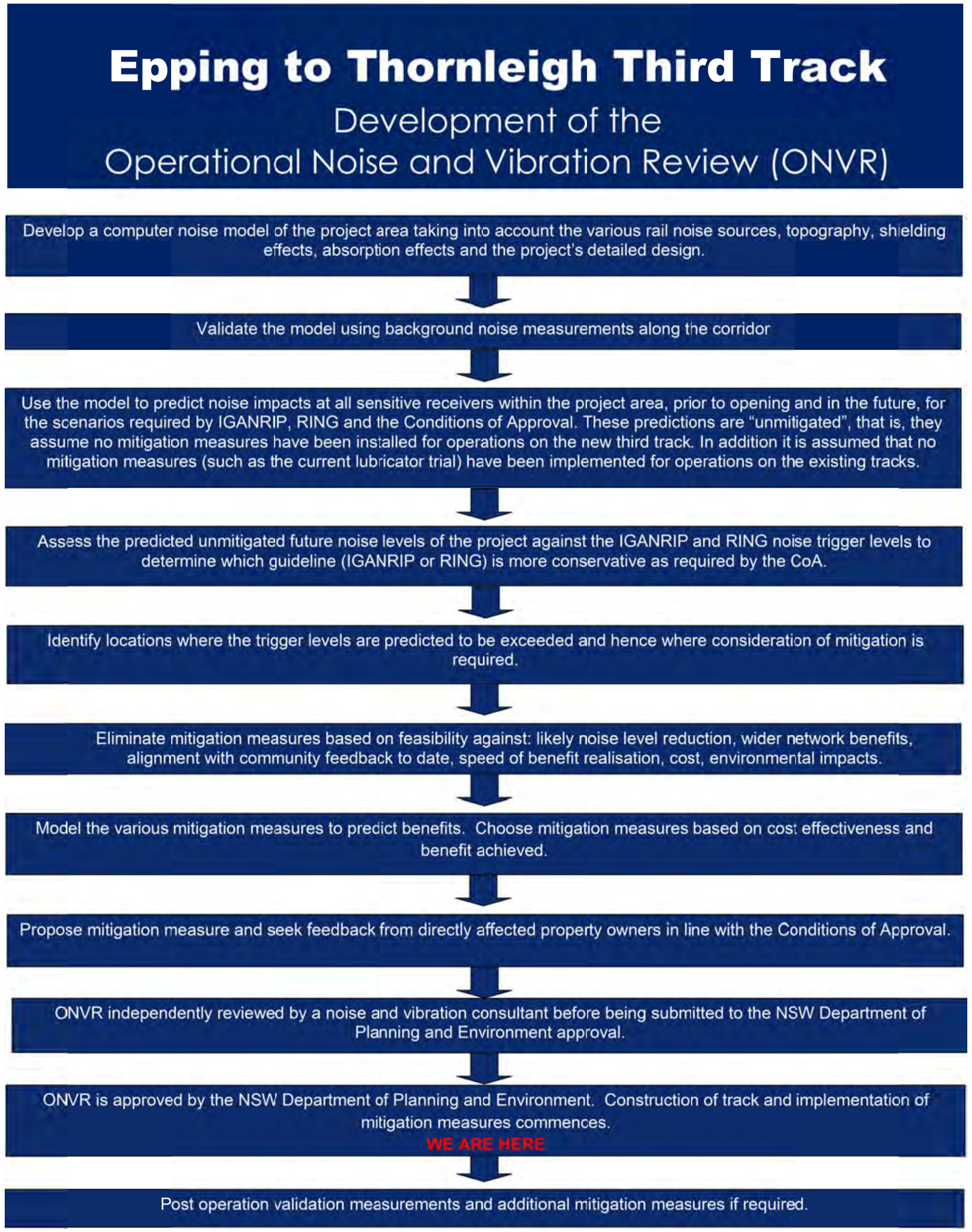
- source controls – which reduce the noise at its origin, for example using track lubrication to mitigate rail / wheel contact noise
- path controls – where a solid object, such as a barrier or earth mound alters the direction of noise from the source
- receiver controls – such as window and door seals to improve noise levels at the affected property

**Source and path controls are always preferred as they provide benefits both outside and inside properties, and to more residents. Receiver controls only improve amenity inside a property, and require windows and doors to be closed to be effective.*

A total of 56 mitigation measures were initially proposed and then eliminated based on how they rated against:

- Likely noise level reduction they would provide;
- What benefits they could provide to receivers across the wider rail network;
- How they align with community feedback received to date;
- How quickly they can be implemented and benefits realised;
- Engineering feasibility;
- Cost of implementation; and
- Environmental impacts that could result.

Figure 1 ONVR development



OUTCOMES AND CONSULTATION

The remaining measures were then added to the acoustic model to predict benefits they would have for the 133 identified properties before being chosen on the basis of cost effectiveness and benefit they achieve.

The measures proposed to mitigate operational noise impacts associated with the project are:

- Rail lubricators on the new third track
- Investigation of swing-nose crossings in proposed turnouts at Epping and Thornleigh
- A technical assessment of theoretical benefits that may be achieved by targeting high noise locomotives, to inform community and regulator consideration of this issue
- Three extents of noise barrier in the Beecroft area, with a total length of approximately 1,300m
- Individual property treatments (40 properties eligible to be assessed for suitability)
- Upgrading an existing prototype noise monitoring station to become a permanent noise monitoring station for ongoing use in targeting high noise wagons.

Subject to the outcomes of consultation with directly affected property owners and approval of the ONVR by DP&E, these measures would start to be implemented in 2015.

The ONVR was publicly released to allow members of the community and directly affected property owners to comment on the proposed mitigation measures.

Feedback was considered by the ETTT Project and where possible, suggestions were incorporated into the ONVR. The document has now been submitted to the NSW Department of Planning and Environment (DP&E) for approval.

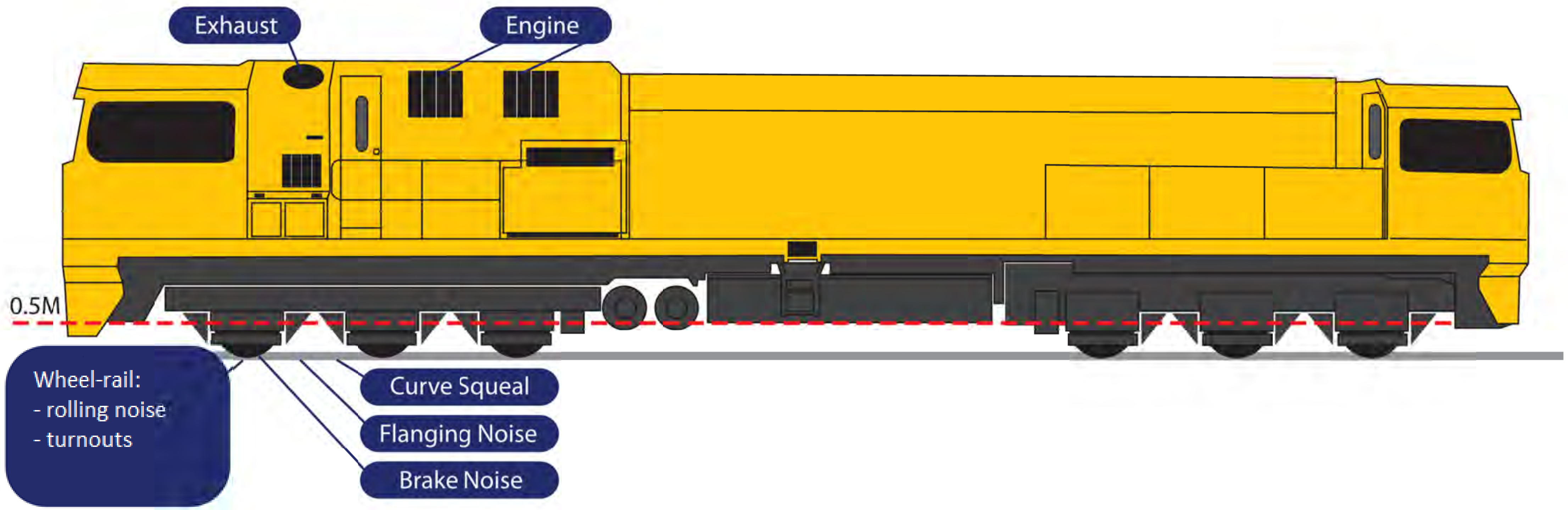
It is very important to note that since the proposed mitigation measures were developed based on mandated guidelines and cost effectiveness considerations there is limited scope to alter the proposed measures and as such feedback that conflicts with guidelines / standards and items that go outside the outlined assessment process and associated science will not be implemented.

No exceedances of the operational vibration requirements are expected as a result of the project.

FREIGHT TRAIN NOISE

Figure 2 below identifies the major noise sources for a typical freight train. As illustrated in the diagram, noise from the diesel engine and exhaust are located towards the top of the locomotive and would require large barriers to effectively shield noise levels at nearby receivers who trigger the consideration of mitigation measures. All other noise sources are located towards the bottom of the train near the wheel/rail interface.

Figure 2 Major noise sources for a typical freight train



The key feature of any noise barrier is its height relative to the straight-line path between the noise source of interest and the receiver of interest.

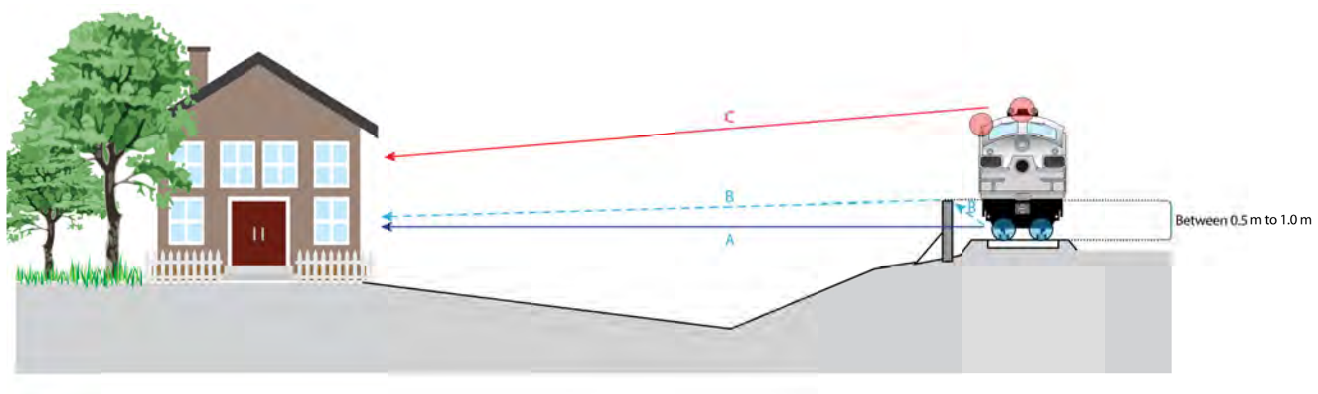
In general:

- Barriers attenuate more noise when they have a relative height that is greater than the noise source height (as perceived by the receiver)
- Barriers attenuate more noise when they are located closer to the noise source.

In particular, to have an effect, noise barriers must break the line of sight between the source and receiver. The performance is then dependent upon the degree to which the noise propagation path is interrupted.

This is illustrated in the following diagrams:

Figure 3 Indicative low height noise barrier close to the track



In this diagram three "noise paths" are shown:

- A – the straight-line path between rail/wheel noise source and the receiver of interest
- B – the in-direct path between the rail/wheel noise source and the receiver of interest
- C – the straight-line path between engine/exhaust noise source and the receiver of interest

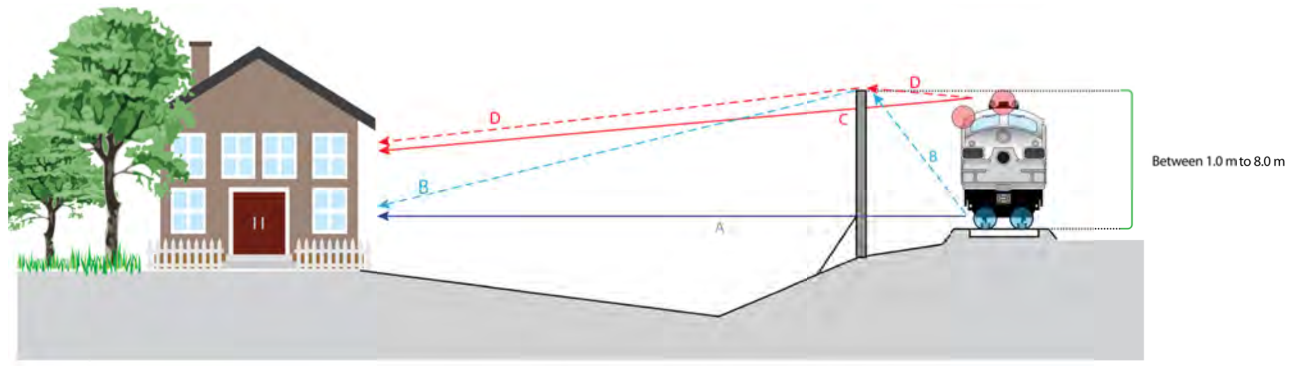
In this example the barrier is relatively low and close to the track. The barrier height is between 0.5 m and 1 m above the level of the track.

Noise from the rail/wheel cannot travel along path A as it is interrupted by the barrier. Instead the noise must travel along path B and is attenuated by the barrier.

Noise from the engine/exhausts travels along path C and is not interrupted by the barrier. Therefore this noise is not attenuated by the barrier.

Low barriers are suitable to attenuate noise sources which are located near to the ground such as rail/wheel noise, curving noise, flanging noise and braking noise.

Figure 4 Indicative conventional noise barrier located further from the track



In this diagram four "noise paths" are shown:

- A – the straight-line path between rail/wheel noise source and the receiver of interest
- B – the in-direct path between the rail/wheel noise source and the receiver of interest
- C – the straight-line path between engine/exhaust noise source and the receiver of interest
- D – the in-direct path between the engine/exhaust noise source and the receiver of interest

In this example the barrier is a conventional barrier located further from the track. The barrier height is between 1 m and 8 m above local ground level.

Noise from the rail/wheel cannot travel along path A as it is interrupted by the barrier. Instead the noise must travel along path B and is attenuated by the barrier.

Noise from the engine/exhausts cannot travel along path C as it is interrupted by the barrier. Instead the noise must travel along path D and is attenuated by the barrier.

In this example path B is significantly greater than path D and as such the barrier will provide more attenuation to the noise travelling along path B compared to path D.

High barriers are suitable for attenuating noise sources that are located towards the top of trains such as engine/exhaust noise. High barriers also provide attenuation to low noise sources such as rail/wheel noise.

WHAT IS THE TYPICAL NOISE REDUCTION PRODUCED BY A NOISE BARRIER?

Typical noise reductions from noise barriers are in the order of 5 dB to over 10 dB, depending on the location of the source, the receiver location and the height of the noise barrier.

The noise reduction also depends on the geometry between the railway corridor and the receiver location. For example, noise barriers are not effective for multi-level unit blocks where receivers would overlook the noise barrier.

ABSORPTIVE NOISE BARRIERS

In some instances, noise barriers are lined with acoustically absorptive material to avoid a potential loss of performance due to noise reflecting off the barrier and the body of the train, or to minimise the risk of increased noise levels on the other side of the track.

In most situations, however, absorptive barriers are not required as they provide only a small additional benefit at a much higher construction cost. In some situations where very large noise reductions are required, absorptive barriers can have a noticeable effect on the receiver noise levels compared with standard barriers.

WILL I STILL HEAR TRAINS?

Noise barriers do not always fully satisfy the expectations of the community. They reduce, but do not eliminate noise. In addition residential dwellings may also be affected by shadow effects, loss of view, loss of breezes and degradation of outlook due to barriers.

NEXT STEPS

The ONVR has been updated in response to community feedback, and submitted to DP&E for approval. Once approved the final ONVR document will be placed on the ETTT Project website.

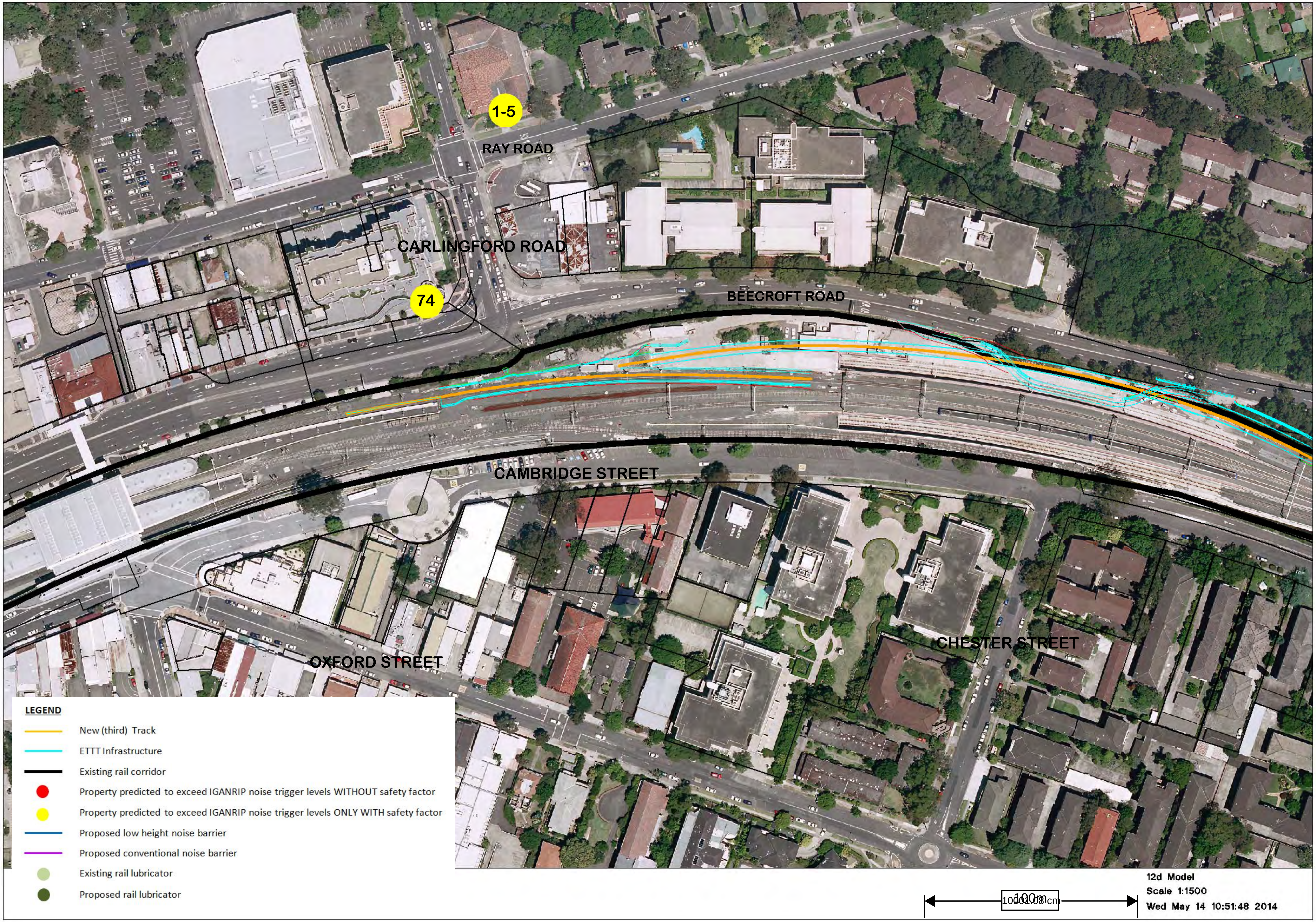
Community consultation regarding the appearance of proposed noise barriers will also be undertaken. Noise barrier consultation will be focused around the urban design of the noise barriers and findings will become an addendum to the already approved Urban Design and Landscape Plan.

Subject to approval of the ONVR by DP&E, these measures would start to be implemented in 2015.

On completion of the project, noise and vibration compliance monitoring to confirm the predictions of the noise assessment and mitigation measures will be undertaken, 1 year, 5 years and 10 years after completion. If the assessment indicates that noise and vibration objectives have not been met, further feasible and reasonable measures will be investigated/ implemented in consultation with affected property owners.

MAPS

The following 10 sheets show the locations of proposed physical mitigation measures. These include rail lubricators, noise barriers, properties eligible to be assessed for building treatment and the proposed noise monitoring station.


1-5
RAY ROAD
CARLINGFORD ROAD
74
BEECROFT ROAD
CAMBRIDGE STREET
OXFORD STREET
CHESTER STREET
LEGEND
New (third) Track
ETTT Infrastructure
Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
100m
12d Model
Scale 1:1500
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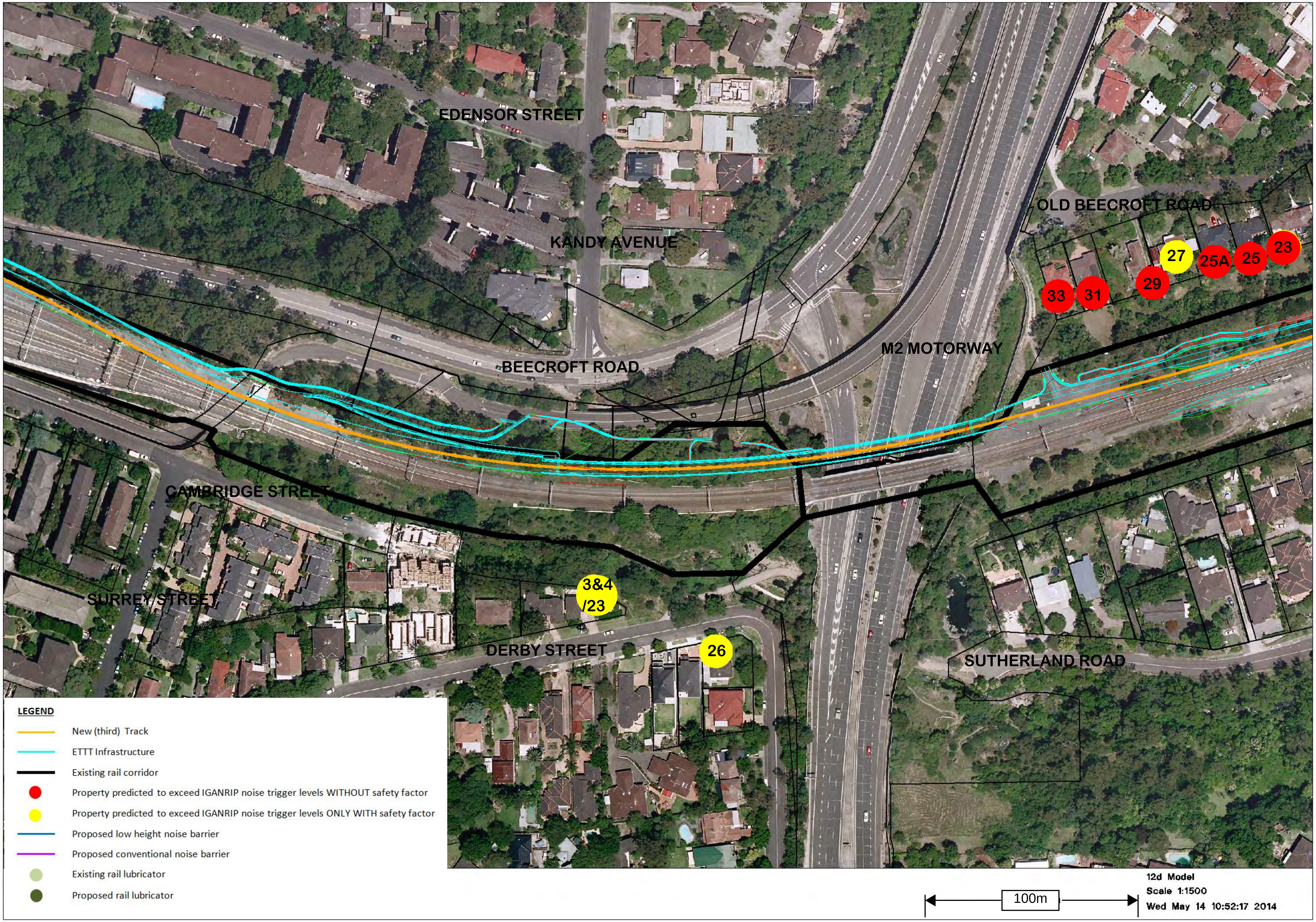

EDENSOR STREET
KANDY AVENUE
BEECROFT ROAD
OLD BEECROFT ROAD
M2 MOTORWAY
CAMBRIDGE STREET
SURREY STREET
DERBY STREET
SUTHERLAND ROAD
33
31
29
27
25A
25
23
3&4 /23
26
LEGEND
New (third) Track
ETTT Infrastructure
Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
100m
12d Model
Scale 1:1500
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OLD BEECROFT ROAD
LYNE ROAD
23
25A
25
23
21
19
17
108
106
104
102
88
86
84
82
80
78
76
THE CRESCENT
PROPOSED RAIL LUBRICATOR
EXISTING RAIL LUBRICATOR
1
2
SUTHERLAND ROAD
COBRAN ROAD
LEGEND
New (third) Track
ETTT Infrastructure
Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
100m
12d Model
Scale 1:1500
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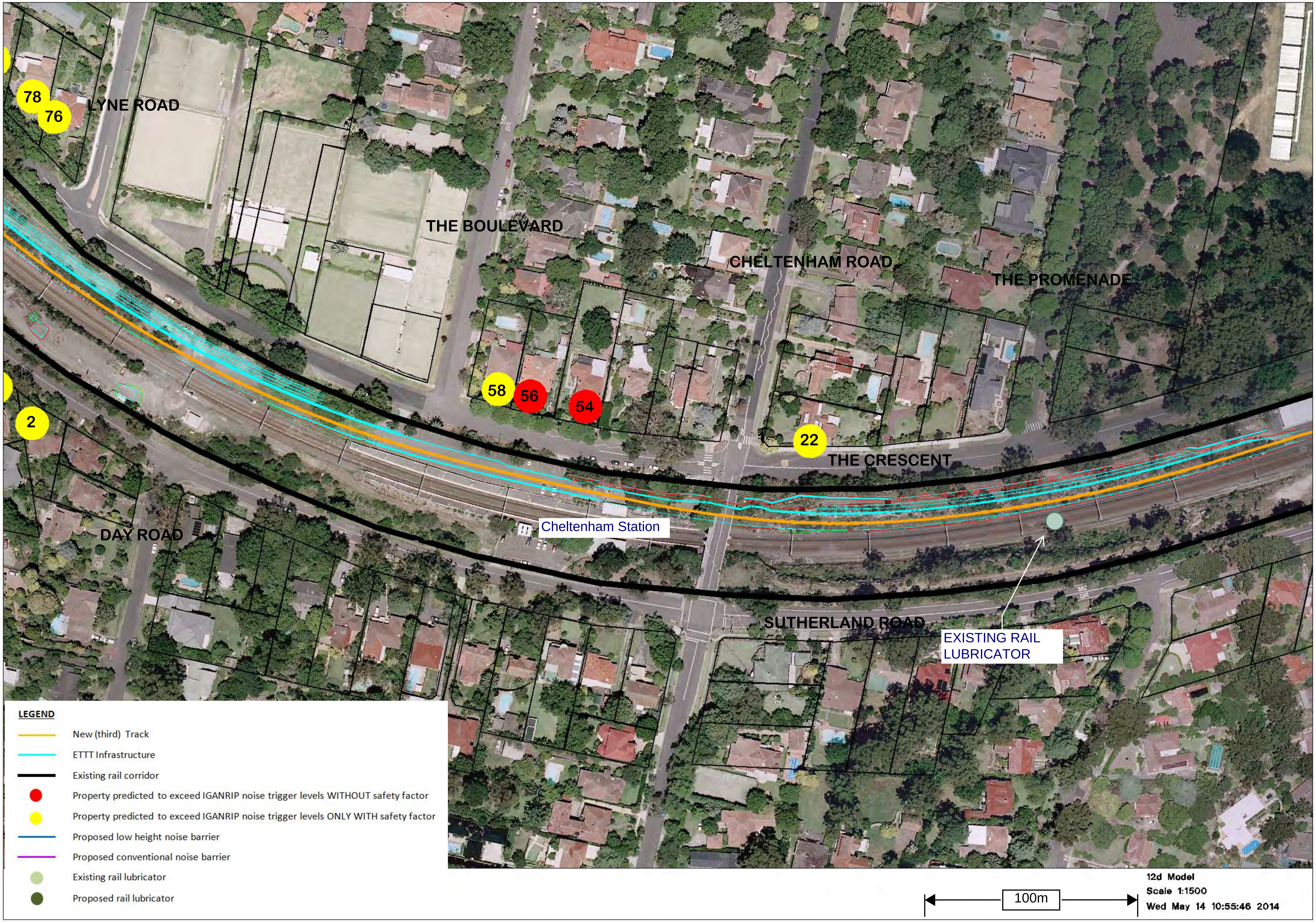

12d Model
Scale 1:1500
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MURRAY ROAD
BEECROFT ROAD
127
125
28
26
32
2
24A
24
22
20
18
16
14A
14
12
10
8
2C
THE CRESCENT
SUTHERLAND ROAD
SUMMERWOOD WAY
PROPOSED RAIL LUBRICATOR
EXISTING RAIL LUBRICATOR
SCOUT HALL
LEGEND
New (third) Track
ETTT Infrastructure
Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
100m
12d Model
Scale 1:1500
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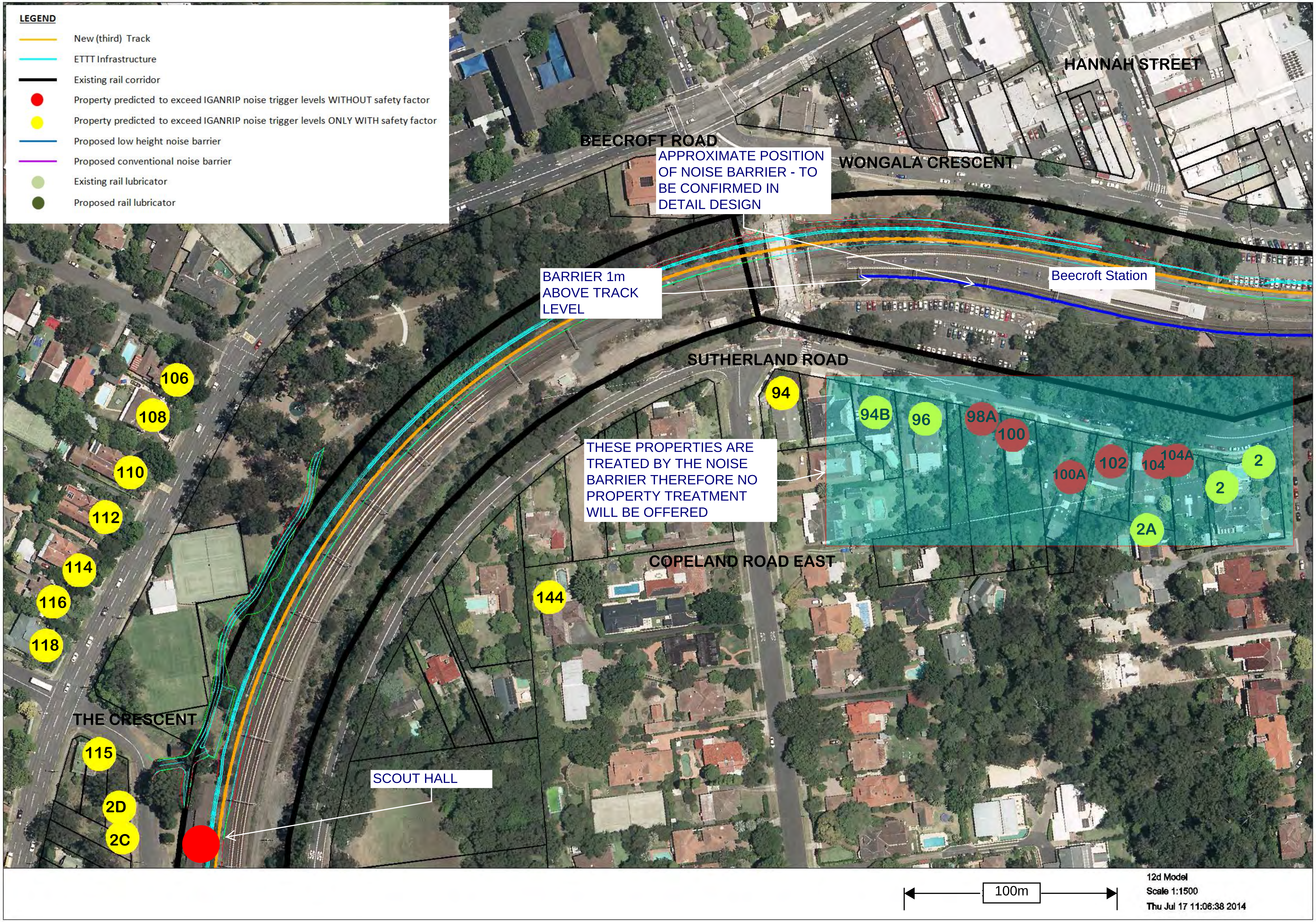
LEGEND
New (third) Track
ETTT Infrastructure
Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
HANNAH STREET
BEECROFT ROAD
APPROXIMATE POSITION OF NOISE BARRIER - TO BE CONFIRMED IN DETAIL DESIGN
WONGALA CRESCENT
BARRIER 1m ABOVE TRACK LEVEL
Beecroft Station
SUTHERLAND ROAD
94
94B
96
98A
100
100A
102
104
104A
2
2
2A
106
108
110
112
114
116
118
THESE PROPERTIES ARE TREATED BY THE NOISE BARRIER THEREFORE NO PROPERTY TREATMENT WILL BE OFFERED
COPELAND ROAD EAST
144
THE CRESCENT
115
2D
2C
SCOUT HALL
100m
12d Model
Scale 1:1500
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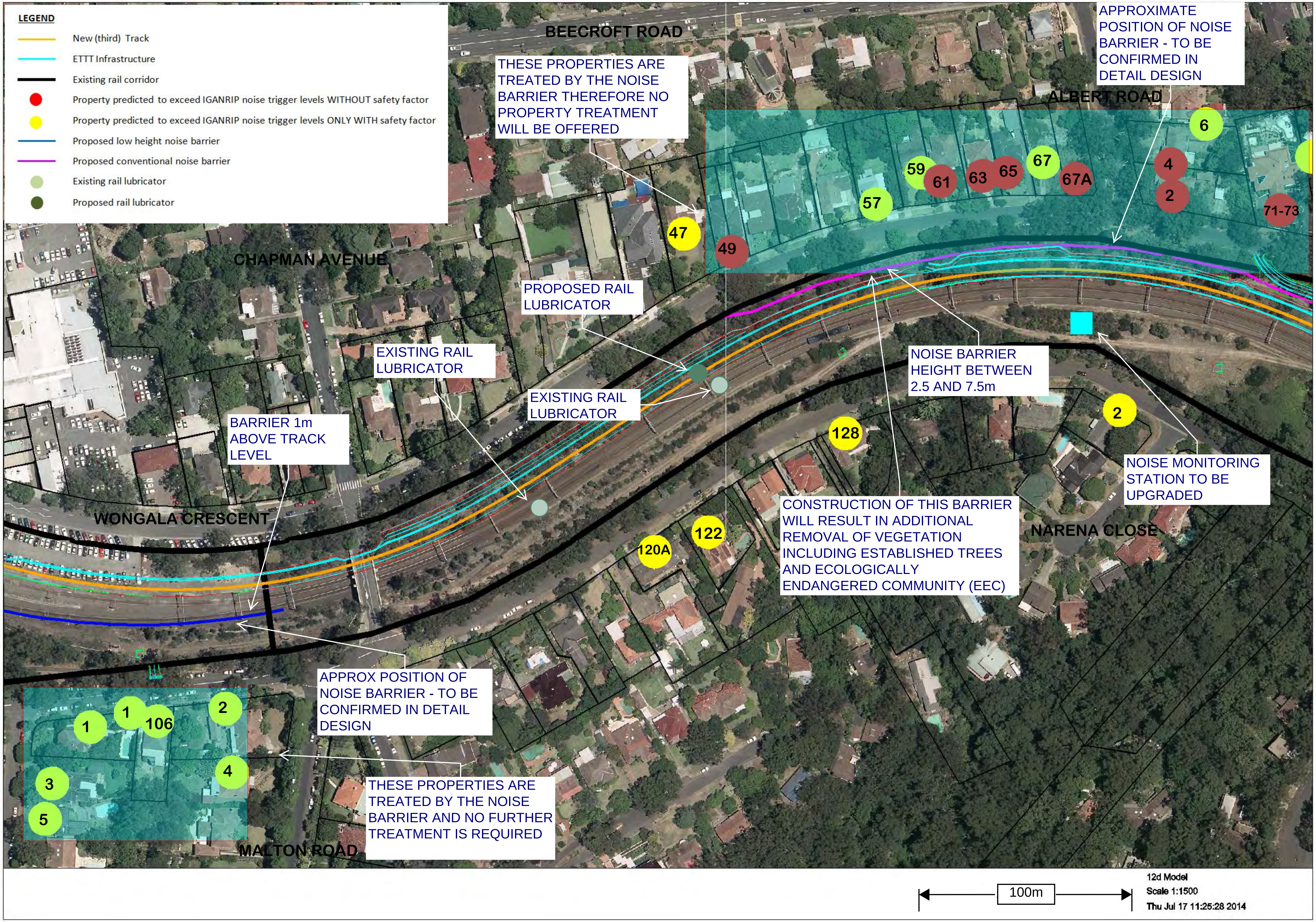

LEGEND
New (third) Track
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Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
BEECROFT ROAD
THESE PROPERTIES ARE TREATED BY THE NOISE BARRIER THEREFORE NO PROPERTY TREATMENT WILL BE OFFERED
APPROXIMATE POSITION OF NOISE BARRIER - TO BE CONFIRMED IN DETAIL DESIGN
ALBERT ROAD
CHAPMAN AVENUE
PROPOSED RAIL LUBRICATOR
EXISTING RAIL LUBRICATOR
EXISTING RAIL LUBRICATOR
NOISE BARRIER HEIGHT BETWEEN 2.5 AND 7.5m
BARRIER 1m ABOVE TRACK LEVEL
NOISE MONITORING STATION TO BE UPGRADED
WONGALA CRESCENT
CONSTRUCTION OF THIS BARRIER WILL RESULT IN ADDITIONAL REMOVAL OF VEGETATION INCLUDING ESTABLISHED TREES AND ECOLOGICALLY ENDANGERED COMMUNITY (EEC)
NARENA CLOSE
APPROX POSITION OF NOISE BARRIER - TO BE CONFIRMED IN DETAIL DESIGN
THESE PROPERTIES ARE TREATED BY THE NOISE BARRIER AND NO FURTHER TREATMENT IS REQUIRED
MALTON ROAD
47
49
57
59
61
63
65
67
67A
6
4
2
71-73
128
2
122
120A
1
1
106
2
3
4
5
100m
12d Model
Scale 1:1500
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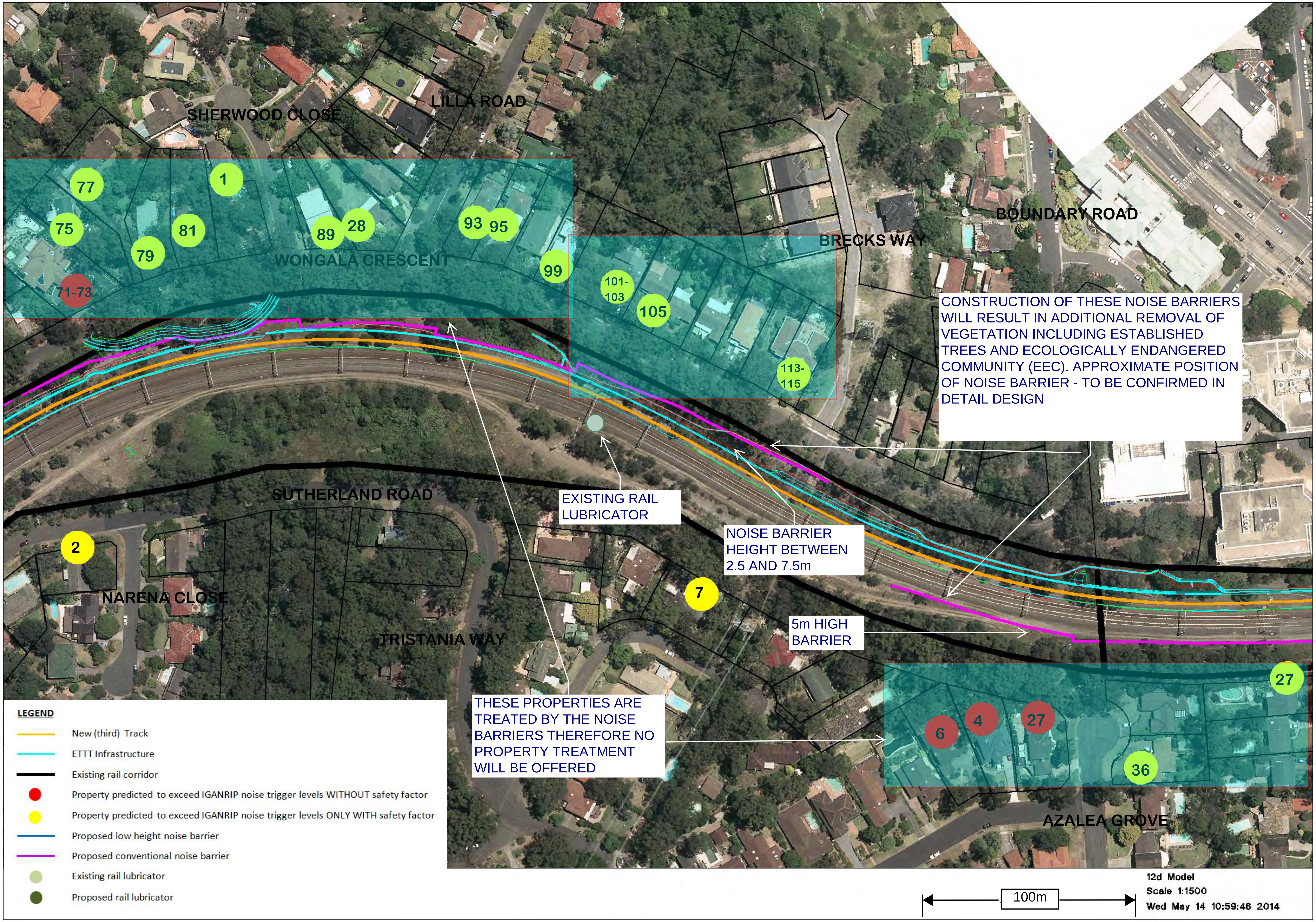
SHERWOOD CLOSE
LILLA ROAD
BOUNDARY ROAD
BRECKS WAY
WONGALA CRESCENT
77
1
75
81
79
89
28
93
95
99
71-73
101-103
105
113-115
CONSTRUCTION OF THESE NOISE BARRIERS WILL RESULT IN ADDITIONAL REMOVAL OF VEGETATION INCLUDING ESTABLISHED TREES AND ECOLOGICALLY ENDANGERED COMMUNITY (EEC). APPROXIMATE POSITION OF NOISE BARRIER - TO BE CONFIRMED IN DETAIL DESIGN
SUTHERLAND ROAD
EXISTING RAIL LUBRICATOR
NOISE BARRIER HEIGHT BETWEEN 2.5 AND 7.5m
2
NARENA CLOSE
7
TRISTANIA WAY
5m HIGH BARRIER
27
6
4
27
36
THESE PROPERTIES ARE TREATED BY THE NOISE BARRIERS THEREFORE NO PROPERTY TREATMENT WILL BE OFFERED
AZALEA GROVE
LEGEND
New (third) Track
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Existing rail corridor
Property predicted to exceed IGANRIP noise trigger levels WITHOUT safety factor
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Proposed rail lubricator
100m
12d Model
Scale 1:1500
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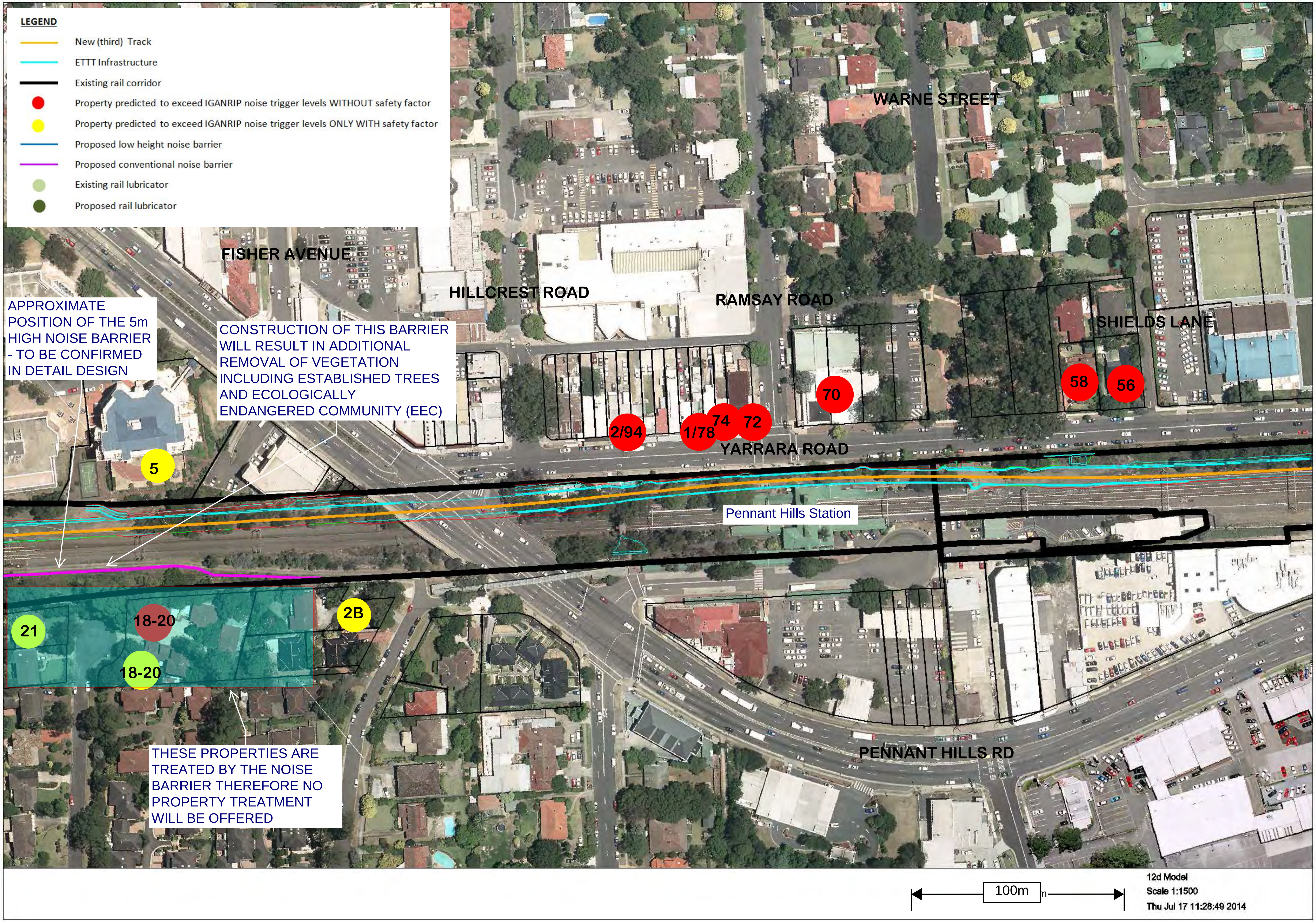
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Property predicted to exceed IGANRIP noise trigger levels ONLY WITH safety factor
Proposed low height noise barrier
Proposed conventional noise barrier
Existing rail lubricator
Proposed rail lubricator
WARNE STREET
FISHER AVENUE
HILLCREST ROAD
RAMSAY ROAD
SHIELDS LANE
APPROXIMATE POSITION OF THE 5m HIGH NOISE BARRIER - TO BE CONFIRMED IN DETAIL DESIGN
CONSTRUCTION OF THIS BARRIER WILL RESULT IN ADDITIONAL REMOVAL OF VEGETATION INCLUDING ESTABLISHED TREES AND ECOLOGICALLY ENDANGERED COMMUNITY (EEC)
70
58
56
2/94
1/78
74
72
YARRARA ROAD
5
Pennant Hills Station
21
18-20
2B
18-20
THESE PROPERTIES ARE TREATED BY THE NOISE BARRIER THEREFORE NO PROPERTY TREATMENT WILL BE OFFERED
PENNANT HILLS RD
100m
12d Model
Scale 1:1500
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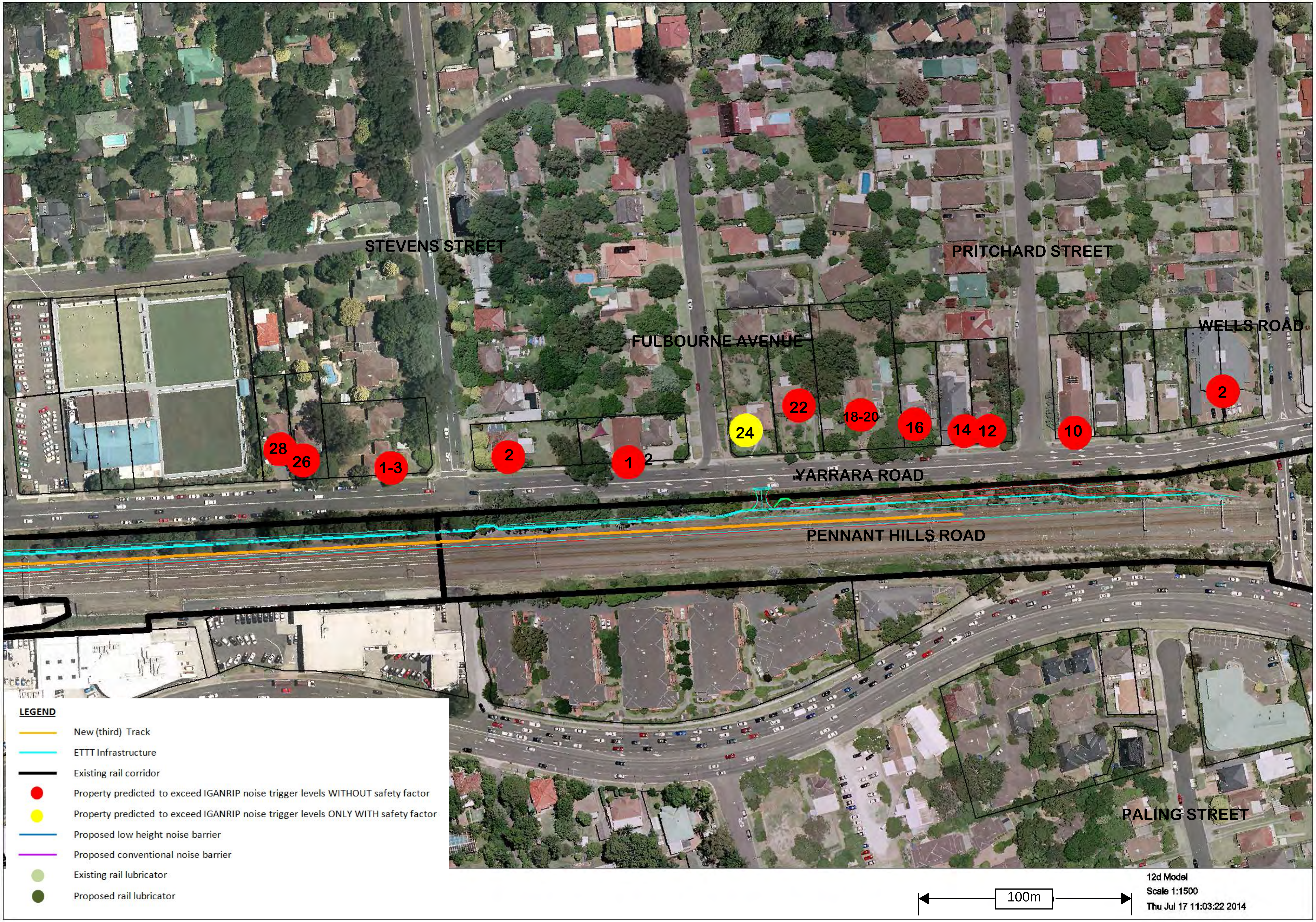
STEVENS STREET
PRITCHARD STREET
FULBOURNE AVENUE
WELLS ROAD
YARRARA ROAD
PENNANT HILLS ROAD
PALING STREET
28
26
1-3
2
1
2
24
22
18-20
16
14
12
10
2
LEGEND
New (third) Track
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Proposed rail lubricator
100m
12d Model
Scale 1:1500
Thu Jul 17 11:03:22 2014

Epping to Thornleigh Third Track

Operational Noise and Vibration Review – Jan 2015 – PART 2

Australian Government

Transport for NSW

DOCUMENT CONTROL

Revision	Status	Date
Rev 0	For public display and consultation with directly affected property owners.	22 May 2014
Rev 1	Updated to address feedback received during the community consultation period. Submitted to Department of Planning and Environment for approval.	22 August 2014
Rev 2	Approved by Department of Planning and Environment	15 January 2015

List of Abbreviations

Abbreviation	Definition
CoA	Condition/s of Approval
DP&E	Department of Planning and Environment
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPL	Environment Protection Licence
ETTT	Epping to Thornleigh Third Track
FRD	Freight and Regional Development division of Transport for NSW
FTA	Federal Transit Administration
IGANRIP	Interim Guideline for Assessment of Noise from Rail Infrastructure Projects
MBVA	Marginal Benefit Value per Unit Area
NSW	New South Wales
OEH	Office of Environment and Heritage
ONVR	Operational Noise and Vibration Review
PA	Public Address
RING	Rail Infrastructure Noise Guideline
RMS	Root Mean Square
RMS	Roads and Maritime Services
SLR	SLR Consulting Australia Pty Ltd
TNB	Total Noise Benefit
TNBA	Total Noise Benefit per Unit Area
UDLP	Urban Design and Landscape Plan
VDV	Vibration Dose Value

Table of Contents

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 Background

The Epping to Thornleigh Third Track Project (ETTT) involves the construction of six kilometres of new and upgraded track within the rail corridor between Epping and Thornleigh Stations on the western side of the existing tracks.

The new (third) track will separate northbound freight from all-stops passenger train movements along the steep incline between Epping and Thornleigh. This will help provide additional capacity for northbound interstate container freight trains, particularly during the daytime when passenger trains currently have priority.

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The key SLR personnel responsible for developing the ONVR technical content are Dr Briony Croft and Conrad Weber.

Dr Briony Croft is a professional engineer with more than 10 years post graduate experience in the field of railway noise and vibration. Dr Croft was awarded her PhD in 2009, for her thesis "The Development of Rail-head Acoustic Roughness". Her work in the field of contact mechanics examined the effect of rail dampers on the development of roughness and corrugation. Dr Croft's experience includes the measurement, modelling, assessment and control of noise and vibration emissions from roads and railways, including a variety of passenger and freight rail projects in the Sydney Metropolitan area.

Conrad Weber is a professional engineer with approximately 16 years experience covering a broad spectrum of projects, including the measurement, assessment and control of noise and vibration from transportation, mining, construction and excavation projects. Mr Weber has been involved in most new rail projects in NSW over the past ten years as well as significant projects in Victoria, Western Australia, Singapore and Dubai. Conrad has managed the environmental noise and vibration assessment on passenger and freight rail projects in Sydney including the Rail Clearways Program, North West Rail Link and freight noise studies for ARTC and Sydney Trains (formerly RailCorp).

The ONVR is divided into two parts:

PART 1
- Brief description of ONVR requirements, development, findings and next steps
- Maps showing proposed mitigation measures

PART 2 (This Part)
- Description of the noise modelling process and outcomes
- Full technical details of all aspects of ETTT operational noise and vibration

Included within this Part 2 is a complete technical description of the process of noise prediction & modelling, all mitigation measures considered; and those recommended for adoption. Part 2 also describes predicted noise from stations; vibration; community consultation; independent verification; post operation testing and monitoring; and complaints management.

1.2 Terminology

Specific acoustic terminology is used within this document. An explanation of common terms is included as **Appendix A**. Consistent with normal rail terminology, the Down and Up directions refer to trains travelling from Central Station and to Central Station respectively. The Down and Up sides of the corridor are the left-hand and right-hand sides respectively, when facing away from Central Station (ie facing in the direction of increasing chainage).

Within the ETTT project area, the Down side is on the western side of the railway corridor and the Up side is on the eastern side of the railway corridor.

2 COMPLIANCE REQUIREMENTS

Approval to construct and operate the ETTT was granted by the Minister for Planning and Infrastructure on 17 July 2013. The Project Approval is subject to a number of conditions. The Conditions of Approval (CoA) relate to operational noise and vibration and the relevant associated guidelines are summarised in the following sections. The CoA are reproduced in full in **Appendix B**.

2.1 Conditions of Approval – Operational Noise and Vibration

The Conditions relating to operational noise and vibration are contained in the CoA Schedule C - Environmental Performance and in Schedule F – Operational Environmental Management. The relevant Conditions are reproduced in **Table 1**, along with a summary of where each is addressed in this ONVR.

Table 1 CoA for Operational Noise and Vibration

Condition	Addressed
C1. Rail line components of the SSI shall be designed and operated with the objective of not exceeding the airborne and ground-borne noise trigger levels at existing development, at each stage of the SSI, as presented in IGANRIP or RING, whichever is the most conservative.	**Section 5** **Section 5.8.1**
For the purpose of this condition, existing development includes all development that at the date of this approval, has been carried out in the vicinity of the rail corridor and any such development approved prior to the determination of this SSI, but only to the extent that the location of the development is known.	**Section 3.2**
C2. Stationary facilities (including stations) shall be designed and operated with the objective of meeting operational noise levels derived from the NSW Industrial Noise Policy (NSW Government, 2000).	**Section 4**
C3. The SSI shall be designed and operated with the objective of not exceeding the vibration goals for human exposure for existing sensitive receivers, as presented in Assessing Vibration: a Technical Guideline (DECC, 2006).	**Section 6**
C4. The Proponent shall prepare an Operational Noise and Vibration Review (ONVR) to confirm noise and vibration control measures that will be implemented for the SSI. The ONVR shall be prepared in consultation with the EPA and relevant Councils and shall: (a) identify the appropriate operational noise and vibration objectives and levels for receiving existing development, including all sensitive receivers;	**This Report** **Section 5.4** **Section 6**
(b) predict the operational noise and vibration impacts at receiving existing development based on the final design and operation of the SSI. This prediction shall include a safety factor on train numbers and re-examination of curve squeal. Noise predictions shall be presented in catchments with each sensitive receiver clearly identified and described (including type and number of storeys) with their appropriate noise predictions. Absolute noise levels shall be presented to the nearest whole decibel, and the 'increase' in noise presented to a single decimal place;	**Section 5.9** **Section 6.4** **Section 5.6.2** **Appendix D**
(c) assess all feasible and reasonable noise and vibration mitigation measures, with a preferential focus on source control and design consistent with IGANRIP. The feasible and reasonable analysis shall be transparent and fully justified and shall include, but not be limited to the consideration of subjective noise factors, such as the number of noisy events, the duration of noisy events and the characteristics of the noise (e.g. wheel squeal, low frequency noise) and consideration of the following mitigations measures: - signal relocation; - composite sleepers; - rail dampeners; - gauge face lubricators for curve track and squeal; - noise barriers/bunds, including low profile rail barriers close to the track; and - property treatments;	**Section 7** **Section 8**
(d) include a mitigation plan for each catchment showing all sensitive receivers where IGANRIP triggers are exceeded and a strategy to mitigate the noise, including the identification of specific physical and other mitigation measures for controlling noise and vibration at the source and at the receiver including location, type and timing for the implementation of mitigation measures;	**Section 9 & maps in ONVR Part 1**
(e) include a consultation strategy to seek feedback from directly affected property owners on the noise and vibration mitigation measures;	**Section 10**
(f) include procedures for operational noise and vibration complaints management, including investigation and monitoring (subject to complainant agreement); and	**Section 15**
(g) incorporate results from the Source Noise Monitoring Plan (condition C5).	**Section 14**
Notwithstanding the feasible and reasonable noise mitigation assessment, gauge face lubricators for curve squeal shall be implemented as part of the SSI. Should operational noise monitoring (conditions C5 and F2) identify lubricators not effective in reducing curve squeal, property treatments or other mitigation measures if deemed more practicable, are to be implemented for sensitive receivers immediately adjacent (generally within 50m from the newly constructed track) to rail curves on the downside (western side) of the rail corridor, irrespective of IGANRIP/RING noise trigger level exceedances.	**Section 8.4**
The ONVR (and any subsequent amendment) is to be independently verified by a noise and vibration expert. The scope of the verification exercise undertaken by the noise and vibration expert is to be developed by the Proponent in consultation with the EPA. The verification will be undertaken at the Proponent's expense and the independent expert shall be approved by the Director-General. The ONVR and independent review is to be submitted to and approved by the Director-General prior to the commencement of the laying of rail track or the construction of physical noise mitigation structures, unless otherwise agreed to by the Director-General.	**Section 11**
The Proponent shall implement the identified noise and vibration control measures prior to operation and make the ONVR publicly available.	**Section 12**
C5. The Proponent shall prepare a Source Noise Monitoring Plan for the SSI rail corridor to assist in identifying and managing noisy freight locomotives and their rolling stock. The Plan shall be prepared prior to operation and in consultation with the EPA and shall include: (a) real time noise monitoring at a representative rail curve that potentially cause wheel squeal and other annoying rail noise characteristics; (b) the identification of noisy freight locomotives and their rolling stock and associated noise levels; and (c) the reporting of monitored data to be made publicly available within a reasonable time frame.	**Section 14**
Monitoring results shall be incorporated into the development of initiatives to address broader rail noise within the corridor and across the rail network. Monitoring results shall be reported and addressed in the Operational Noise and Vibration Compliance Monitoring and Assessment Report (condition F2).	**Section 8.11**

Condition	Addressed
F2. The Proponent shall undertake noise and vibration compliance monitoring and assessments to confirm the predictions of the noise assessment and mitigations referred to in the ONVR (condition C4). The noise and vibration compliance assessment shall be developed in consultation with the EPA and be undertaken at twelve months, 5 years and 10 years of the commencement of operation of the SSI, or as otherwise agreed by the Director-General. The assessment shall include, but not necessarily be limited to: (a) noise and vibration monitoring and compliance assessment, to assess compliance with conditions C1 to C3 of this approval and the ONVR; (b) an assessment methodology and the outcomes of the Source Noise Monitoring Plan and other relevant Rail Noise Initiatives developed and implemented for the SSI (condition F3); (c) details of any complaints received relating to operational noise and vibration impacts; (d) an assessment of the performance and effectiveness of the applied noise and vibration mitigation measures; (e) any required recalibration of the noise and vibration model, including consideration of freight train movements should the average number of night time trains exceed the projected value used for the noise mitigation design of the ONVR; and (f) identification, if required, of further noise and vibration mitigation measures to meet the requirements of C1 to C3 of this approval and the objectives identified in the ONVR. An Operational Noise and Vibration Compliance Assessment Report providing the results of the assessment shall be submitted to the Director-General and the EPA within 60 days of its completion and made publicly available. If the assessment indicates an exceedance of the noise and vibration objectives and predictions identified in the ONVR, the Proponent shall implement further feasible and reasonable measures to mitigate these exceedances in consultation with affected property owners (where required).	**Section 13**
F3. The Proponent shall ensure that the rail corridor associated with the SSI is considered in the development of initiatives to manage existing noise across the rail network. Where feasible and reasonable, initiatives that would address broader rail noise should be implemented as they relate to the SSI corridor. The implementation of these initiatives shall be reported in the Operational Noise and Vibration Compliance and Monitoring Assessment Report (condition F2).	**Section 8.11** **Section 14**

2.2 Relevant Guidelines

The noise and vibration guidelines for operations referenced in the CoA are managed by the Environment Protection Authority[1] (EPA). The EPA guidelines applicable to this assessment are:

- Rail Operational Noise - *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (IGANRIP - DECC 2007).
- Rail Operational Noise – *Rail Infrastructure Noise Guideline* (RING – EPA 2013)
- Operational Noise from Stations – *NSW Industrial Noise Policy* (INP - EPA 2000).
- Operational Vibration (human comfort) - *Assessing Vibration - a technical guideline* (DEC 2006).

[1] Noise and Vibration guidelines managed by EPA are available at the following web address http://www.environment.nsw.gov.au/noise/noise_legislation.htm.

3 PROJECT AREA AND SENSITIVE RECEIVERS

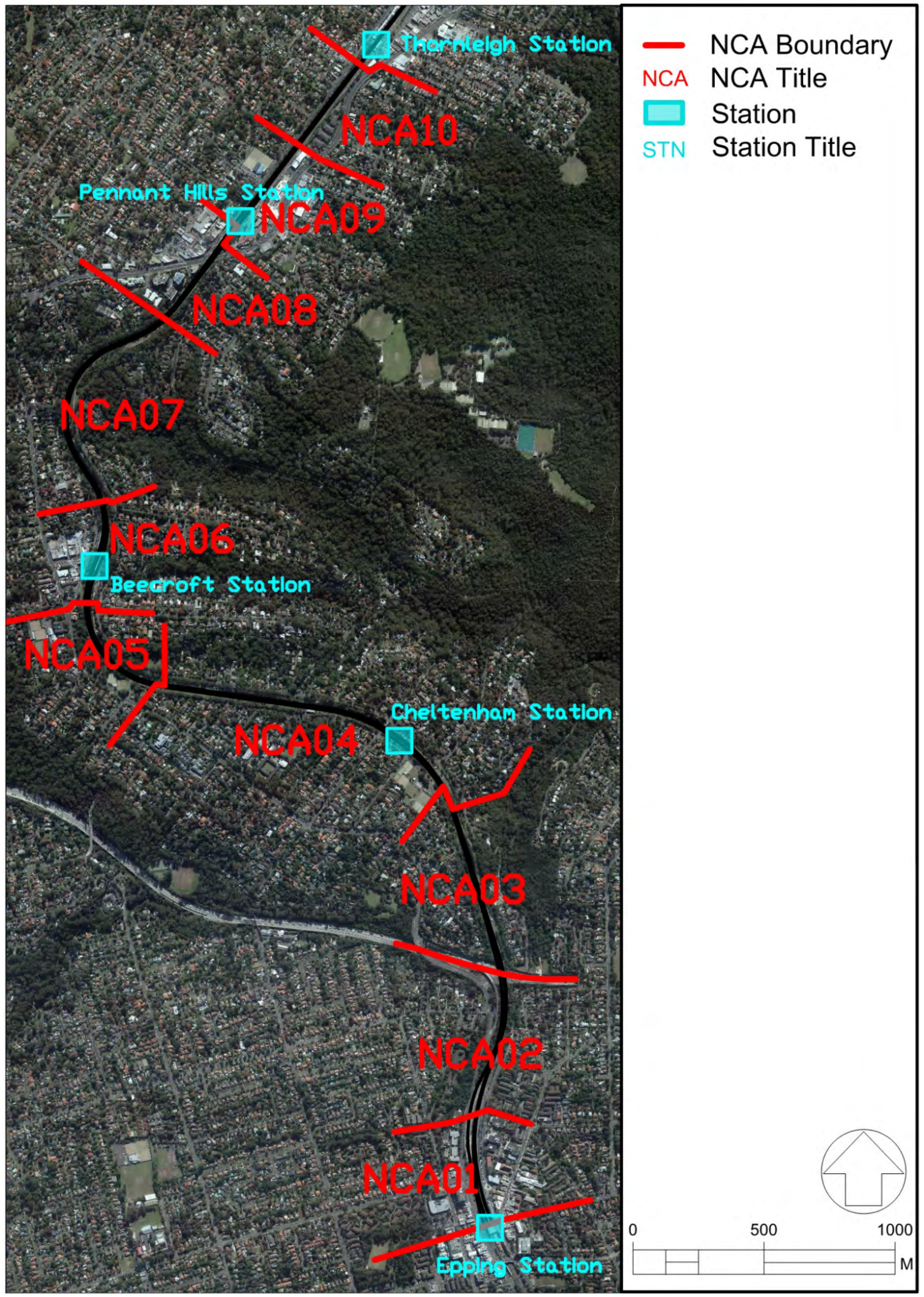
3.1 The Project Area

The ETTT study area extends along both the Up and Down side of the Main North Line from Epping Station to Thornleigh Station. The land adjacent to the rail corridor in the study area is predominantly characterised by low density residential housing, open spaces and smaller sections of business and/or industrial facilities. The corridor is adjacent to or within the Beecroft Conservation Area and The Crescent Conservation Area.

In order to assess the operational noise emissions for the ETTT Project, ten Noise Catchment Areas (NCAs) have been considered. Each NCA is divided by the rail corridor and the Up (East) and Down (West) side of the NCA is assessed individually. These NCAs are consistent with those used in the Environmental Impact Statement (EIS) for the project.

A plan view of the project area indicating the extent of the NCAs is shown in **Figure 1**. A more detailed view of each catchment area showing land use and sensitive receivers is provided in **Figure 2** to **Figure 11**. These figures also show the locations used in the assessment to validate the operational rail noise model by comparison of predictions with measurements (see also **Section 5.7**).

Figure 1 ETTT Noise Catchment Areas



3.2 Noise and Vibration Sensitive Receivers

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. The sensitivity may also depend on the existing environment. The NSW operational rail noise guidelines define the following sensitive receiver categories:

- Residential
- Schools, educational institutions and child care centres
- Hospitals
- Places of worship
- Open space – passive use
- Open space – active use

In addition to these categories, a receiver category of “Other Sensitive” is used in this ONVR. This receiver type is applied to land uses such as libraries and community centres. While these receiver types are not defined in the operational rail noise guidelines as sensitive, activities in these buildings are varied and in some cases incorporate educational uses.

Within the noise model, point receiver calculations have been undertaken for all sensitive receivers up to two rows of houses back from the railway corridor. Noise contour mapping was also undertaken to confirm that all sensitive receivers with predicted noise levels above the overall noise trigger levels were included in the point receiver calculations.

Commercial and industrial land uses are not considered sensitive receivers for the purpose of operational rail noise impact assessment under the relevant NSW guidelines (for more information on the NSW operational rail noise guidelines see **Section 5.4**).

A summary of each NCA identified within the project area and the land uses in each is provided in the following sections. A summary of individual receivers that are non-residential and sensitive to noise and/or vibration is given in **Table 2**.

Figure 2 to Figure 11 below also show validation points, which have been used to calibrate the model against actual measurements. This calibration process and selected validation points are further discussed in Section 5.7.

3.2.1 Noise Catchment Area 01

NCA 01 extends from the southern boundary of the project area at the start of the Epping Station platforms to Chester Street in Epping. Streets included in NCA 01 are Cambridge Street (south of Chester Street), Oxford Street, Beecroft Road (south of Chester Street), Carlingford Road and Ray Road (to the intersection with Edensor Street.

The noise sensitive receivers are shown in **Figure 2**. Sensitive receivers (other than residential) in NCA 01 are:

- Epping Baptist Church, 1-5 Ray Road, Epping
- Epping Community Centre, 9 Oxford Street, Epping
- Our Lady Help of Christians School and Place of Worship 29-31 Oxford Street, Epping

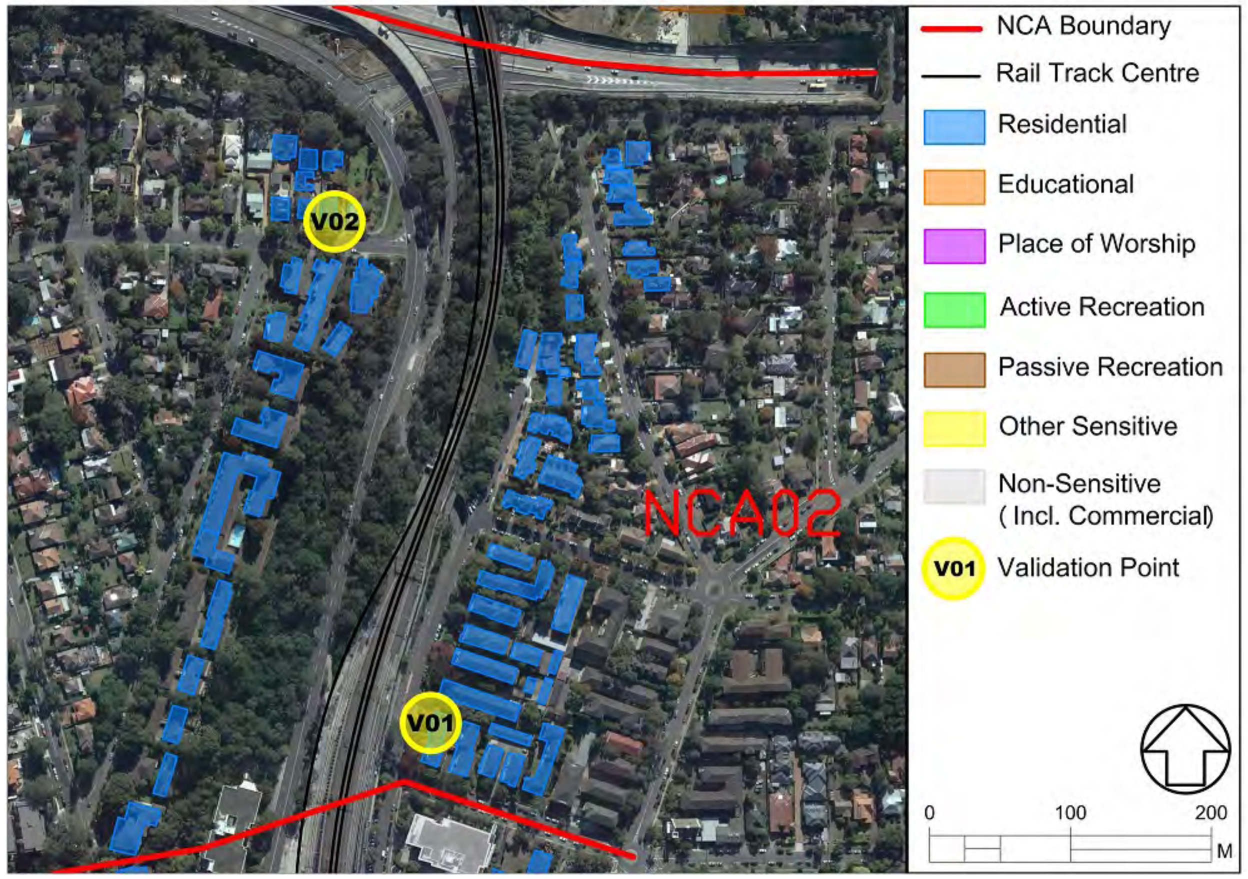
Figure 2 NCA01 Land Use and Model Validation Points

3.2.2 Noise Catchment Area 02

NCA 02 covers the area between Chester Street and the M2 motorway. Streets included in NCA 02 are Cambridge Street (north of Chester Street), Surry Street, Derby Street, Beecroft Road (north of Chester Street), Edensor Street and Kandy Avenue.

The noise sensitive receivers are shown in **Figure 3**. Sensitive receivers in NCA 02 include residential receivers of varying heights and constructions on both sides of the alignment.

Figure 3 NCA02 Land Use and Model Validation Points

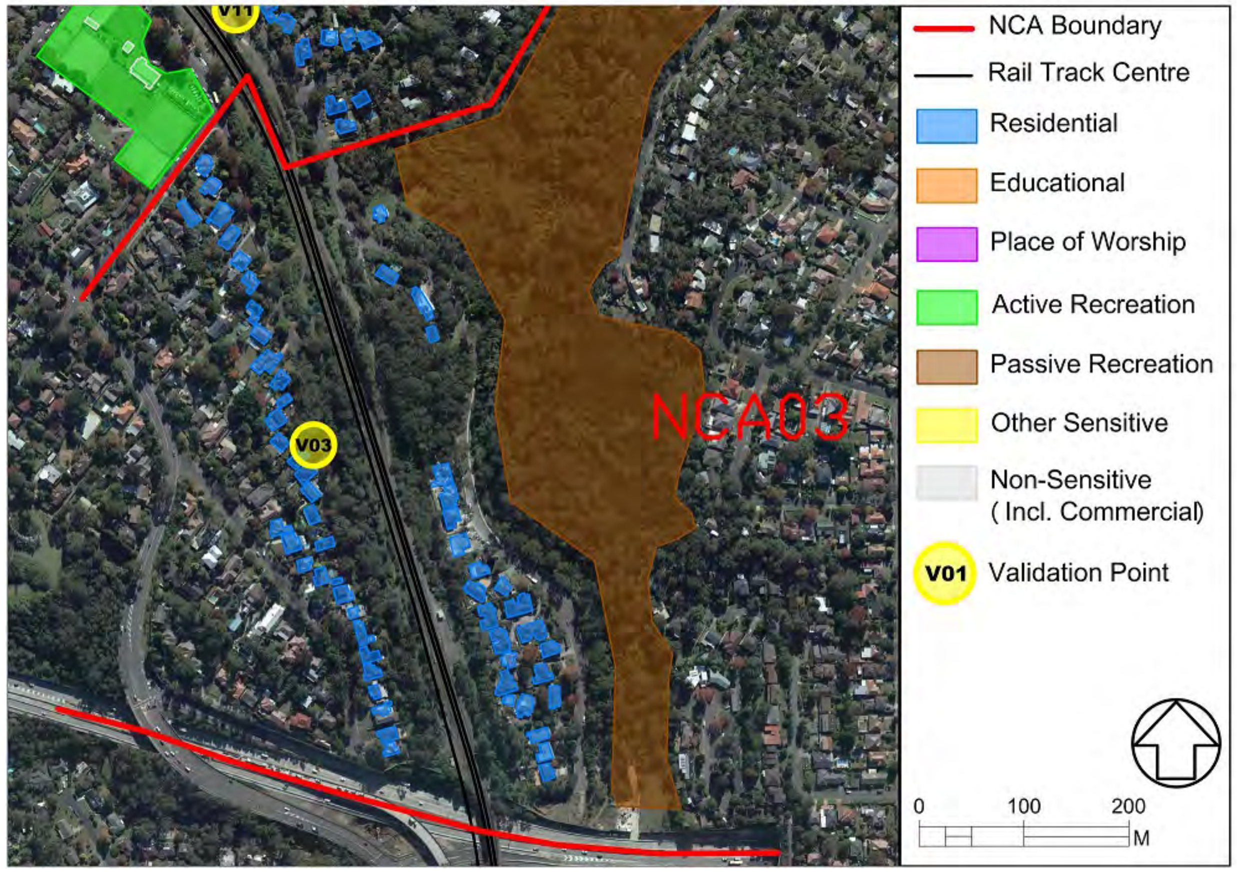


3.2.3 Noise Catchment Area 03

NCA 03 extends from the M2 motorway in the south to the Lyne Road (on the Down side) and to the northern edge of the bushland around Devlin's Creek on the Up side. The Up side of NCA 03 includes the Lane Cove National Park bush reserve and properties on Sutherland Road up to 61 Sutherland Road. On the down side, streets included are Old Beecroft Road and The Crescent up to the intersection with Lyne Road.

This NCA has been extended slightly to the north on the Down side so that the NCA boundary does not fall between immediately adjacent residential properties on The Crescent.

Figure 4 NCA03 Land Use and Model Validation Points



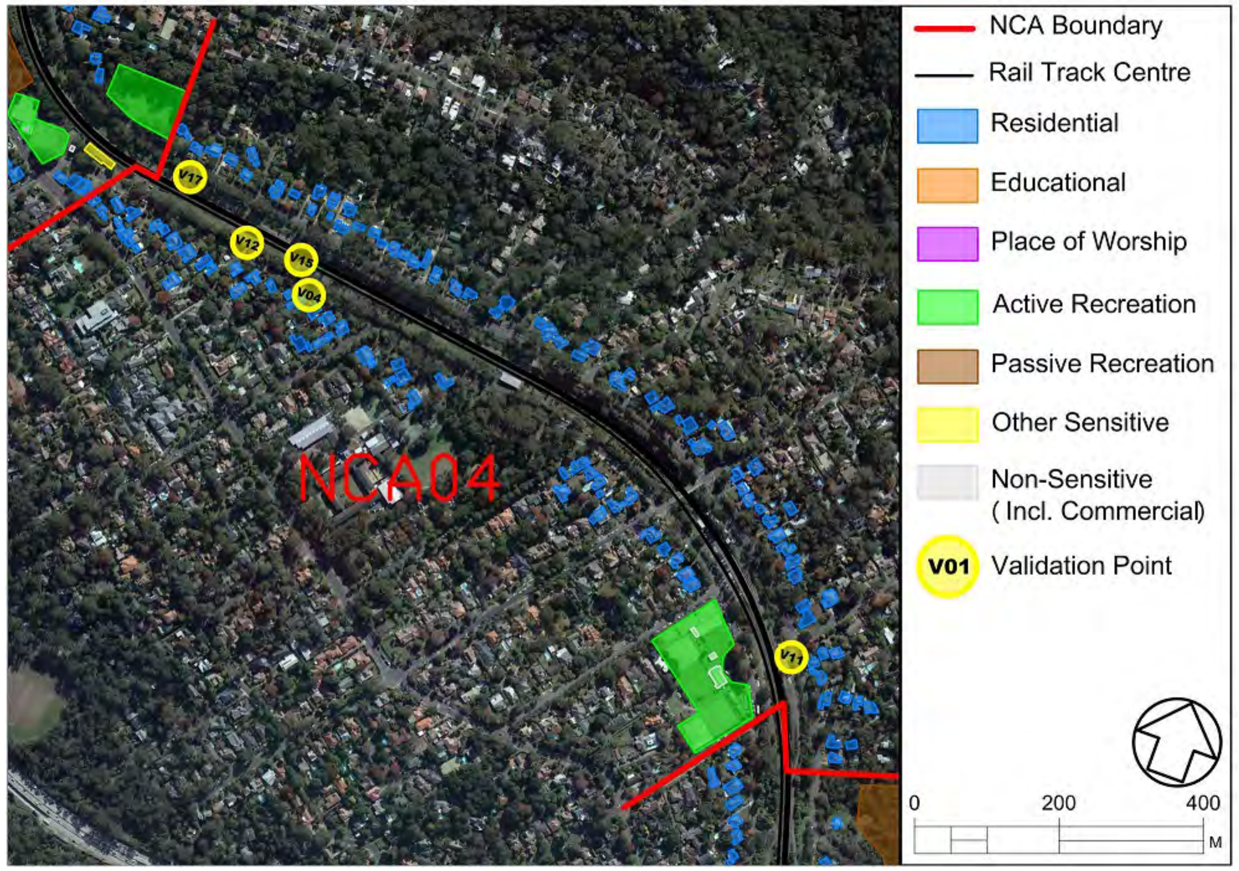
3.2.4 Noise Catchment Area 04

Moving to the north, NCA 04 includes Cheltenham Station, and covers the area north of Lyne Road to the start of the first small radius curve at Beecroft. On the Up side, this includes properties on both sides of Cobran Road, and Sutherland Road between Cobran Road and Booth Park. Streets intersecting with Sutherland Road in this catchment include Glenelg Place, Summerwood Way, Kethel Road, Chorley Avenue, Day Road, Cheltenham Road and Cobran Road.

On the Down side, NCA 04 includes properties between Lyne Road and 2 The Crescent (i.e. properties east of the Beecroft Scout Hall. Cross streets off The Crescent in this catchment include Cheltenham Road, The Promenade, The Boulevard, and Murray Rd.

The noise sensitive receivers are shown in **Figure 5**. Sensitive receivers (other than residential) in NCA 04 include active recreation areas associated with the tennis courts at 74-60 The Crescent, Beecroft.

Figure 5 NCA04 Land Use and Model Validation Points



3.2.5 Noise Catchment Area 05

NCA 05 extends from the Beecroft Scout Hall and Booth Park through to Copeland Road East at the southern end of Beecroft Station.

On the Up side, this catchment includes receivers on Sutherland Road (south of Copeland Road East). On the Down side, this catchment includes properties on Beecroft Road as far north as Copeland Road and south to 121 Beecroft Road, as well as the following other sensitive receivers:

- Beecroft Scout Hall, The Crescent, Beecroft
- Beecroft Village Green, corner of Beecroft Road and Mary Street, Beecroft
- Beecroft Lawn Tennis Club, corner or The Crescent and Beecroft Road, Beecroft
- Beecroft Public School, 90-98 Beecroft Rd, Beecroft
- Beecroft Community Centre, 111 Beecroft Road, Beecroft

The noise sensitive receivers are shown in **Figure 6**.

Figure 6 NCA05 Land Use and Model Validation Points

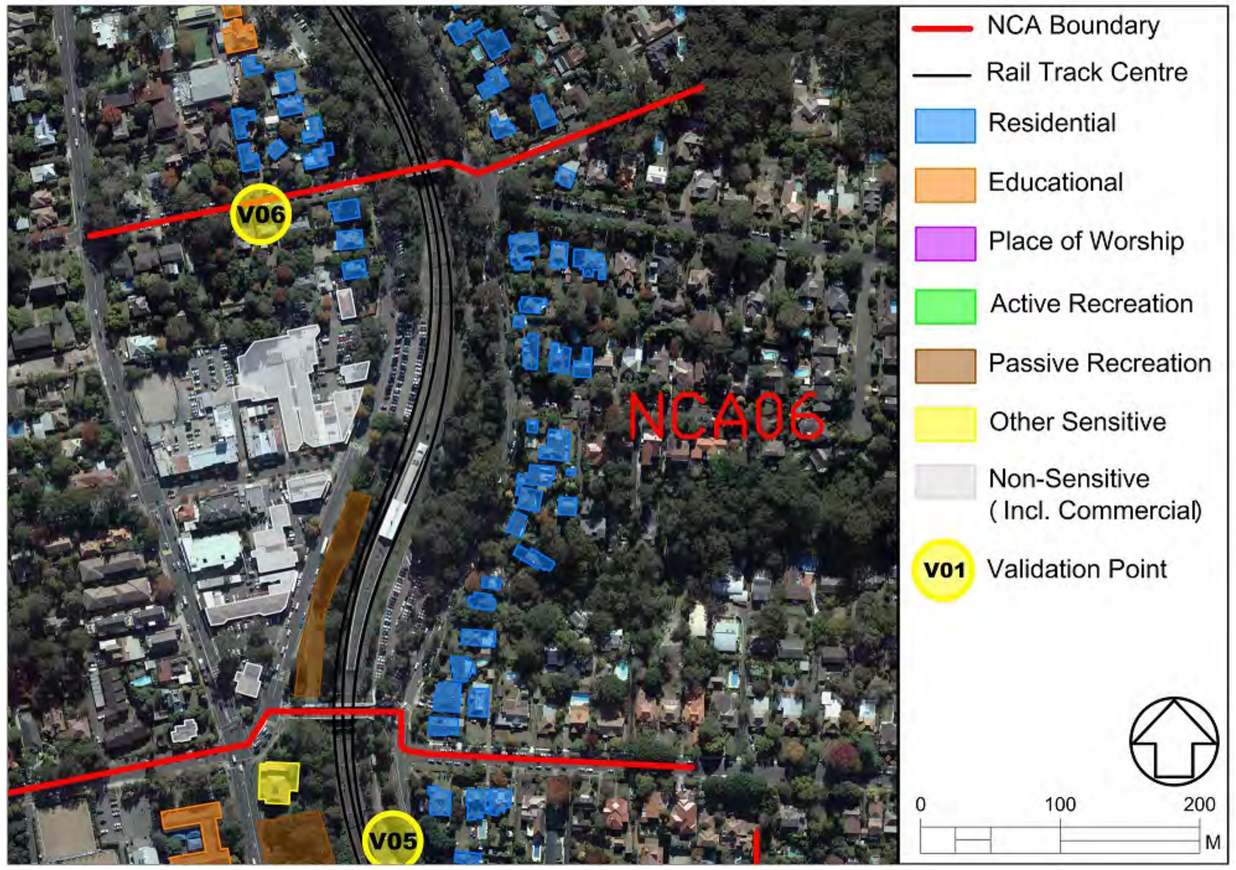
3.2.6 Noise Catchment Area 06

NCA 06 extends north from Copeland Road East and includes Beecroft Station and the Beecroft shopping precinct. The northern boundary of NCA 06 is Chapman Avenue. Streets included in NCA 06 are Sutherland Road (between Copeland Road East and Chapman Avenue), and Wongala Crescent to the intersection with Chapman Avenue.

NCA 06 includes a passive recreation area outside Beecroft Station (public park area) between the Down side of the rail corridor and Beecroft Road.

The noise sensitive receivers are shown in **Figure 7**.

Figure 7 NCA06 Land Use and Model Validation Points



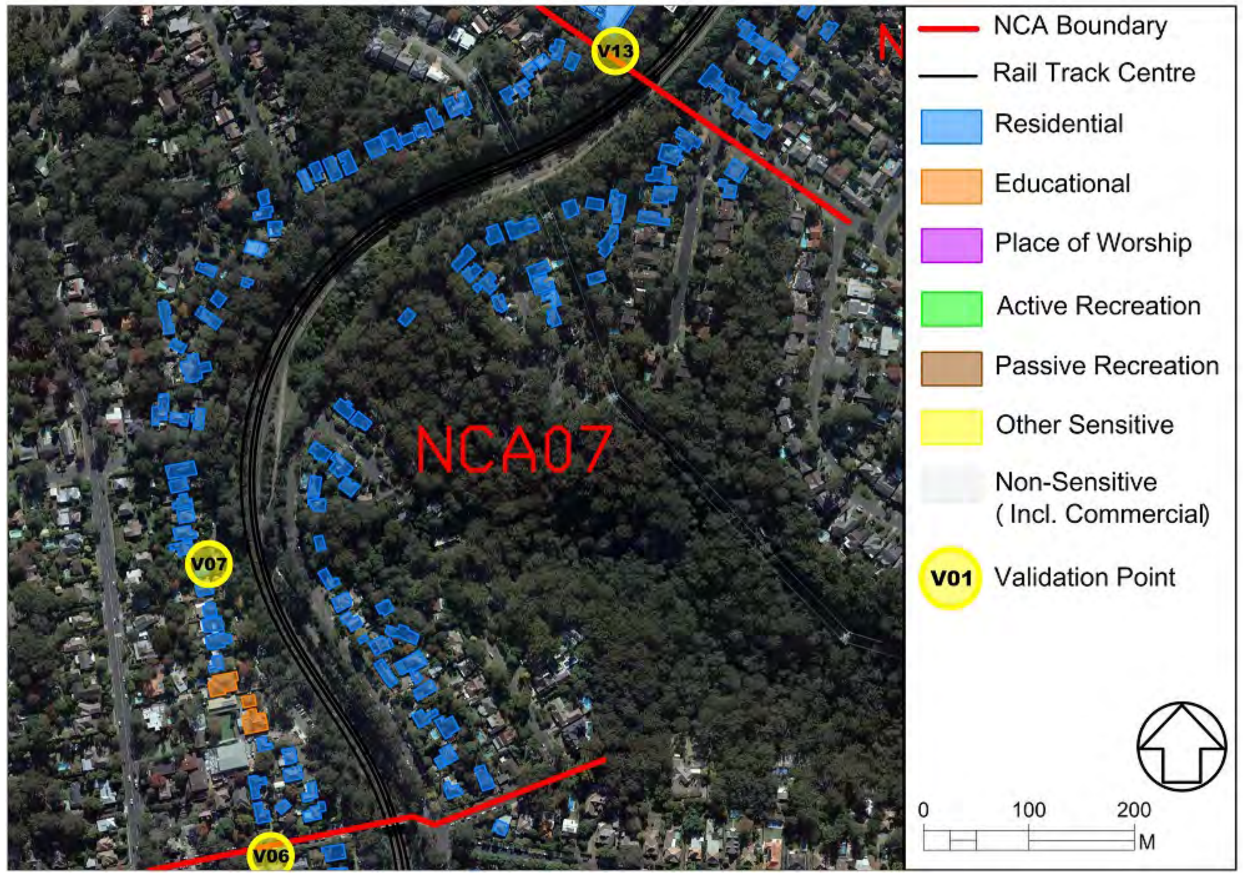
3.2.7 Noise Catchment Area 07

NCA 07 covers the northernmost small radius curve near Beecroft, extending from Chapman Avenue north to Boundary Road on the Down side and Azalea Grove on the Up side. Streets included in NCA 07 are Wongala Road (between Chapman Avenue and Boundary Road), Sutherland Road (between Garrett Road and Tristania Way), Cassia Grove and Clement Close.

NCA 07 includes Arden Anglican School at address 39-41 Wongala Crescent, Beecroft, and a childcare centre at 45 Wongala Crescent, Beecroft.

The operational rail noise sensitive receivers are shown in **Figure 8**.

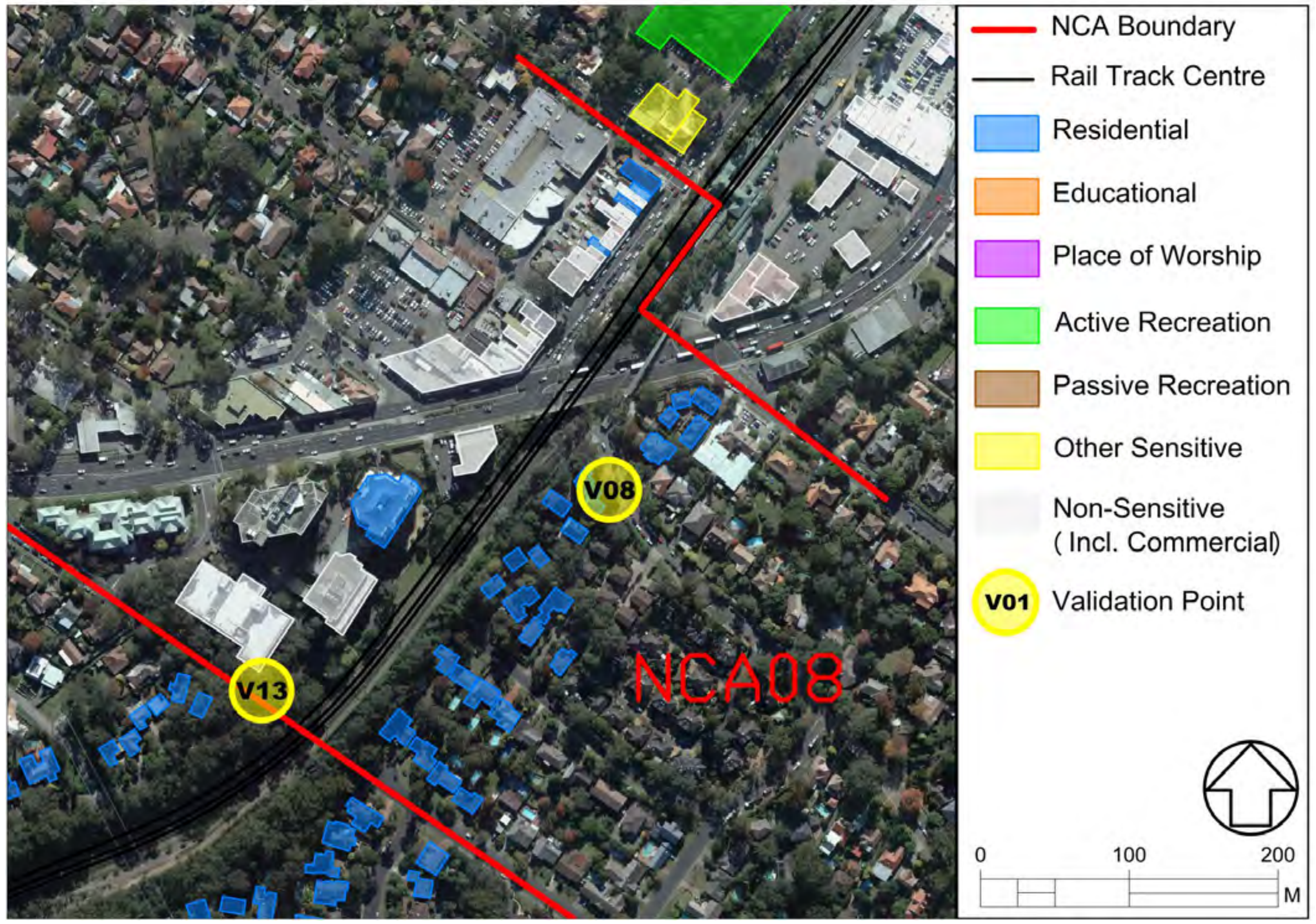
Figure 8 NCA07 Land Use and Model Validation Points



3.2.8 Noise Catchment Area 08

NCA 08 includes the Pennant Hills Road bridge over the railway. On the Up side, NCA 08 extends from Azalea Grove to the intersection of The Crescent with Pennant Hills Road, including Binomea Place and Hampden Road. On the Down side, this catchment includes properties between Boundary Road and Pennant Hills Road, and also properties on Yarrara Road south of Ramsay Road. This catchment includes the Pennant Hills shopping precinct, with some mixed use commercial / residential buildings in this stretch of Yarrara Road as shown in **Figure 9**.

Figure 9 NCA08 Land Use and Model Validation Points



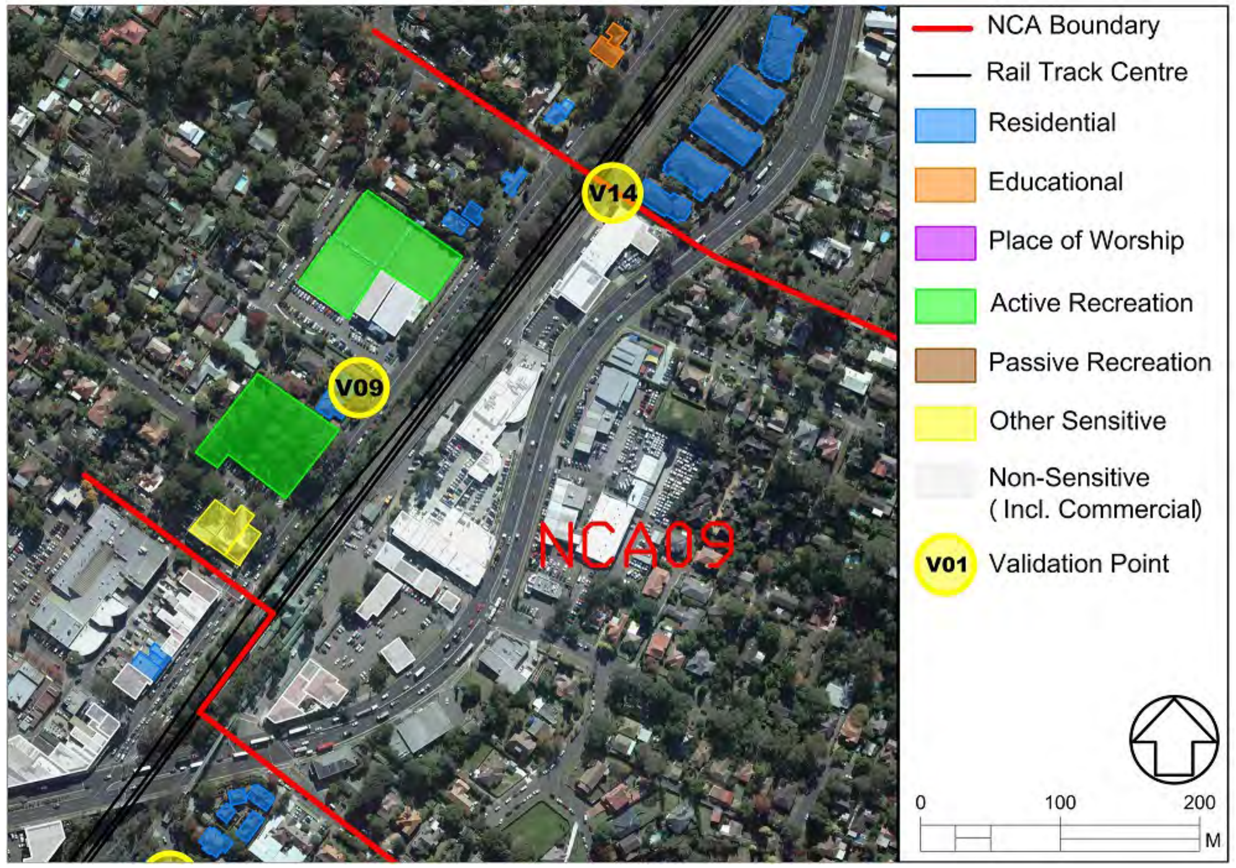
3.2.9 Noise Catchment Area 09

NCA 09 covers the area north of Pennant Hills Station to Stevens Street. On the Up side, this includes properties on Pennant Hills Road between The Crescent and Stevens Street. On the Down side this catchment includes Yarrara Road between Ramsay Road and Stevens Street.

This catchment includes the Pennant Hills Library and Community Centre on the Down side of the alignment at address 70 Yarrara Road, Pennant Hills. Other operational rail noise sensitive receivers in NCA 09 include active recreation areas at address 60 Yarrara Road, Pennant Hills (Wollundry Park), and at address 52 Yarrara Road, Pennant Hills (Pennant Hills Bowling Club).

The noise sensitive receivers are shown in **Figure 10**.

Figure 10 NCA09 Land Use and Model Validation Points



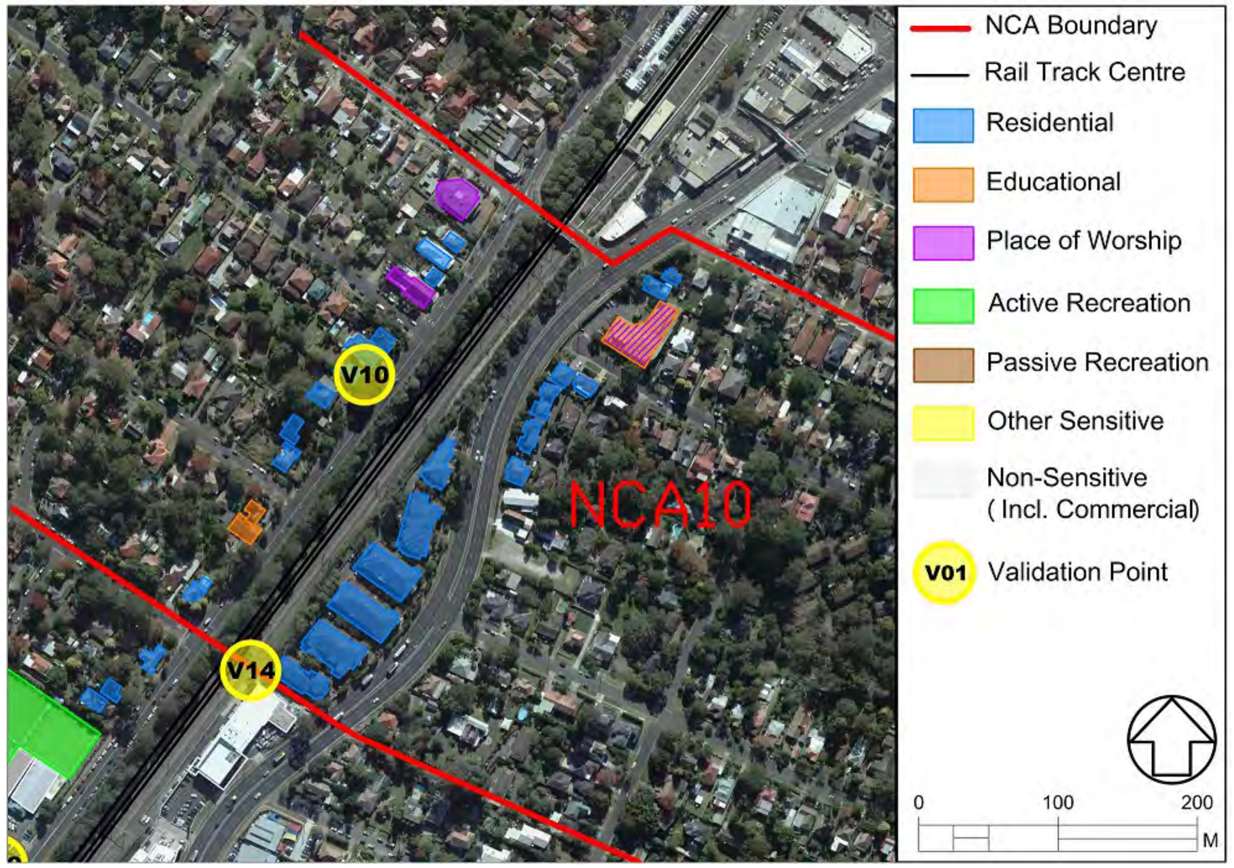
3.2.10 Noise Catchment Area 10

The northernmost catchment extends from Stevens Street to the Wells Street Overbridge at the southern end of Thornleigh Station.

The noise sensitive receivers are shown in **Figure 11**. Sensitive receivers (other than residential) in NCA 10 are:

- Pennant Hills Pre-school, 1 Fulbourne Avenue, Pennant Hills
- Seventh Day Adventist Church, 10 Yarrara Road, Pennant Hills
- Catholic Church, 2 Yarrara Road, Pennant Hills
- Uniting Church and Pre-School, 309-311 Pennant Hills Road, Thornleigh

Figure 11 NCA10 Land Use and Model Validation Points



3.2.11 Summary of Noise and Vibration Sensitive Receivers

A summary of individual receivers that are non-residential and sensitive to noise and/or vibration is given in **Table 2** below.

Table 2 Individual Non-Residential Receivers Identified within the Project Area

NCA	Receiver Type	Description	Address
01	Place of worship	Epping Baptist Church	1-5 Ray Road, Epping
01	Other sensitive	Epping Community Centre	9 Oxford Street, Epping
01	Educational	Our Lady Help of Christians School	29-31 Oxford Street, Epping
01	Place of worship	Our Lady Help of Christians Church	29-31 Oxford Street, Epping
03	Passive recreation	Lane Cove National Park	Sutherland Road, Cheltenham
04	Active recreation	Tennis Courts	74-60 The Crescent, Beecroft
05	Educational	Beecroft Scout Hall	The Crescent, Beecroft
05	Passive recreation	Beecroft Village Green	Beecroft Road and Mary Street, Beecroft
05	Active recreation	Beecroft Lawn Tennis Club	The Crescent and Beecroft Road, Beecroft
05	Educational	Beecroft Public School	90-98 Beecroft Rd, Beecroft
05	Other sensitive	Beecroft Community Centre	111 Beecroft Road, Beecroft
06	Passive recreation	Beecroft Station Park	Wongala Crescent, Beecroft
07	Educational	Arden Anglican School	39-41 Wongala Crescent, Beecroft
09	Other sensitive	Pennant Hills Library	70 Yarrara Road, Pennant Hills
09	Active recreation	Wollundry Park	60 Yarrara Road, Pennant Hills
09	Active recreation	Pennant Hills Bowling Club	52 Yarrara Road, Pennant Hills
10	Educational	Pennant Hills Pre-school	1-5 Ray Road, Epping
10	Place of worship	Seventh Day Adventist Church	10 Yarrara Road, Pennant Hills
10	Place of worship	Catholic Church	2 Yarrara Road, Pennant Hills
10	Place of worship	Uniting Church	309-311 Pennant Hills Road, Thornleigh
10	Educational	Pre-school	309-311 Pennant Hills Road, Thornleigh

4 NOISE FROM STATIONS

4.1 Station Noise Assessment Requirements

The ETTT Project includes the modification of Cheltenham Station and Pennant Hills Station to accommodate the additional third track and to provide additional facility upgrades.

Condition C2 of the project CoA requires an operational noise compliance assessment for the station modification works:

> *C2. Stationary facilities (including stations) shall be designed and operated with the objective of meeting operational noise levels derived from the NSW Industrial Noise Policy (NSW Government, 2000).*

A commitment was also made in the *Northern Sydney Freight Corridor Epping to Thornleigh Third Track Submissions Report* (March 2013), that PA systems:

> *"would be designed and installed in accordance with applicable best practice standards/guidelines."*

Assessment of the station upgrades includes measurements of the existing background noise levels, quantifying existing station noise emissions at the nearest receivers, and comparison of predicted future operational noise levels against project-specific noise criteria derived with reference to the existing noise environment. **Appendix C** to this ONVR contains a report documenting the assessment of station noise impacts in accordance with the CoA and the commitments made in the Submissions Report. This chapter provides an overview of the assessment and conclusions.

4.2 Description of Station Upgrades

4.2.1 Cheltenham Station Upgrade

The key feature of the Cheltenham Station upgrade is an access upgrade to make the station compliant with the Disability Discrimination Act (1992). The new design includes construction of a small concourse (on the southern side of the existing overbridge) to allow space for ticketing facilities, two new lifts, and stairs to provide access to the existing platforms.

The Cheltenham Station upgrade includes installation of a new station Public Address (PA) system. Currently the station PA is limited to 2 loudspeakers located under the Up-side shelter, one loudspeaker located on the Up-side Platform 1, and three loudspeakers located within the Down-side Platform 2 shelter which only service the area underneath and immediately adjacent the loudspeakers. The existing PA system does not change its volume depending on ambient noise levels.

The new PA design will include 22 loudspeakers distributed along Platform 1, 22 loudspeakers distributed along Platform 2, and 12 loudspeakers distributed within the new concourse area. The new PA will respond to ambient noise levels as described in Section 4.3 below.

4.2.2 Pennant Hills Station Upgrade

The Pennant Hills Station upgrade includes extension of the concourse, a new lift and stairs, modifications to the footpath and roadway on Yarrara Road, and a replacement footbridge south of the station. It also includes modification to the existing station PA system with 21 new loudspeakers to be installed along Platforms 2 and 3, and 14 loudspeakers to be distributed within the concourse area. Currently loudspeakers are located on Platform 1, Platform 2 and the existing concourse. The existing PA system does not change its volume depending on ambient noise. The additional speakers to be installed will simply extend the existing system and will therefore not change its functionality.

4.3 Station Noise Modelling Overview

The normal operation of the upgraded stations includes PA systems which include speakers placed at strategic locations to provide clear announcements and warning signals at platform and concourse areas and minimising noise levels at nearby sensitive receivers.

The PA system at Cheltenham Station will include a feature whereby sound pressure levels will be automatically controlled relative to the ambient noise environment, but would remain within maximum and minimum levels required to meet the relevant standards. This reflects the commitment made in the *Northern Sydney Freight Corridor Epping to Thornleigh Third Track Submissions Report* (March 2013) that "The PA system at Cheltenham Station would be designed and installed in accordance with applicable best practice standards/guidelines."

The noise sources with potential for noise emissions during standard operation of the stations include lifts on platforms, station PA systems, station building mechanical plant, cars in the car park area at Cheltenham and the transport interchange at Pennant Hills.

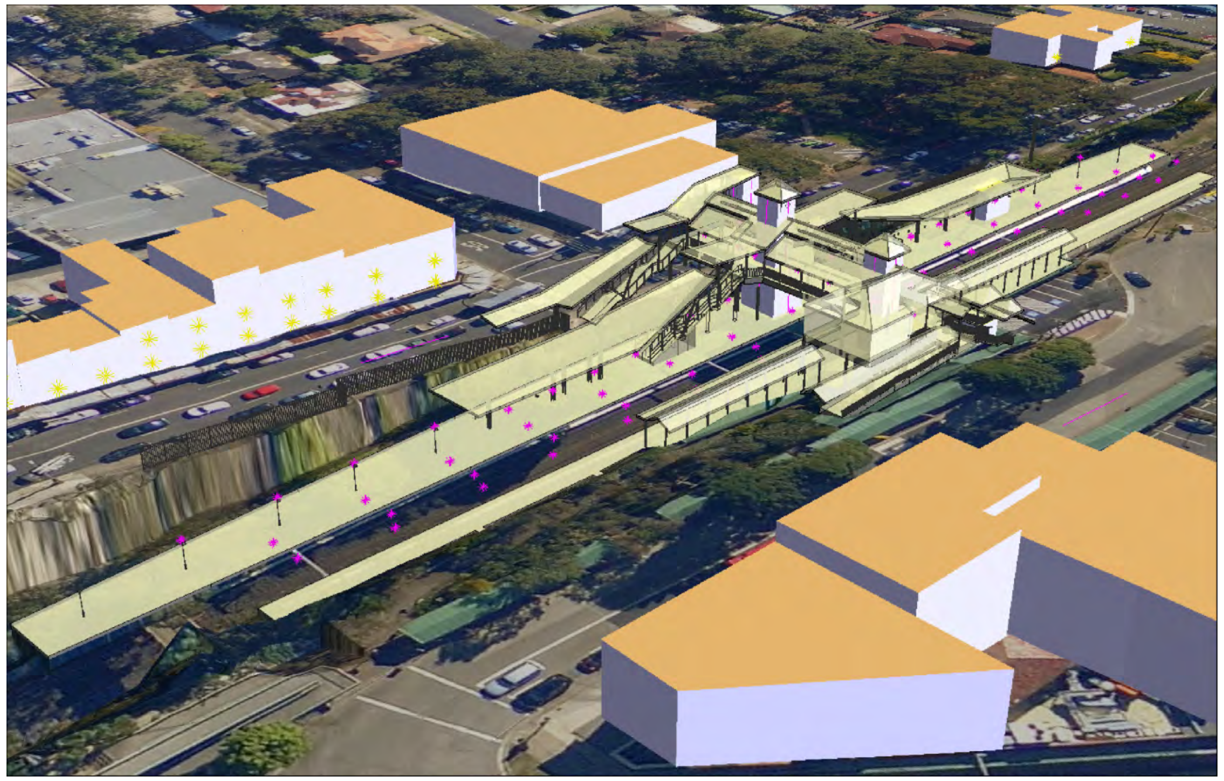
It is assumed that all noise sources may operate at any time, irrespective of the time of day. The key assumptions made in modelling each of these noise sources are summarised as follows. For a full description of the modelling process, see **Appendix C**.

- It has been assumed that air conditioning plant for the station buildings would operate continuously and will not be acoustically enclosed.
- Automated PA announcements are expected to be broadcast twice per train and with no more than one additional automated safety message broadcast every 15 minutes per platform.
- Loudspeaker mounting positions and orientations for Cheltenham and Pennant Hills Stations have been derived from the project drawings. The loudspeaker directionalities have been based on the performance specifications published by the loudspeaker manufacturer.
- Modelling of commuter car park noise emissions is representative of cars entering, searching for a car parking space, opening and closing car doors, re-starting the engine and exiting the car park.
- As the Pennant Hills Station transport interchange upgrade does not include supply of additional bus services or significant road modifications, there will be no increase in road traffic or interchange noise due to the project. Therefore, transport interchange facility noise has not been considered further.

The noise levels due to station operations have been predicted at the nearby noise sensitive receivers using computer noise modelling. The model takes account of factors such as the source sound power levels and locations, distance attenuation, ground absorption, air absorption and shielding attenuation, as well as meteorological conditions, including wind effects. The model of the Cheltenham Station is shown in **Figure 12** and Pennant Hills Station in **Figure 13**.

Figure 12 Cheltenham Station Noise Model

Figure 13 Pennant Hills Station Noise Model



4.4 Summary of Station Noise Modelling Results and Assessment

The noise modelling results presented in **Table 3** and **Table 4** summarise the noise impacts from the future station facilities at the worst-affected sensitive receivers under normal operating conditions. Also shown in **Table 3** and **Table 4** are the site-specific noise criteria, in accordance with the INP. For a full description of the derivation of criteria, see **Appendix C**.

Table 3 Worst Case Predicted Operational Noise Levels – Cheltenham Station

Receiver Type	Predicted Noise Level, dBA				Intrusiveness Criteria, dBA LAeq(15minute)			Amenity Criteria, dBA LAeq(period)			Sleep Disturbance Screening Criteria, dBA LA1(1minute)
	Day LAeq	Evening LAeq	Night LAeq	LAmax[1]	Day	Evening	Night	Day	Evening	Night	
Residential	43	38	36	60	48	46	36	55	45	40	46
Active Recreation	40	35	33	49	n/a	n/a	n/a	55	n/a	n/a	n/a

Note 1: Night-time LAmax level – shaded levels exceed the sleep disturbance screening criterion.

Table 4 Worst Case Predicted Operational Noise Levels – Pennant Hills Station

Receiver Type	Predicted Noise Level, dBA				Intrusiveness Criteria, dBA LAeq(15minute)			Amenity Criteria, dBA LAeq(period)			Sleep Disturbance Screening Criteria, dBA LA1(1minute)
	Day LAeq	Evening LAeq	Night LAeq	LAmax[1]	Day	Evening	Night	Day	Evening	Night	
Residential (South of station)	42	38	29	55	48	47	43	55	45	43	53
Residential (North of station)	53	49	40	65	53	51	44	55	51	49	54
Commercial	52	48	39	65	n/a	n/a	n/a	65	n/a	n/a	n/a
Educational	31	27	18	44	n/a	n/a	n/a	45	n/a	n/a	n/a
Active Recreation	41	38	28	54	n/a	n/a	n/a	55	n/a	n/a	n/a

Note 1: Night-time LAmax level – shaded levels exceed the sleep disturbance screening criterion.

From the operational noise modelling results presented in **Table 3** for Cheltenham Station and in **Table 4** for Pennant Hills Station, it can be seen that LAeq noise levels are predicted to comply with the project specific noise criteria at all receivers.

The predicted maximum noise levels shown in **Table 3** for Cheltenham Station show an exceedance of the sleep disturbance screening criterion by up to 14 dB. The source of this exceedance is noise from the car-park (eg car door closing). The maximum noise levels from the PA system at night at residential receivers are predicted to be 48 dBA, giving a minor exceedance of 2 dB.

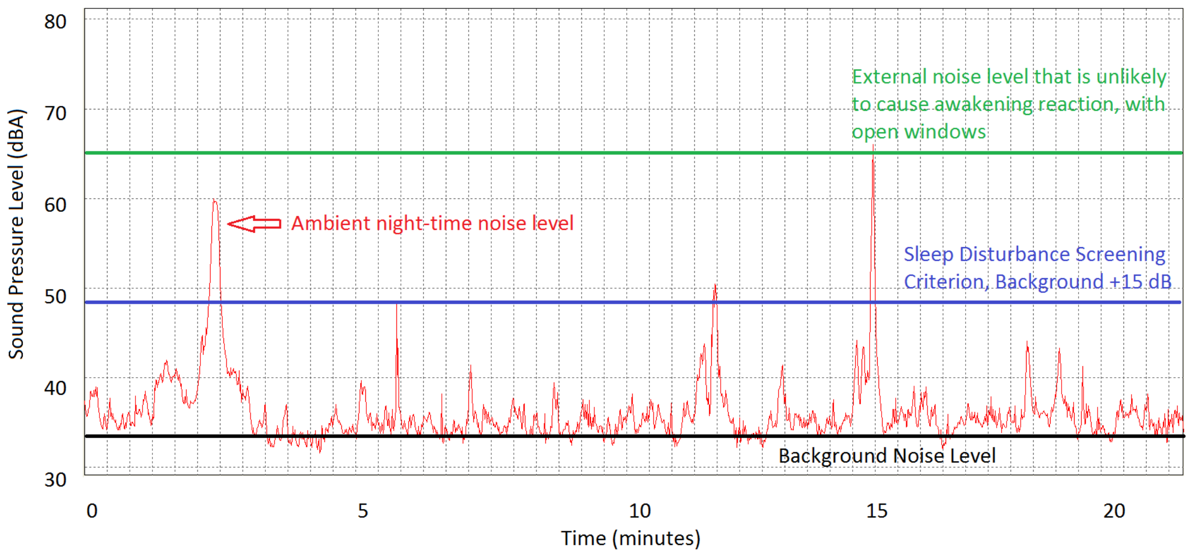
An exceedance of the sleep disturbance screening criterion does not indicate that sleep disturbance is expected to occur, rather that the potential for sleep disturbance impacts should be investigated further. The predicted maximum levels at residential receivers are less than 65 dBA, which is the external noise level above which awakening reactions might be expected with open bedroom windows.

Noise generated by people parking cars and closing car doors is considered to be consistent with the current noise environment, and would not represent a new source of noise as a result of the station upgrade. The project will also not result in any net increase in parking spaces. For these reasons, sleep disturbance impacts are not expected as a result of the station upgrade at Cheltenham.

The predicted maximum noise levels shown in **Table 4** for Pennant Hills Station also show potential exceedances of the sleep disturbance screening criterion by up to 2 dB (south of the station) and 11 dB (north of the station). These maximum noise levels are due to the PA system. However, the predicted maximum levels at residential receivers remain below the level that would be expected to cause awakening reactions (i.e. < 65 dBA); therefore, sleep disturbance impacts are not expected as a result of the station upgrade at Pennant Hills.

A figure illustrating the difference between the background noise level, the sleep disturbance screening criterion, and the external noise level that may give rise to awakening reactions is given in **Figure 14**.

Figure 14 Example Night-time Noise Level and Sleep Disturbance Indicators



Note: The peaks in the example night-time ambient noise level may be due to cars driving past on a quiet suburban street or other transient events.

4.5 Station Noise Assessment Conclusions

The noise predictions indicate that the operational noise levels at the nearest sensitive receivers to both upgraded stations will be compliant with the INP intrusiveness and amenity noise goals.

While there is the potential for exceedances of the sleep disturbance screening criteria at Cheltenham due to maximum noise emissions from the car park, and at Pennant Hills due to the PA system, the predicted maximum levels remain below the level that would be expected to cause awakening reactions. For this reason, sleep disturbance impacts are not expected as a result of the station upgrades at either Cheltenham or Pennant Hills.

5 NOISE FROM TRAINS

5.1 Introduction

The installation of the third track will result in a number of operational changes with potential noise impacts. Operational noise impacts from trains are likely to be associated with the following operational changes:

- Additional trains due to growth in freight numbers over time.
- New track location closer to existing receivers or resulting in a reduction of existing shielding effect from cuttings to some receivers
- Impact noise at new crossover locations, potentially increasing nearby L_{Amax} noise levels and subjective noise impacts.
- Noise from trains braking to a stop at a new signal location.
- Noise from stationary diesel locomotives at a new signal location.

It is noted that horn noise has not been considered in this assessment, as the project will not result in any change in the level or frequency of horn soundings. For the application of train horns during normal operations, it is generally understood that these are a safety critical device and are therefore exempt from the standard assessment criteria.

5.2 Assessment Process

Guidance in relation to the operational assessment process for the project is provided in the IGANRIP and the RING. The main purpose of these guidelines is to assist the ongoing expansion of rail transport by ensuring that potential noise impacts associated with rail developments are assessed in a consistent and transparent manner.

The following process has been used to review operational noise impacts in this Chapter:

- Develop a computer noise model of the project area taking into account the various rail noise sources, topography, shielding effects, and absorption effects.
- Validate the model using measured noise data collected during the EIS and in subsequent measurement programs.
- Use the model to predict noise impacts at all sensitive receivers within the project area, prior to opening and in the future, for the scenarios required by IGANRIP, RING and the CoA. These predictions are “unmitigated”, that is, they assume no mitigation measures have been installed for operations on the new third track. In addition it is assumed that no mitigation measures (such as the current lubricator trial) have been implemented for operations on the existing tracks.
- Assess the predicted unmitigated future noise levels of the project against the IGANRIP and RING noise trigger levels.
- Determine which guideline (IGANRIP or RING) is more conservative as required by the CoA.
- Identify locations where the trigger levels are predicted to be exceeded and hence where consideration of mitigation is required.

The assessment process has included consideration of a ‘safety factor’ on train numbers as required by the CoA. The EIS and this ONVR are based on levels of freight train movements predicted in the Northern Sydney Freight Corridor (NSFC) business case. In order to provide a safety factor or buffer on these forecast freight train movements, the assessment has considered the line capacity. The forecasts on which the business case was based show that freight train demand (usage) is expected to reach the capacity of the Main North Line by 2028, which is only two years after the predictions for the ONVR. Therefore noise levels were also predicted based on an additional scenario in which freight train movements were forecast to reach the line capacity two years ahead of predictions.

Later chapters of this ONVR consider the mitigation requirements for the project, on the basis of the “unmitigated” noise predictions. As described in Section 8, inclusion of the safety factor has resulted in a significant length of noise barrier being proposed that would otherwise not have been required.

5.3 Operational Noise Metrics

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

L_{Amax} The “Maximum Noise Level” occurring during a train passby noise event. L_{Amax} levels used in this report are 95th percentile levels, that is, the noise level that is not exceeded by 95% of rail pass-by events.

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

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

L_{AE} The “Sound Exposure Level”, which is used to indicate the total acoustic energy of an individual noise event. This parameter is used in the calculation of L_{Aeq} values from individual noise events.

The subscript “A” indicates that the noise levels are filtered to approximate normal human hearing characteristics (ie A-weighted).

5.4 Noise Trigger Levels

The EPA administers guidelines which provide noise trigger levels for rail infrastructure projects. These noise trigger levels indicate when a project should consider mitigating noise impacts.

The relevant EPA guideline until May 2013 was the Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects or IGANRIP. The IGANRIP was applicable to the project at the Environmental Impact Statement (EIS) Stage. In May 2013 (prior to ETTT project approval) the Rail Infrastructure Noise Guideline or RING replaced the IGANRIP. The CoA requires that both the IGANRIP and RING should be considered in this ONVR, with the mitigation requirements to be determined by whichever of these guidelines is most conservative (or stringent).

The IGANRIP and RING trigger levels for redevelopment of a heavy rail line are consistent; however, there are differences in the methodology required by the two guidelines to calculate and assess the impacts of a project and determine whether consideration of noise mitigation is required. The trigger levels for residential receiver locations are provided in **Table 5** and for other noise sensitive receiver locations in **Table 6**.

Table 5 Airborne Heavy Rail Redevelopment Noise Trigger Levels for Residential Land Uses

Type of Development	Residential Noise Trigger Levels (dBA)		Commentary
	Day (7.00 am to 10.00 pm)	Night (10.00 pm to 7.00 am)	
Redevelopment of existing rail line	Development increases existing rail noise levels AND Resulting rail noise levels exceed:		These numbers represent levels of noise that trigger the need for an assessment of potential noise mitigation measures to reduce noise levels from a rail infrastructure project. An increase in existing rail noise levels is taken to be an increase of 2.0 dB or more in the L_{Aeq} or an increase of 3.0 dB or more in the L_{Amax}.
	65 $L_{Aeq(15hour)}$ 85 L_{Amax}	60 $L_{Aeq(9hour)}$ 85 L_{Amax}	

Note: LAmax refers to the maximum noise levels not exceeded for 95% of rail pass-by events.

Table 6 Airborne Rail Redevelopment Noise Trigger Levels for Other Sensitive Land Uses

Sensitive Land Use	Noise Trigger Levels (dBA) (When in Use) Redevelopment of Existing Rail Line
	Development increases existing rail noise levels by 2.0 dB or more in LAeq AND resulting rail noise levels exceed:
Schools, educational institutions – internal	45 $L_{Aeq(1hour)}$
Places of worship – internal	45 $L_{Aeq(1hour)}$
Hospitals – internal	35 $L_{Aeq(1hour)}$
Hospitals – external	60 $L_{Aeq(1hour)}$
Open space – passive use (eg parkland, bush reserves)	65 $L_{Aeq(15hour)}$ [1]
Open space – active use (eg sports field, golf course)	65 $L_{Aeq(15hour)}$ [1]

Note 1: For passive recreation, IGANRIP specifies LAeq as per the residential limits. RING specifies LAeq(15hour). For active recreation areas, IGANRIP specifies LAeq(24hour) while RING specifies LAeq(15hour).

For projects involving a shared rail corridor (ie passenger and freight trains), the interim guideline specifies that all noise from the rail corridor needs to be considered in the assessment process. To allow relative noise contributions from different usages to be identified, both cumulative noise levels (passenger plus freight) and contributed noise levels should be reported.

In assessing noise levels at residential receiver locations, the outdoor noise level to be addressed is considered at a location 1 m in front of the most affected building facade. Any internal noise level refers to the noise level at the centre of the habitable room that is most exposed to the noise source and assumes windows are open sufficiently to provide adequate ventilation (notionally an open area equal to 5% of the floor area of the room). A typical noise reduction through the facade of 10 dB with open windows has been assumed in this report to convert internal noise level criteria to external noise level criteria for the assessment.

The noise trigger levels apply both immediately after operations commence and for projected traffic volumes at an indicative period into the future to represent the expected typical level of rail traffic usage (ten years or similar period into the future). The pertinent differences between the IGANRIP and RING for the purpose of this assessment are summarised in **Table 7.**

Table 7 Differences in RING and IGANRIP Assessment Requirements

Description	IGANRIP Approach	RING Approach	Discussion
Increase in LAeq noise levels	2.0 dB LAeq increase was to be assessed “in any hour”, for residential and other sensitive receivers	2.0 dB LAeq increase was to be assessed “for that period”, for residential and other sensitive receivers	The RING approach requires proponents to assess the magnitude of any increase at residences over the 15 hour “day” and 9 hour “night-time” periods. This change from the IGANRIP “in any hour” approach was introduced because practical application of the IGANRIP found that the requirement to assess changes in any hour was onerous and frequently impossible given data constraints about future train movements and timetables.[1] In practice, most IGANRIP assessments (including the ETTT EIS) assumed the increase in any hour was equivalent to the increase in that period. In this ONVR, the LAeq increase is taken over the 15 hour “day” and 9 hour “night-time” periods.
Minor works	Some redevelopment work was exempted as being minor work, such as the installation of track signalling devices, unless the works would result in an increase in existing rail noise levels beyond the trigger levels.	All rail infrastructure projects should be assessed to consider if they are likely to exceed the noise trigger levels	The noise impacts of all aspects of the works are considered in this ONVR. In particular, the noise due to trains stopping and idling at new signal locations is considered as part of the overall noise emissions from the operational rail corridor.
Rail traffic volumes for assessment	Rail traffic numbers preferably to be average weekday volumes.	Rail traffic numbers should reflect the reasonable maximum use, or “worst-case” typical day rather than average use.	This ONVR considers both approaches as required by the CoA.
Assessment years / build vs no build scenarios	Evaluation of noise is required prior to opening, immediately after opening, and at an indicative period (eg 10 years) in the future. This approach means the calculated noise increase includes a component from any growth in rail traffic, as well as any increases due to physical infrastructure changes.	Evaluation of noise is required at the time of commencement of operations, and for a design year (typically 10 years) after opening. For each of these timeframes, a comparison is made between the rail noise levels with the project (the “build” option), and the corresponding noise levels including general traffic growth that would have occurred without the project (the “no-build” option).	This ONVR considers both approaches as required by the CoA. It is noted that the IGANRIP approach is more stringent than the RING for a rail redevelopment project, as the IGANRIP methodology calculates the increase due to the project including growth in rail traffic over time, as well as any immediate increase due to the physical construction of the project. The RING methodology specifically excludes natural growth in rail traffic, and includes only growth in traffic that is directly facilitated by the project (ie growth in traffic above the “no-build” line capacity).

Note 1: EPA Information sheet – Key Changes in the Rail Infrastructure Noise Guideline

5.5 Noise Modelling Method

SoundPLAN Version 7.1 has been used to calculate railway noise emission levels for this project. Of the train noise prediction models available within SoundPLAN, the Nordic Rail Traffic Noise Prediction Method (Kilde 1984) has been used.

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

Noise emissions from freight trains tend to be higher than those from passenger vehicles. The highest L_{Amax} levels are generally caused by locomotive engine and exhaust noise. The wheel condition of freight vehicles tends to be worse than passenger vehicles as they have more wheel flats which causes higher noise levels. The length of freight trains compared to passenger vehicles means that a freight train will generate noise over a greater duration during a passby. However, where there are high numbers of passenger trains these can contribute more to the overall L_{Aeq} noise levels than freight traffic.

Impact noise from rail discontinuities such as turnouts and mechanical joints or uneven welded joints can also have an effect on the level of wheel-rail noise emission, as impulsive noise is emitted as each wheel of the train impacts the discontinuity. Existing and future turnouts in the study area have been included in the model.

In areas where there are tight curves flanging noise or curve squeal may also increase the levels of noise emission. Curve noise is an existing problem in the project area, as discussed in **Section 5.6.10**.

5.6 Noise Modelling Inputs

5.6.1 Track Alignment, Ground Terrain and Receiver Locations

The track alignments for the existing railway line and ground terrain data for the "existing" scenario are as provided by Transport for NSW for the EIS stage. Receiver locations are based on geo-referenced aerial photography. Building heights and number of storeys have been based on visual inspection and information available online. Detailed design information for the project including future track alignments, earthworks, locations of crossovers and signals has been provided by the ETTT Alliance. Hard ground has been assumed in the noise model.

Noise generated by the wheel-rail interface have been modelled with sources effectively at Top of Rail (TOR) height. Noise from locomotive exhausts has been modelled with an effective source height of 4.0 m above TOR.

5.6.2 Train Numbers and "Safety Factor"

The overall number of trains is shown in **Table 8** and has been sourced as follows:

- Passenger train numbers are based on the Passenger Standard Working Timetable, and advice from Transport Services Division of Transport for NSW. For passenger trains, the number of train movements in the 2016 scenarios has increased from the 2011 scenario as a result of the timetable change in October 2013. The 2016 scenarios include some empty (positioning) services. It is anticipated that that these empty car movements will be replaced with passenger services over time, giving effectively no net change in passenger services to 2026 from the 2016 scenario.

- Freight train numbers are based on the same forecasts that were included in the NSFC business case.

CoA C4(b) requires that the assessment of impacts in this ONVR "include a safety factor on train numbers". It is understood that this condition has been imposed to address community concern about the accuracy of forecast freight numbers, and a perception that the increase in freight traffic over time may be more than anticipated in the demand forecasts. For this reason, the "safety factor" is considered to be applicable to freight traffic only.

It is further understood that the "safety factor" CoA is a response to the sensitivity of the noise modelling predictions to the overall train numbers. For the ETTT project, many properties adjacent to the rail lines are exposed to existing rail noise levels that are in many cases above the overall trigger levels. In this situation, the requirement for a project to consider noise mitigation measures is triggered only at locations where the increase in L_{Aeq} (average) noise levels is 2 dB or more, or the increase in L_{Amax} noise levels is 3 dB or more. As identified in the EIS, the ETTT project will move northbound freight trains a few metres closer to existing properties on the Down side. However, this distance shift is not sufficient to increase the L_{Amax} noise levels at the facade by 3 dB. The requirement to consider noise mitigation in the EIS was therefore determined by the increase in L_{Aeq} (average) noise, particularly during the night-time period. Consideration of noise mitigation was triggered at only 27 scattered residential properties, with the majority of affected properties predicted to experience an L_{Aeq} increase slightly below the 2 dB trigger level. Because the triggered locations were scattered, it was concluded that noise barriers were unlikely to be a reasonable and feasible mitigation measure.

The community response to the EIS was that the existing level of rail noise in the area (especially maximum noise emissions from freight trains, with particular issues around curves) was unacceptable. Although the EIS process was in accordance with the EPA's guideline, triggering consideration of noise mitigation on the basis of the increase in "average" noise does not correspond well with the perceived impacts, which correlate to an increase in the number of noisy events. Effectively, the requirement to apply a "safety factor" to the train numbers means that the predicted increase in noise due to the project will be artificially increased, triggering consideration of noise mitigation at more locations. With more receivers triggered, noise barriers and other source or path control mitigation measures would potentially become a reasonable and feasible mitigation measure.

The magnitude of the "safety factor" to be applied is not defined in the CoA. In light of the above discussion, the weekly capacity freight numbers (in the form of the average per day) have been used in place of the forecast average freight numbers specified in the IGANRIP. This "safety factor" is considered to represent the realistic upper limit of noise impacts due to the ETTT project, assessed under IGANRIP. The noise increase due to the project with the safety factor under IGANRIP is then calculated from the difference between the forecast 2016 no-build scenario (average train numbers) and the capacity 2026 build scenario (average train numbers).

It is noted that the RING requires the use of typical maximum train numbers per day. For the RING assessment, the "safety factor" has been taken to be the maximum train numbers in any one day with the line operating at capacity after construction of the ETTT project. The noise increase due to the project with the safety factor under RING is then calculated from the difference between the forecast 2026 no-build scenario (maximum train numbers on any one day) and the capacity 2026 build scenario (maximum train numbers on any one day).

Table 8 Train Numbers for Noise Modelling

Scenario[1]	Train Type	Trains Per Weekday Period			
		Day 7.00 am to 10.00 pm		Night 10.00 pm to 7.00 am	
		Up	Down	Up	Down
2011	Electric Passenger	101	106	27	23
	Diesel Passenger	5	5	0	0
	Freight daily average	5	6	5	4
	Freight peak on any day	8	9	8	7
2016 No build	Electric Passenger	109	111	28	30
	Diesel Passenger	5	5	0	0
	Freight forecast daily average	6	7	7	6
	Freight forecast peak on any day	9	11	12	10
2016 Build	Electric Passenger	109	111	28	30
	Diesel Passenger	5	5	0	0
	Freight forecast daily average	7	7	7	6
	Freight forecast peak on any day	10	11	11	10
2026 Build	Electric Passenger	109	111	28	30
	Diesel Passenger	5	5	0	0
	Freight forecast daily average	10	13	12	9
	Freight capacity daily average[1]	11	14	13	10
	Freight forecast peak on any day	14	18	17	13
	Freight capacity peak on any day[1]	14	20	18	17
2026 No Build	Electric Passenger	109	111	28	30
	Diesel Passenger	5	5	0	0
	Freight forecast daily average	6	8	10	8
	Freight forecast peak on any day	9	11	15	12

Note 1: EA modelling under IGANRIP was based on the average freight numbers per day. Typical peak numbers per day are required for the RING assessment. Capacity average and peak represent the inclusion of a safety factor on train numbers as required by the Conditions of Approval.

For comparison purposes, the above train numbers for ONVR noise modelling are reproduced in **Table 9** in the format used in the submissions report to describe the numbers used in the EIS noise modelling (Submissions Report Table 5.4). **Table 9** also shows the train numbers used during the EIS stage.

Table 9 Average Daily Train Movements EIS vs ONVR Noise Modelling (both directions)

Assessment Stage	Year	Freight			Passenger		
		Day	Night	Total	Day	Night	Total
EIS	2011 (existing)	11	9	20	217	50	267
	2016 (at opening)	14	14	28	223	50	273
	2026 (10 years after opening)	23	21	44	223	50	273
	2026 (10 years after opening without project)	14	18	32	223	50	273
ONVR	2011 (existing)	11	9	20	217	50	267
	2016 (at opening)	14	13	27	230	58	288
	2026 (10 years after opening)	23	21	44	230	58	288
	2026 (10 years after opening without project)	14	18	32	230	58	288
	2026 (10 years after opening with safety factor)	25	23	48	230	58	288

Note: Average daily movements shown. Freight numbers on individual days may be more or less than shown, see **Table 8** for details of peak daily movements and where these have been modelled in the ONVR.

5.6.3 Train Types and Fleet Mix

In the EIS, rail traffic numbers and fleet mix for the existing case and for future operating scenarios were provided by Transport for NSW in consultation with Sydney Trains.

The passenger timetable has since been updated, as of October 2013. The passenger train numbers and mix for future scenarios have therefore been updated accordingly on the basis of the *Standard Working Timetable 2013 – Rail passenger Services Book 1 Version 2.05 (130823)*. Consideration was also given to predicted increases in service frequency over time and the likely effect of the North West Rail Link on network operations. It was concluded that the existing 'empty' train set operations between Hornsby and Epping would be progressively replaced with revenue services as service frequency increased, resulting in no net increase in the number of passenger trains. Services that currently operate via the Epping to Chatswood line would operate via Strathfield following introduction of the North West Rail Link, but this is not predicted to affect the number of services between Epping and Thornleigh.

Passenger Fleet Mix

The passenger fleet mix assumed for noise modelling purposes is summarised in **Table 10**, beginning with the overall fleet mix percentages provided by Sydney Trains (previously RailCorp) for 2011. The fleet mix for 2016 is based on the 2013 Standard Working Timetable. For the future scenarios ten years after opening it is assumed the older double deck suburban train sets will be effectively phased out over time.

Some classes of passenger train are combined in the noise model where previous noise measurement data has indicated similar noise emissions. Combining some train types gives the following mix of electric passenger trains for detailed design modelling purposes:

Table 10 Electric Passenger ETTT Fleet Mix Assumed for Noise Modelling

Type	2011	2016	2026
Double deck suburban (C/K/S/L/R sets)	57%	29%	1%
A/M/T/H sets	15%	53%	81%
V-Set (Intercity)	28%	18%	18%

Based on the timetable corresponding to 2011 (and unchanged through to October 2013), around 63% of all electric passenger trains were express trains through the project area, while 37% stopped at all stations. The V-Sets were all express services, meaning approximately half of the remaining electric passenger services were also express (ie half the DDS, and half the more modern train sets). This represents a refinement from the EIS assessment which treated only V-sets and diesel passenger (XPT) services as express trains.

A new passenger timetable was introduced in October 2013. Under this timetable, 45% of passenger services are express and 55% are stopping services. V-Sets are all express services, and almost all the Double Deck Suburban services are stopping services. Approximately half the more modern train sets are express services.

In the future (2026) scenarios when the DDS services are almost phased out, 33% of the more modern train sets would be express trains and 67% would be stopping services. This assumption maintains the current balance of express and stopping services.

A summary of the express and stopping trains is provided in **Table 11**.

Table 11 Electric Passenger ETTT Express and Stopping Services for Noise Modelling

Type	2011		2016		2026	
	Express	Stopping	Express	Stopping	Express	Stopping
Double deck suburban (C/K/S/L/R sets)	50%	50%	0%	100%	0%	100%
A/M/T/H sets	50%	50%	50%	50%	37%	67%
V-Set (Intercity)	100%	0%	100%	0%	100%	0%

Freight Fleet Mix

For the existing (2011) scenario, the length of freight trains and the number of locomotives has been set based on freight traffic axle counts in the project area over ten days in 2012, and throughout October 2013. The number of locomotives and wagon length for the future scenarios has been set to give the same overall average forecast length as used in the EIS based on the NSFC business case predictions. The resulting parameters used to describe typical freight train lengths and numbers of locomotives for the detailed design modelling are:

- Existing (2011) Scenario Freight – 750 m of wagons, with 60 m of locomotives (approximately 3 locomotives on average).
- All Future Scenario Freight (2016-2026) – 1,100 m of wagons with 70 m of locomotives (approximately 3.6 locomotives on average).

5.6.4 Train Source Noise Levels

The source noise levels used for the ONVR modelling are listed in **Table 12** and **Table 13** for rolling noise and engine / exhaust noise respectively. The source levels are based on measurement data in the *RAC Line-Based Noise PRP Study – Noise Source Working Paper* (Richard Heggie Associates, 2000), supplemented by additional measurement data collated by SLR Consulting as part of the Rail Clearways Program.

For passenger trains, the model also factors in the average length of passenger services, as determined from the timetabled number of cars for services of each train type from the Passenger Standard Working Timetable. Stopping services and DDS trains are generally 8 car sets, while express and intercity trains comprise a mix of 4 car and 8 car sets with an average of 6 cars.

Table 12 Rolling Noise Source Levels used for Modelling

Train Types	LAE	LAmax (dBA)
Double Deck Suburban (DDS)	91	87
M-Set / T-Set / H-Set / A-Set	88	85
V–Set	90	92
Diesel passenger	90	90
Freight locomotives rolling noise per 20 m (80 km/h)	85	87
Freight wagons rolling noise per 1000 m (80 km/h)	100	93

Note Reference conditions 15 m from track centreline and 80 km/h, free-field. LAmax noise levels are the 95th exceedance levels.

Table 13 Engine / Exhaust Noise Source Levels used for Modelling

	LAE (dBA)						LAmax (dBA)
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	All Speeds
Freight Diesel Engine (Low Notch)	78	77	76	75	74	74	78
Freight Diesel Engine (Medium Notch)	86	85	84	83	82	82	85
Freight Diesel Engine (High Notch)	92	91	90	89	88	88	91
Freight Dynamic Brake (High)	91	90	89	88	87	87	90
Diesel Passenger (Low Notch)	81	80	79	78	77	77	80
Diesel Passenger (Medium Notch)	85	84	83	82	81	81	84
Diesel Passenger (High Notch)	88	87	86	85	84	84	88

Note Reference conditions 15 m from track centreline, free-field. Reference noise levels are per locomotive (20m). LAmax noise levels are the 95th exceedance levels.

The above LAmax figures are calculated as a 95th percentile sound level based on the freight fleet only, ie without including passenger trains. The noise modelling in the ONVR assumes the following:

- Within the model, each train type is modelled using source noise levels representative of the LAmax,95% (typical maximum noise level for each train type)
- This generates a LAmax,95% noise level for each sensitive receiver for each train type. The highest LAmax,95% value is reported as the receiver noise level.
- The same approach is used for the future noise scenarios with the modified alignment and operating conditions
- The change in LAmax,95% noise levels at sensitive receivers represents the change in maximum noise levels that sensitive receivers would notice if the same train operated with and without the project (ie, the direct change in LAmax noise levels as a result of alignment changes and changes in operating conditions). SLR understands that this is the intent of the LAmax,95% noise trigger levels.
- By modelling train noise as above, this approach over-estimates the LAmax,95% noise levels when all trains are considered in the sample. In the case where freight trains on the near track generate the highest LAmax,95% levels, the addition of quieter trains on the near track and other trains on further tracks would statistically lower the overall LAmax,95% levels.

Consideration was also given to the effect of calculating LAmax levels based on the entire train fleet including passenger trains. To examine this situation in more detail, a spreadsheet was set up to model the statistical variation of all train types operating on the respective tracks consistent with the ONVR noise modelling scenarios. For each train type, noise levels were modelled using source levels consistent with the ONVR assumptions. The statistical variation in noise levels for each train type was assumed to be normally distributed with a standard deviation of 2.5 dB. This results in a LAmax,95% noise level 4 dB higher than the mean. Using the train numbers for the Year 2016 (no build) and Year 2026 (build with safety factor) scenarios consistent with the ONVR, a random number generator was used to generate a statistical distribution of noise levels across a typical daytime and night-time period for each noise modelling scenario. Using a Monte Carlo simulation, 1,000 averages (representing 2+ years) of daily noise distributions were run to determine the average LAmax,95% levels for the 4 modelling scenarios at a typical receiver. For the daytime scenario, the average increase in LAmax,95% levels as a result of the project (2026 with safety factor minus 2016) was 1 dB, consistent with the EIS modelling results. For the night-time scenario, the average increase in LAmax, 95% levels as a result of the project (2026 with safety factor minus 2016) was 1.3 dB. The additional 0.3 dB change represents that change associated with the disproportionate increase in freight trains.

On the basis of the above analysis, it is concluded that the increase in number of freight trains relative to passenger trains has only a small effect on the overall LAmax, 95% noise levels. In the assessment only three properties are predicted to exceed trigger levels based on the LAmax criterion (more properties are predicted to exceed trigger levels based on the LAeq criterion). Inclusion of the passenger fleet in the calculation of LAmax level increases would result in an additional six receivers exceeding trigger levels. However these six additional receivers are all also triggered in the LAeq assessment, therefore there would be no net change.

Observations of freight wagon passbys indicates that wheel defects are relatively common in the existing fleet. These defects result in increased wheel-rail noise emissions during passbys, and additional subjective annoyance factors. Since wheels can be reprofiled, there is potential for long term reductions in freight wagon noise in the long term with improved maintenance regimes.

Similarly, it is likely that changes in the locomotive fleet mix will occur over time, and that this may lead to reductions in noise impacts in future due to the phasing out of noisy locomotives.

This assessment does not assume any reduction in freight source noise levels over time. This approach is conservative in the assessment of impacts to determine locations where consideration of noise mitigation measures is required. The potential benefits of changes to the locomotive fleet mix and maintenance practices are discussed further in Section 8.11 in considering noise mitigation options.

5.6.5 Notch Settings

The notch settings assumed in the assessment for both freight locomotive and diesel passenger services in both directions are shown in **Figure 15** and **Figure 16** along with the corresponding image of the track diagrams showing gradient (refer *Infrastructure Engineering Manual Curve and Gradient Diagrams Volume 1* - Rail Access Corporation, 1999). For freight trains, the modelled notch settings correspond to high notch settings on the Down tracks and low to medium notch settings on the Up track with dynamic braking applied from 200 m north of Pennant Hills Station through to the M2 overbridge.

Figure 15 Notch settings in Down direction (uphill)

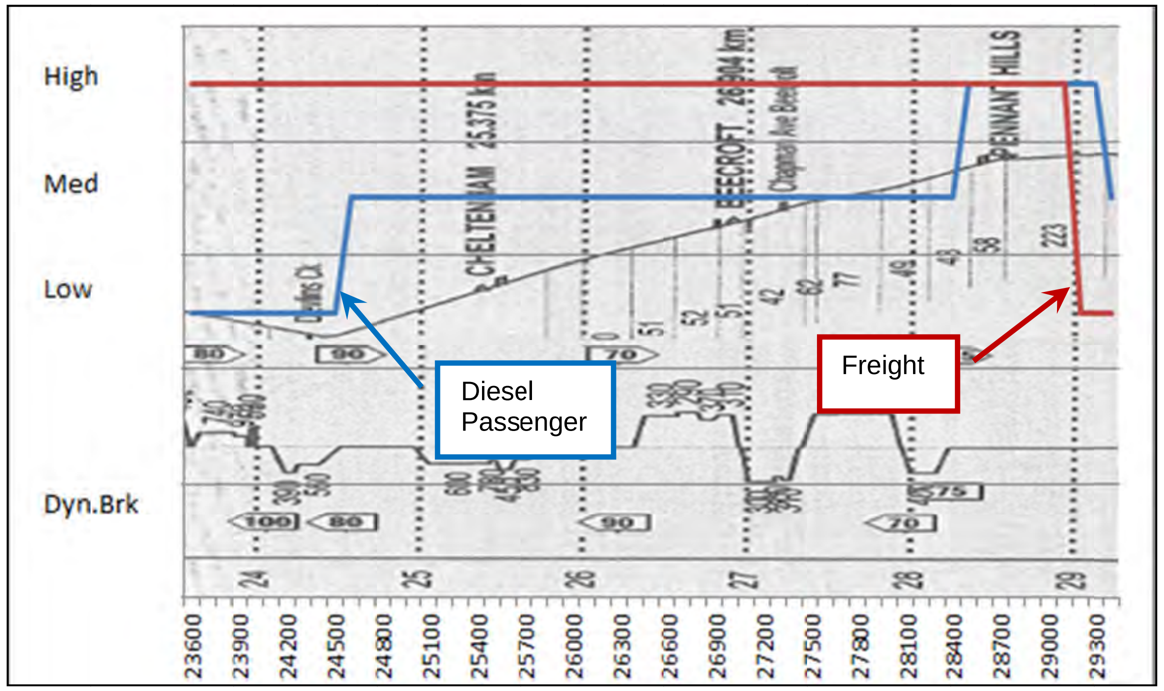
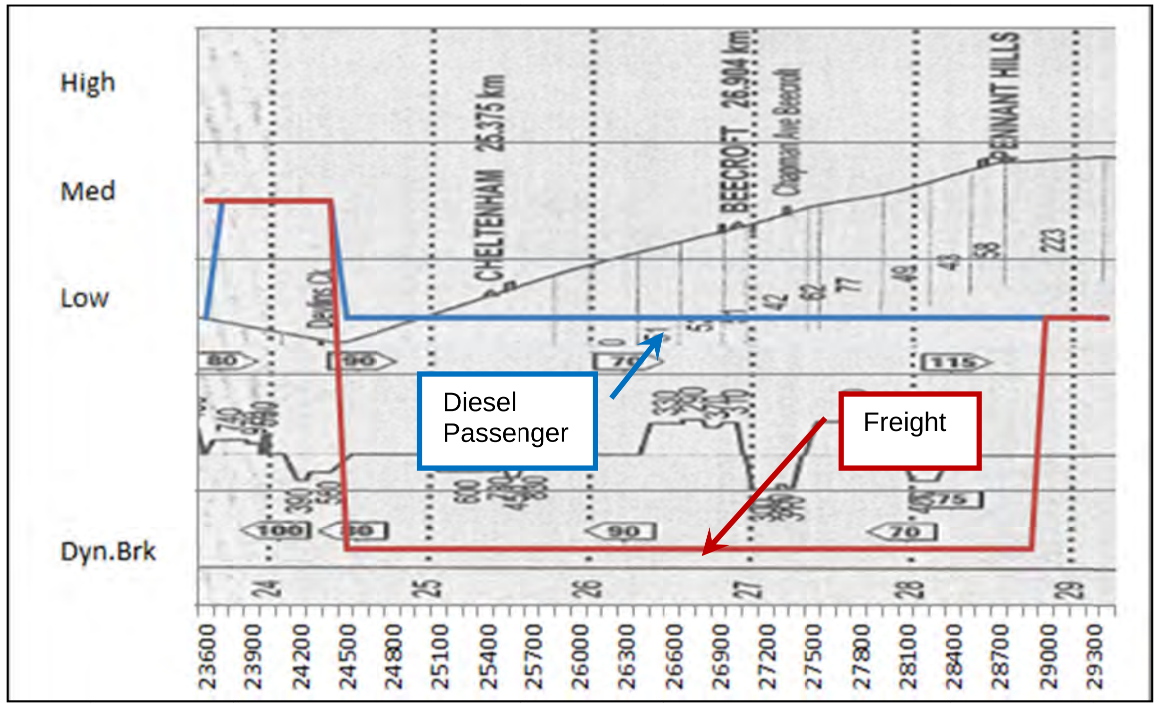


Figure 16 Notch settings in Up direction (downhill)



5.6.6 Train Speeds

Passenger Speeds

Passenger speeds are assumed to be the same in the "build" and "no-build" scenarios, with the exception of diesel passenger services which would run at lower speeds on the ETTT than on the existing Down Main.

The speed profiles for passenger trains have been updated from the simplified assumptions used in the EIS to allow for differences in speed between the different train types, differences between stopping and express services, and locations where speed restrictions are in place. The passenger speeds are consistent with observed speeds during attended measurements on site reported in the EIS (reproduced in **Table 14**).

Table 14 Summary of Observed Passenger Train Speeds

Chainage (km)	Number of Electric Passenger Trains		Average Observed Passenger Speeds (km/h)	
	Up	Down	Up	Down
25.200	24	21	64	57
26.150	23	23	72	63
28.125	21	26	61	63
28.950	21	19	65	73

The passenger train speeds for noise modelling purposes are shown in **Figure 17** to **Figure 20**.

Figure 17 Assumed Typical / Average Passenger Train Speeds Down – No Build

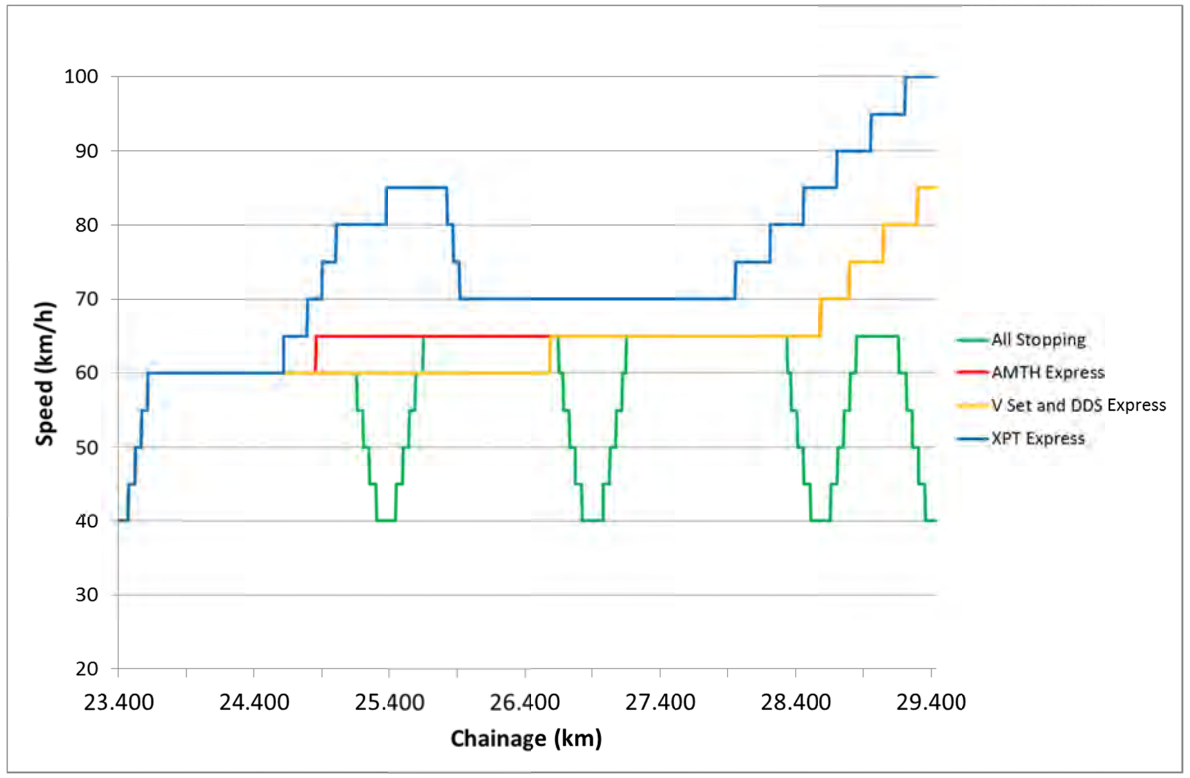


Figure 18 Assumed Typical / Average Train Speeds Up – No Build

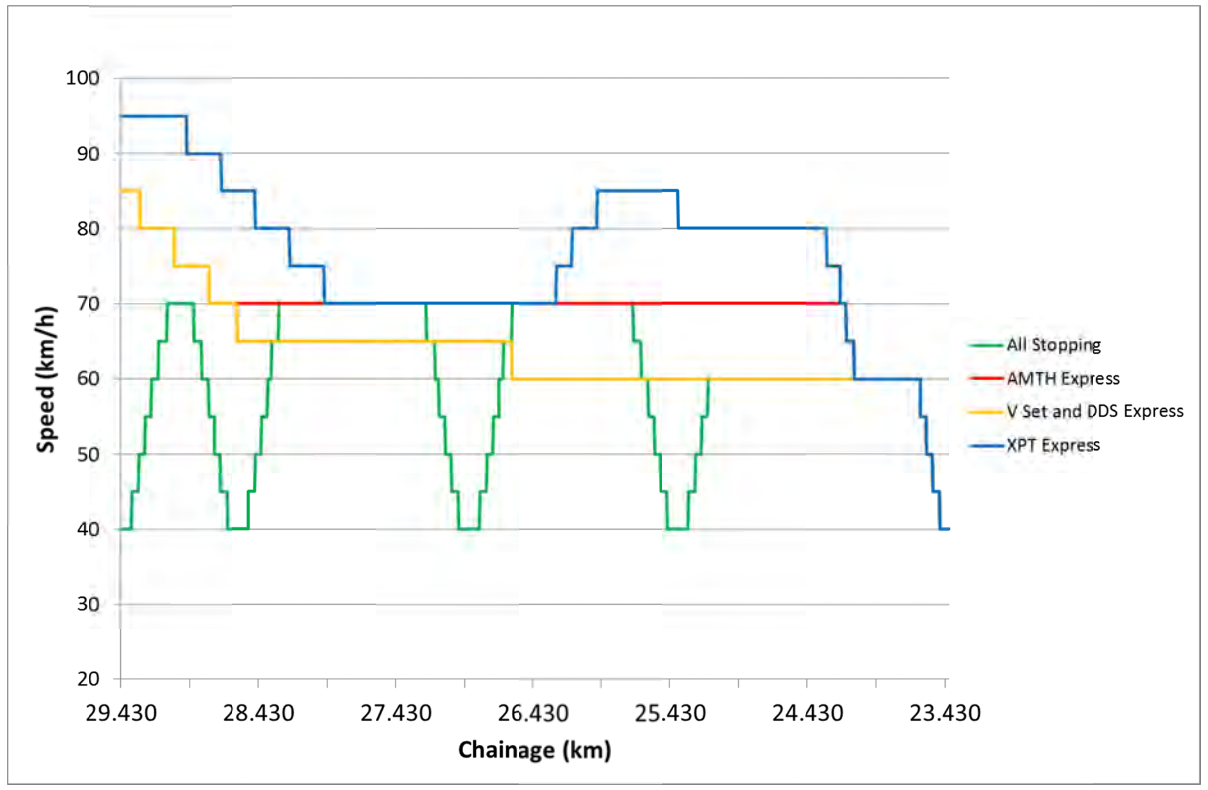


Figure 19 Assumed Typical / Average Train Speeds Down – With ETTT

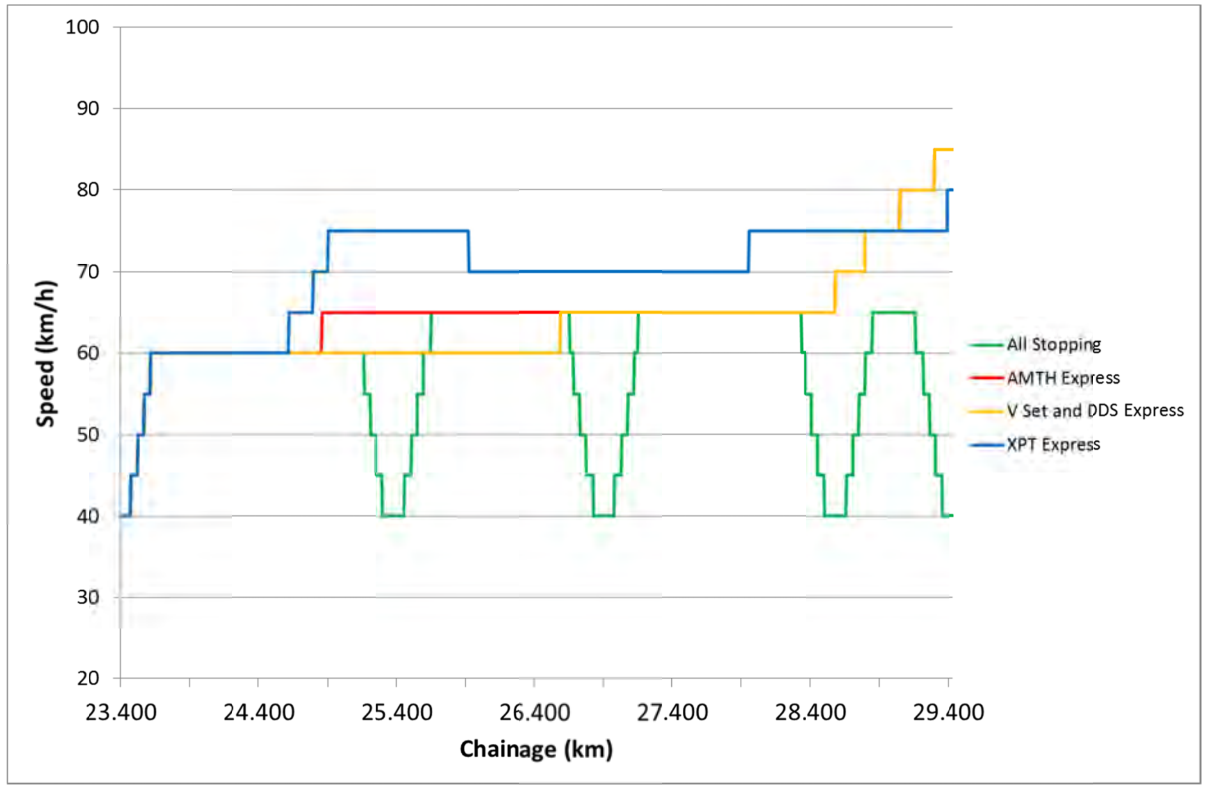
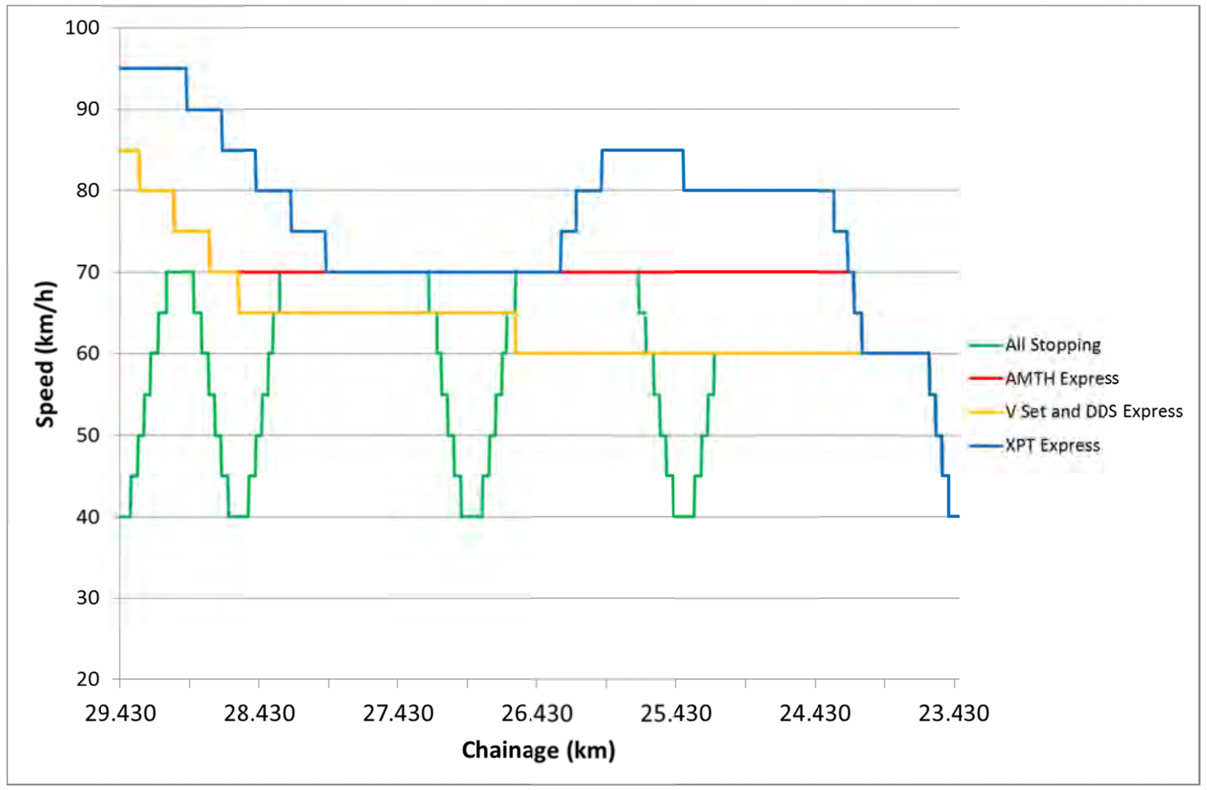


Figure 20 Assumed Typical / Average Train Speeds Up – With ETTT



Freight Speeds

In the EIS stage the assumed typical speed profile for freight trains had speeds between 40 km/h and 50 km/h on the Up Main and between 20 km/h and 50 km/h in the Down direction. The lowest speeds were assumed for freight trains in the Down direction between Cheltenham and Beecroft, through the small radius curves.

Subsequent studies have indicated that freight speeds throughout the project area are highly variable, with speeds varying between 10 km/h and 70 km/h commonly observed. The average speeds observed on site by SLR Consulting and by Transport for NSW Freight and Regional Development (FRD) in the Beecroft / Cheltenham area are summarised in **Table 15**.

Table 15 Summary of Observed Freight Train Speeds

Data Source	Number of Freight Trains		Average Freight Speeds (km/h)	
	Up	Down	Up	Down
SLR measurements November 2012	67	81	46	40
FRD Source Noise Monitoring Station October 2013	315	304	42	37
FRD Source Noise Monitoring Station January 2013	236	234	40	36

Modelling freight traffic at low speeds is the worst case assumption for engine / exhaust noise, as the source is present for more time while the locomotives move slowly past a receiver. However, rolling noise generated at the wheel-rail interface is proportional to increasing speed. For rolling noise, the worst-case modelling assumption is high speeds.

In order to investigate the sensitivity of the ONVR outcomes to variation in the freight speed, investigations have been made to calculate the overall number of residential receiver locations across the project area with overall levels above the absolute IGANRIP and RING trigger levels under different speed assumptions, with the maximum freight numbers in the future 2026 scenario. The speed assumptions investigated were:

- Low speed freight – 30 km/h in the Down direction, and 40 km/h in the Up direction. This scenario reflects the fact that some freight trains travel very slowly through the project area, particularly in the uphill (Down) direction
- Average speed freight – freight speeds throughout the project area of 40 km/h in the Down direction, and 50 km/h in the Up direction (higher speeds on the downhill track). These speeds are close to the highest average observed speeds in each direction between Cheltenham and Beecroft.
- High speed freight - 50 km/h in the Down direction, and 60 km/h in the Up direction. This scenario is representative of freight speeds that are above the average observed speeds, but are physically achievable by the majority of freight trains.
- Maximum speed freight - 60 km/h in the Down direction, and 70 km/h in the Up direction. This scenario is representative of the upper limit of possible speeds through the area for the majority of freight trains. These speeds would be realised by only a small number of freight trains.

Table 16 shows the number of residential receiver points with levels above the overall night-time $L_{Aeq(9hour)}$ and L_{Amax} trigger levels in each of the speed scenarios.

Table 16 Sensitivity of Noise Predictions to Freight Speed

Scenario	Number of Residential Locations with $L_{Aeq(9hour)}$ >60 dBA	Percentage Change from Average Speed	Number of Residential Locations with L_{Amax} >85 dBA	Percentage Change from Average Speed
Low speed freight	480	0%	492	-2%
Average speed freight	481	0%	500	0%
High speed freight	521	8%	513	3%
Maximum speed freight	563	17%	539	8%

Note: LAeq(15hour) daytime results not shown, as the LAeq(9hour) night-time period controls the assessment

The results in **Table 16** indicate that use of “low” speeds in place of “average” speeds would not make a large difference to the outcomes for either L_{Aeq} or L_{Amax}.

Maximum noise levels from freight exhausts are independent of speed. While general wheel-rail freight noise is proportional to speed, the maximum noise level around curves has also been observed to be independent of speed (see **Section 5.6.10**). For this reason, the use of “high” speeds would make a relatively small difference to the predicted maximum noise levels from freight trains.

The use of “high” freight speeds in the noise model would result in an increase in the overall night-time L_{Aeq} predictions by 0.8 dB on average across all locations. This would increase the number of properties with predicted noise levels above the L_{Aeq} night-time trigger level, by around 8%. The assumption of maximum freight speeds would increase the overall night-time L_{Aeq} predictions by 1.6 dB on average and increase the number of properties above the trigger levels by 17%, provided all freight trains travelled at the maximum speed.

With reference to the model validation results in **Section 5.7**, the freight model and the measurements have been found to be in good agreement with a modelling assumption of average speeds. Increasing the freight speeds by 10 km/h in each direction would introduce a tendency to over predict the freight contribution by around 1 dB. Increasing the freight speeds by 20 km/h in each direction would lead to a general over prediction of around 2 dB in the freight contribution.

It has been concluded that the average freight speeds are appropriate for noise modelling purposes, and that modelling higher speeds would lead to an over-prediction of impacts. Recognising that the addition of the safety factor has also added conservatism to the L_{Aeq} noise predictions, the average freight speeds have been used throughout the remainder of this assessment.

5.6.7 Traffic Distribution Between Tracks

For the existing, prior to opening and future "no build" scenario, all traffic would operate on the existing Down and Up Main Lines.

For the after opening and future "build" scenarios, all freight and XPT services in the Down direction are assumed to shift onto the new third track. All other traffic (including express passenger trains) remains on the main lines. It is noted that there is the potential for afternoon peak intercity express services to also use the new third track to overtake stopping services. This has not been modelled, as the number of trains is anticipated to be low (ie not affecting overall daytime L_{Aeq} model results). Furthermore, modelling indicates that the maximum noise levels from freight trains on the new third track are marginally higher than those associated with express passenger services on this track.

5.6.8 Braking and Wagon Bunching Noise

Whilst the presence of brake squeal is unpredictable and levels are highly variable, the likelihood increases in the vicinity of track leading up to signals where trains come to a stop. This may include distances of up to 1 km leading up to signals (for long trains).

Some freight services travelling on the new third track may be required to stop and stand at Thornleigh between the hours (approximately) of 8:00 am and 3:00 pm, while awaiting clearance to re-join the Down Main track. This is due to the frequency of freight and passenger train services on the two northbound tracks and the fact that these two tracks converge at Thornleigh (where the third track will end). Freight services are expected to operate only infrequently between 3pm and the end of the evening peak, due to the high number of northbound passenger services timetabled to operate in this period. After the end of the evening peak through until 8:00 am the following morning freight operations are expected to operate without needing to stop at Thornleigh, due to the lower frequency of passenger trains during these times. For planning purposes, it is assumed up to 50% of long term freight paths during this time period may require stopping and standing at Thornleigh between 8:00 am and 3:00 pm. Outside of this time period (ie during the evening and night-time) it is not expected that any freight services will require standing at Thornleigh under normal operations.

The maximum noise levels due to braking and wagon bunching noise is typically between 80 dBA and 90 dBA at 15 m from the source. These levels are equivalent to or lower than the maximum noise levels from express passenger services, and hence the predicted maximum noise levels due to braking and bunching noise are not modelled as independent sources. The resulting L_{Amax} levels from braking and bunching would be no higher than the express passenger services. The noise impacts of braking and bunching are therefore captured in the $L_{Amax,95\%}$ parameter of the model results.

5.6.9 Diesel Locomotives Idling at Signals

In some situations where a freight train has insufficient margin to stay ahead of a passenger service, freight trains may need to stop briefly within the third track to allow for overtaking. These staged freight trains would then follow closely behind the overtaking passenger service.

A source noise level for stationary idling freight locomotives has been taken from the ARTC and Sydney Trains Environmental Protection License (EPL) noise limits for stationary operating conditions as shown in **Table 17**. This source level has been observed by SLR Consulting to be consistent with measured idling noise levels in service and from locomotive type testing.

Table 17 Freight Locomotive Idling Noise Emissions

Distance	Maximum Noise Level[1]	Maximum Sound Power Level per Locomotive	$L_{Aeq(15hour)}$ Sound Power Level per Locomotive[2]
15 m	70 dBA	102 dBA	84 dBA

Note 1 For a constant noise such as a stationary diesel engine, the LAeq noise level will be approximately equal to the L_{Amax} noise level.
Note 2 Based on each locomotive idling for 15 minutes during the 15 hour period

Some freight services travelling on the Down track may be required to stop and stand at Thornleigh between the hours (approximately) of 8:00 am and 3:00 pm. For planning purposes, it is assumed up to 50% of long term freight paths during this time period may require stopping and standing at Thornleigh. It is assumed that the average idling time of each train would be up to 15 minutes, to allow a passenger train to proceed ahead of the freight train.

Outside of this time period (ie during the evening and night-time) it is not expected that any freight services will require standing at Thornleigh under normal operations.

With reference to the numbers of freight trains and hence locomotives expected in the down direction in the future scenarios with the ETTT, **Table 18** shows the anticipated total number of locomotives that may be held at the signals at Thornleigh per day (during the daytime period).

Table 18 Freight Locomotive Idling Numbers

Scenario	Total Number of Idling Locomotives per day[1]
After Opening 2016	6
Future Year 2026 (average per day)	11
Future Year 2026 (peak per day)	15

Note 1 The number of idling trains per day would be less, ie the total number of idling locomotives divided by the average number of locomotives in each consist.

Idling locomotives have been included in the noise model as point sources distributed along the track in the 100 m leading up to the signal location. Idling noise sources have been included in the daytime "build" scenarios only, ie they are not included in the prior to opening and "Future 2026 No Build" scenarios, or in night-time scenarios. This means that the anticipated noise impacts of idling locomotives are captured in the overall noise model results.

5.6.10 Curve Noise

Curve squeal around the existing small radius curves at Beecroft (NCA 5, NCA 6 and NCA7) has been a particularly annoying noise source affecting the local community over many years.

The EIS noise study identified that existing squeal noise levels in this particular area were higher than the modelled levels (which relied on typical curve noise modelling source level corrections). The EIS recommended lubrication of the tracks and further investigation of squeal impacts in the detailed design stage. The EIS noted that the project was not expected to increase the existing maximum noise levels due to curve squeal by the 3 dB trigger amount that would consideration of mitigation due to L_{Amax} noise impacts. The reason is that the distance shift of rail traffic on the Down side to the third track closer to receivers is not sufficient to increase L_{Amax} noise levels by 3 dB.

The CoA include a number of conditions that are unique to this project, reflecting the situation where community opposition to the ETTT project is strongly linked to the existing curve noise issue. CoA C4 requires a re-examination of curve squeal noise impacts. It also requires the project to mitigate the existing curve squeal problem, irrespective of the IGANRIP or RING requirements and assessment outcomes.

Additional studies of curve squeal have been undertaken since the exhibition of the EIS, and the results of these investigations have been incorporated into the noise model of the unmitigated situation. Sydney Trains (previously RailCorp) Report *TR NV 20120809 Investigation into curve gain at Beecroft* (15 August 2012) describes measurements taken simultaneously on the curved track section and the adjacent straight track section. These measurements were used to determine the increase in L_{Amax} and L_{AE} noise emissions on the curves, relative to the noise emissions on straight track.

On the basis of the Sydney Trains (previously RailCorp) report, the ONVR noise modelling includes the following allowances for localised increases in noise emission around the Beecroft curves in the unmitigated case prior to lubrication:

- +5 dB passenger L_{AE}
- +14 dB passenger L_{Amax}
- +9 dB freight L_{AE}
- +21 dB freight L_{Amax}

At other curves in the project area with a radius of less than 500 m an allowance of +3 dB in L_{AE} and L_{Amax} has been applied.

Investigations also indicate that severe squeal noise around the Beecroft curves is not proportional to speed. The above correction factors for curve squeal used in the model are applicable at the average speeds used in the model. A discussion of the model validation for curve squeal noise impacts is provided in **Section 5.7**.

5.6.11 Other Modelling Factors

The noise modelling also includes the following allowances for localised increases in noise emission:

- Turnouts +6 dB over 15 m track distance (L_{AE} and L_{Amax}).
- A facade reflection of 2.5 dB for receivers located adjacent to buildings.

5.7 Noise Model Validation

To validate the noise model, receiver points representing noise measurement locations have been established in the model for the existing situation. The model is then used to calculate noise levels at the locations where measured data is available. In the EIS stage, this validation check was carried out at four logger points.

Since the EIS state, additional noise logging has been undertaken by SKM (for the purpose of establishing construction noise goals). Further data has been collected by acousticians from SLR Consulting, by Sydney Trains and by Transport for NSW, with emphasis on improving the modelling of freight noise emissions both on tangent track and around curves in the project area.

The addition of more recent data to the EIS logging locations gives a total of seventeen measurement points distributed across the noise catchments, of which fifteen are appropriate to use for validation of either the overall model results, the contribution of freight or passenger trains, or the maximum noise levels around small radius curves. Two of the logger locations used to establish background levels for setting construction noise goals were not able to be used for rail noise validation purposes, due to the setback distance from the corridor and the presence of noise from non-rail sources such as road traffic. The measurement locations are described in **Table 19** and shown in **Figure 2** to **Figure 11**. **Table 20** presents the comparison between the model and measurement results.

The measurement types are as follows:

- **Statistical noise logging** records statistical noise parameters such as L_{Aeq} and L_{Amax} in fifteen minute intervals. At locations where the noise environment is dominated by rail traffic, the logger data is representative of the overall daytime and night-time L_{Aeq} rail noise. At quiet locations or by examining the night-time period in isolation, L_{Amax} due to freight traffic can also be estimated under the assumption that the maximum noise level in a 15 minute period can be attributed to a freight train.
- **Ngara noise loggers** record noise levels at 0.1 second time intervals, and also record audio data. Processed Ngara data may be used for overall noise model validation in the same manner as statistical noise logging data. The raw data can also be used to extract the noise contribution from individual freight passby events, allowing validation of the modelled freight contribution independently of noise from other sources.
- **Attended measurements** (for this project) captured the noise from individual train passbys. The majority of these passbys were passenger trains, meaning this data may be used to validate the modelled passenger noise contribution.

Table 19 Noise Measurement Locations

Reference	Location	Date/ Source	Catchment / Side of Corridor	Measurement Description	Comments
V01	32 Cambridge Street, Epping	September 2011 – SLR	NCA01 Up	Statistical noise logger on balcony of Unit 12 (top floor), overlooking rail corridor approximately 1 m from facade	Used for overall model results validation
V02	2 Kandy Avenue, Epping	July 2013 - SKM	NCA02 Down	Ngara noise logger on front balcony, approximately 1 m from facade	Set back from rail corridor and affected by road traffic noise from Beecroft Road – not used for model validation
V03	100 The Crescent, Cheltenham	July 2013 - SKM	NCA03 Down	Ngara noise logger by tree in front yard, approximately 10 m from facade	Used for overall model results and freight contribution validation
V04	20 The Crescent, Cheltenham	September 2011 – SLR	NCA04 Down	Statistical noise logger by tree in front garden, approximately 10 m from facade	Used for overall model results validation
V05	Sutherland Road, near Copeland Road East, Beecroft	July/August 2013 - SKM	NCA05 Up	Ngara noise logger in rail corridor near power pole opposite 136 Copeland Road East	Used for overall model results validation
V06	1 Chapman Road, Beecroft	July 2013 - SKM	NCA06 Down	Ngara noise logger at tree in front yard, approximately 5 m from facade	Set back from rail corridor and affected by noise from other sources including road traffic during the daytime. LAeq used for model validation.
V07	57 Wongala Crescent, Beecroft	September 2011 – SLR	NCA07 Down	Statistical noise logger on front balcony, approximately 1 m from facade	Used for overall model results validation
V08	2 Hampden Road, Pennant Hills	July 2013 - SKM	NCA08 Up	Ngara noise logger at tree near front garden bed	Set back from rail corridor (which is in deep cutting) and affected by road traffic noise from Pennant Hills Road – not used for model validation
V09	56 Yarrara Road, Pennant Hills	July 2013 - SKM	NCA09 Down	Ngara noise logger on balcony, approximately 2 m from facade	Used for overall model results and freight contribution validation
V10	16 Yarrara Rd, Pennant Hills	September 2011 – SLR	NCA10 Down	Statistical noise logger on open porch of residence, facing railway corridor, approximately 1 m from facade	Used for overall model results validation
V11	Chainage 25.200	September 2011 – SLR	NCA04 Up	Attended measurements at end of Day Road, outside rail corridor access gate	Used for passenger contribution validation
V12	Chainage 26.150	September 2011 – SLR	NCA04 Down	Attended measurements and Ngara noise logger, opposite 14 The Crescent, outside rail corridor access gate	Used for passenger and freight contribution validation
V13	Chainage 28.125	September 2011 – SLR	NCA07 / NCA08 boundary Down	Attended measurements near the corner of Wongala Crescent and Boundary Road	Used for passenger contribution validation
V14	Chainage 28.950	September 2011 – SLR	NCA09 / NCA10 boundary Up	Attended measurements at western end of Stevens Street East, by rail corridor fence	Used for passenger contribution validation
V15	Chainage 26.080	November 2012 – SLR	NCA04 Down	Ngara noise logger in rail corridor, measurement at 7.5 m from Down track centreline (Wayside Noise Survey)	Used for freight contribution validation
V16	Beecroft – curved track	June 2012 – Sydney Trains (previously RailCorp)	NCA05 Up	Ngara noise logger in rail corridor, measurement at 19 m from Up track in curved section	Used for freight maximum noise level validation on curves
V17	Beecroft – tangent track	June 2012 - Sydney Trains (previously RailCorp)	NCA04 Up	Ngara noise logger in rail corridor, measurement at 19 m from Up track in tangent section	Used for freight maximum noise level validation on tangent track

Table 20 Modelling Predictions and Measured Noise Levels

Location Reference	Daytime Noise Level LAeq(15hour) dBA			Night-time Noise Level LAeq(9hour) dBA			95th Percentile LAmax dBA		
	Measured	Modelled	Difference[1]	Measured	Modelled	Difference[1]	Measured	Modelled	Difference[1]
Electric passenger contribution validation									
V11	60	60	0	56	56	0	83	85	2
V12	60	62	2	55	57	2	80	86	**6**
V13	59	60	1	55	56	1	83	85	2
V14	61	66	**5**	57	62	**5**	83	92	**9**
Freight contribution validation									
V03	48	50	2	51	51	0	80	83	**3**
V09	57	57	0	58	58	0	88	88	0
V12	60	59	-1	61	60	-1	94	92	-2
V15	63	63	0	64	64	0	97	98	1

Location Reference	Daytime Noise Level LAeq(15hour) dBA			Night-time Noise Level LAeq(9hour) dBA			95th Percentile LAmax dBA		
	Measured	Modelled	Difference[1]	Measured	Modelled	Difference[1]	Measured	Modelled	Difference[1]
V16	Measured LAeq data not available						106	107	1
V17	Measured LAeq data not available						95	93	-2
Overall level validation									
V01	63	63	0	60	61	1	88	88	0
V02	Measurements included non-rail noise								
V03	54	54	0	50	53	**3**	80	83	**3**
V04	57	58	1	57	57	0	88	87	-1
V05	69	71	2	69	70	1	97	109	**12**
V06	Measurements included non-rail noise			48	49	1	Measurements included non-rail noise		
V07	66	64	-2	62	63	1	100	101	1
V08	Measurements included non-rail noise								
V09	62	60	-2	59	59	0	88	88	0
V10	Measurements included non-rail noise			56	57	1	85	86	1

Note 1 A positive difference indicates the model prediction is higher than the measured value. Bold shaded values indicate a difference of greater than 2 dB between model and measurements – these results are discussed below.

The agreement between noise modelling results and measurements is normally considered acceptable if the variation is within 2 dB at all locations for the LAeq and LAmax noise levels. In **Table 20**, results with a difference of more than 2 dB are identified; these are examined in detail in the following sections.

5.7.1 Discussion of Electric Passenger Train Contribution

In general, **Table 20** indicates that the model tends to over predict noise from electric passenger trains slightly on average, when considering the LAeq parameters. At three of the four locations this over prediction is within acceptable bounds, while at one location (V14) the over prediction of LAeq is 5 dB in both the daytime and night-time periods. The model also shows an over prediction of LAmax levels from electric passenger trains at two locations (V12 and V14).

To understand these results, the attended measurement results for electric passenger trains (adjusted to the reference speed and distance) are compared against the model source levels in **Table 21**. This comparison indicates that the measured levels on site were sometimes significantly below the standard source levels assumed in the noise model. In all cases, the modelled source levels were above the measurement results.

Table 21 Measured vs Modelled Electric Passenger Source Levels

Location Reference	Train Types	Number of Measurements	LAE			LAmax		
			Modelled	Measured	Difference	Modelled	Measured	Difference
V11	DDS	15	91	89	2	87	89	-2
	M/T/H/A-Set	16	88	85	3	85	88	3
	V–Set	14	90	88	2	92	91	1
V12	DDS	17	91	88	3	87	88	-1
	M/T/H/A-Set	15	88	82	6	85	83	2
	V–Set	14	90	88	2	92	89	3
V13	DDS	10	91	89	2	87	90	-3
	M/T/H/A-Set	26	88	84	4	85	86	-1
	V–Set	11	90	88	2	92	89	3
V14	DDS	9	91	86	5	87	84	3
	M/T/H/A-Set	25	88	83	5	85	80	5
	V–Set	8	90	87	3	92	86	6
Combined	DDS	51	91	88	3	87	89	-2
	M/T/H/A-Set	82	88	84	4	85	86	1
	V–Set	47	90	88	2	92	90	-2

Note Reference conditions 15 m from track centreline and 80 km/h, free-field. LAmax noise levels are the 95th exceedance levels. Measured levels have been corrected for speed and distance.

For LAeq, it could be argued that the model source levels for electric passenger trains should be reduced by around 2 dB to 3 dB. The results for LAmax are more mixed. Maximum noise levels are highly variable, since the LAmax,95% can be affected by a small number of noisy events. LAeq is a more robust parameter from a model validation perspective.

There are a number of reasons why measurements on site can be less than the standard source levels. One factor is an improvement in rolling stock maintenance practices, with the introduction of Wheel Impact Load Detectors on the network in recent years resulting in fewer passenger trains with flat spots on wheels, and correspondingly reduced noise emissions.

Another key factor is the microscopic acoustic roughness of the rail – this roughness (in combination with the wheel roughness) causes the wheels and track to vibrate resulting in noise. Roughness can vary between different lines and between different locations on the same line, and can change over time. Rail grinding machines used in maintenance activities can sometimes increase acoustic roughness considerably, resulting in a noticeable increase in noise. In the absence of rail grinding, tracks can become smoother (and gradually quieter) over time. Measurements of acoustic rail roughness on the Main North Line from 2011 (Sydney Trains – previously RailCorp – Report *TR N&V 20111025 Corrugation Analysis Trolley (CAT) Survey Report – TORFMA Trial Beecroft* 25 October 2011) confirm very low roughness levels in the ETTT project area. This report notes that rail grinding was last done in September 2009 at the test location, and that the consistently smooth rail is typical of track well worn by freight and passenger traffic over time.

Since roughness could increase throughout the project area in future (for example after a program of maintenance grinding), it is not proposed to reduce the passenger train source levels used in the model. This means that the passenger noise contribution may be overestimated in the “2011 Existing” scenario. However, for the ETTT project in the future scenarios particularly in the night-time periods the noise impacts are dominated by freight vehicles. For this reason, the potential over-prediction of passenger train noise levels in the “2011 Existing” scenario does not affect the outcomes of the assessment.

5.7.2 Discussion of Freight Train Contribution

Table 20 indicates that the model prediction of noise from freight trains is generally in good agreement with measured levels. At one location, V03, the predicted L_{Amax} noise levels are 3 dB higher than measured. At this location the track is transitioning into deep cutting, with relatively complicated terrain. The slight over prediction of freight L_{Amax} noise levels is accepted at this location.

5.7.3 Discussion of Overall Noise Predictions

Table 20 indicates that the model prediction of overall rail noise levels is also generally in good agreement with measured levels, except at two locations where predictions are higher than measurements.

At location V03, the difference between modelled and measured daytime L_{Aeq} and L_{Amax} is 3 dB. As discussed above, the slight over prediction at this location is accepted in light of the complicated terrain.

At V05, adjacent to the tight curves in the alignment through Beecroft, there is a difference of 12 dB in the modelled and measured L_{Amax} noise levels. This location (measured in July / August 2013 by SKM) is only a few metres away from location V16, where Sydney Trains undertook noise logging to establish the site specific curve noise gain in June 2012. The L_{Amax} model predictions at location V16 are in good agreement with the Sydney Trains measurements.

Subsequent to the Sydney Trains measurements, trials of curve lubrication have been taking place throughout this area. At the time of the SKM measurements, a trial lubrication system had been installed. It is therefore likely that the over-prediction of the model in L_{Amax} at this location is due to the trial of mitigation systems, and that no change to the model is required for it to be representative of the "unmitigated' starting point for the noise assessment.

Overall the model is found to agree well with the observed rail noise environment at the site, and is suitable for predicting the increase in rail noise levels caused by the Project.

5.8 Overview of Predicted Noise Levels

Unmitigated noise levels have been predicted for all receivers throughout the project area for the scenarios required by the RING, IGANRIP and CoA. Tables showing the noise predictions at all individual receivers and the contribution of freight and passenger trains are attached as **Appendix D**. This section gives a broad overview of the predicted noise impacts, including:

- The different outcomes arising from the RING, IGANRIP and CoA requirements, including the overall number of locations triggered for consideration of noise mitigation
- A summary of the differences in night-time and day-time noise impacts
- A summary of the contributions of freight and passenger traffic
- The maximum predicted noise levels at residential receiver locations in each catchment

Section 5.9 goes on to describe the impacts in each NCA in more detail.

5.8.1 Different Outcomes Arising from the RING, IGANRIP and CoA Requirements

Condition C1 of the CoA requires that this assessment considers the noise impacts of the project under both the RING and the IGANRIP, with the most conservative guideline to be applied. Condition C4 of the CoA also requires the addition of a safety factor to the train numbers. The safety factor requirement and the use of different guidelines lead to different modelling outcomes. These differences may be summarised by comparison of the number of residential locations where exceedances of the noise trigger levels are predicted in each case, as shown in **Table 22**.

Table 22 Residential Locations Triggered under Different Scenarios

Scenario	Number of Residential Addresses Triggered[1]
IGANRIP	54
IGANRIP + Safety Factor	133
RING	7
RING + Safety Factor	26

Note 1: The number of residential addresses triggered counts addresses once only, in the event that more than one facade or level of the building is triggered. This number will be less than the number of individual properties triggered, where buildings contain multiple dwellings or apartments.

It is also noted that the number of locations triggered for consideration of mitigation without the safety factor has increased since the EIS assessment, where 26 residential addresses were identified. The difference between 54 and 26 is due to improvements made to the detailed design noise model, including updated speed assumptions, more detailed representation of passenger train types, inclusion of detailed design earthworks, and re-examination of curve squeal.

Sensitivity analysis of the detailed design model confirms that the number of triggered locations is very sensitive to small changes, since a change in the predicted increase due to the project of 0.1 dB can tip a particular location from being triggered, or not.

As discussed in Section **5.6.2**, the requirement to include a "safety factor" on the freight numbers is understood to be a response to the sensitivity of the noise modelling predictions and assessment outcomes to the overall train numbers (among other things). The safety factor effectively adds around 0.4 dB to the night-time freight train L_{Aeq} contribution (and a similar amount to the overall predictions, since the freight contribution dominates). Although the absolute difference is small, it corresponds approximately to a 20% factor applied to the increase due to the project. The results in **Table 22** indicate that the requirement to include a safety factor on train numbers gives rise to a significant increase in the number of locations triggered for consideration of mitigation.

It is evident from **Table 22** that the IGANRIP is more conservative than the RING, with more locations triggered for consideration of noise mitigation under the IGANRIP than under the RING. This is as expected, since the IGANRIP methodology calculates the increase due to the project including growth in rail traffic over time, as well as any immediate increase due to the physical construction of the project. The RING methodology specifically excludes natural growth in rail traffic, and includes only growth in traffic that is directly facilitated by the project (ie growth in traffic above the "no-build" line capacity).

On this basis, it is concluded that assessment of impacts under the more conservative IGANRIP is required by Condition C1, and the following sections of this ONVR refer to the predictions under IGANRIP. The RING predictions are provided for information in **Appendix D**.

5.8.2 Comparison of Daytime and Night-time L_{Aeq} Levels

The distribution of rail traffic in the future scenarios is such that the predicted overall daytime and night-time L_{Aeq} noise levels are very similar, typically within 1 dB. Since the night-time residential L_{Aeq} noise trigger levels are set 5 dB below the daytime L_{Aeq} noise trigger levels, the controlling time period for the assessment of impacts on residential locations is the night-time.

5.8.3 Summary of Freight and Passenger Contribution

Prior to the opening of the third track, both passenger and freight contribute to the overall daytime L_{Aeq} noise levels in the project area. At some locations, the daytime passenger contribution is slightly higher than the freight contribution, while at others the freight contribution is slightly higher. In future, the opening of the third track and growth in freight traffic will shift the balance so that the freight contribution to overall daytime L_{Aeq} noise levels is typically higher than the passenger contribution, at most receivers.

During the night-time, freight L_{Aeq} noise levels, both prior to opening and ten years after opening the third track, are higher than the passenger L_{Aeq} contribution.

Since passenger train numbers are not anticipated to increase in the project area, the increase in overall night-time L_{Aeq} noise levels reported in the EIS is attributable to the increase in freight traffic facilitated by the third track project.

Tables showing the noise predictions at all individual receivers including the contribution of freight and passenger trains are attached as **Appendix D**.

5.8.4 Maximum Predicted Noise Levels at Residential Receivers in each Catchment

The predicted highest overall rail noise levels predicted in each NCA immediately after opening and 10 years after opening are summarised in **Table 23**. This information is considered representative of the predicted noise level at the worst affected receiver in each NCA, and is provided for comparison purposes with the modelling results provided in the EIS stage. The primary difference in the current results to those in the EIS stage is in NCA05, NCA06 and NCA07 adjacent to the small radius curves through Beecroft. At these locations, the re-examination of curve squeal noise impacts (see **Section 5.6.10**) has increased the L_{Amax} and L_{Aeq} noise predictions.

Table 23 Summary of Highest Residential Noise Impacts

NCA	Side	2016 Prior to Opening (dBA)			2016 After Opening (dBA)			2026 with Safety Factor (dBA)		
		LAeq(15h)	LAeq(9h)	LAmax	LAeq(15h)	LAeq(9h)	LAmax	LAeq(15h)	LAeq(9h)	LAmax
01	Down	63	63	89	63	63	91	64	65	91
	Up	62	63	90	61	61	89	63	63	89
02	Down	61	61	87	60	60	87	61	62	87
	Up	68	67	93	67	67	92	68	68	92
03	Down	61	61	88	62	62	90	63	63	90
	Up	61	61	90	61	61	89	62	63	89
04	Down	64	64	93	64	64	93	65	65	93
	Up	62	62	91	62	62	91	63	64	91
05	Down	64	65	100	64	65	100	66	67	100
	Up	67	67	104	67	67	104	68	69	104
06	Down	65	66	102	64	64	100	65	66	100
	Up	67	68	104	67	68	104	68	70	104
07	Down	68	68	104	68	68	104	69	70	104
	Up	66	66	103	66	66	102	67	68	102
08	Down	63	63	91	64	63	92	65	65	92
	Up	66	65	93	65	65	93	66	67	93
09	Down	62	62	91	63	63	91	65	65	91
	Up	No residential receiver locations in NCA09 Up								
10	Down	62	62	90	63	62	91	64	64	91
	Up	67	66	93	66	66	93	67	67	93

5.9 Predicted Noise Impacts by Noise Catchment Area

In the following sections, the predicted unmitigated overall rail noise levels (including both freight and passenger traffic) are discussed for each of the NCAs. Tables showing the overall noise level predictions at all individual receivers by NCA and the contribution of freight and passenger trains are attached as **Appendix D**.

In each figure below, the presence of a red coloured 'dot' indicates that the property is predicted to exceed trigger levels based on the modelling scenario that does NOT include the safety factor on train numbers. The presence of a yellow coloured 'dot' indicates that the property is predicted to exceed trigger levels only in the modelling scenario that DOES include the safety factor on train numbers (that is, properties with yellow-colours dots are not predicted to exceed trigger levels unless the safety factor is included).

In several areas, there may be two or more adjacent properties where one receiver has a red coloured dot, and the adjacent receiver may have a yellow dot, or no dot at all. In these circumstances, there may be little or no difference in the overall noise levels, however the change in noise levels as a result of the project may be slightly below or above the relevant noise increase trigger level. In the extreme example, one property may have a predicted L_{Aeq} noise level increase of 1.9 dB as a result of the project (with no coloured dot) and the adjacent receiver may have a predicted L_{Aeq} noise level increase of 2.0 dB (with a yellow or red dot). In the latter case, mitigation measures would be considered for the property with the yellow or red dot. The noise modelling results are therefore very sensitive to small changes in the noise level increase as a result of the project. Some of these factors are described below:

- **Noise transmission path:** Small differences in the noise transmission path between the railway corridor and adjacent residences can influence the change in noise level as a result of the project. Where the track is located in a cutting, the relative influence of locomotive engine/exhaust noise and wheel/rail noise from freight wagons and electric passenger trains changes. As the ETTT alignment traverses undulating terrain for the majority of the alignment small changes in the noise transmission paths between adjacent receivers can explain why one property is slightly below or above the noise increase trigger level.
- **Height of Sensitive Receiver:** The relative height of a receiver compared to neighbouring properties is analogous to a change in the noise transmission path and may therefore alter the change in noise levels as a result of the project.
- **Change in operating conditions:** Within the noise model, the speed of trains, the engine notch settings, the presence of curves and other track features alter the relative contribution of the noise sources at various locations throughout the project area. In some areas where these parameters are changing, the noise level increase as a result of the project may be different for adjacent receivers. These changes may therefore alter the change in noise levels as a result of the project.

5.9.1 Predicted Noise Impacts NCA01

The locations in NCA01 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 21**.

Figure 21 NCA01 Locations Triggered for Consideration of Noise Mitigation

In NCA01, there is a large residential apartment building at 74 Rawson Street, immediately adjacent to the Down side at the northern end of Epping Station. Consideration of mitigation is triggered at this location on the northern end of the facade facing the rail corridor, in the scenario with the safety factor applied. The night-time L_{Aeq} noise level is predicted to be 65 dBA, with an increase due to the project of 2.0 dB. This building facade is approximately 40 m from the future ETTT.

Consideration of mitigation is also triggered at the Epping Baptist Church, 1-5 Ray Road, on the basis that daytime rail L_{Aeq} noise levels are predicted to be 56 dBA in the safety factor case, with an increase of 2.1 dB. The predicted overall level with the safety factor is 1 dB above the external daytime noise goal determined for a Place of Worship under the assumption of open windows.

Compliance with the noise trigger levels is predicted at all other sensitive receiver locations in NCA01.

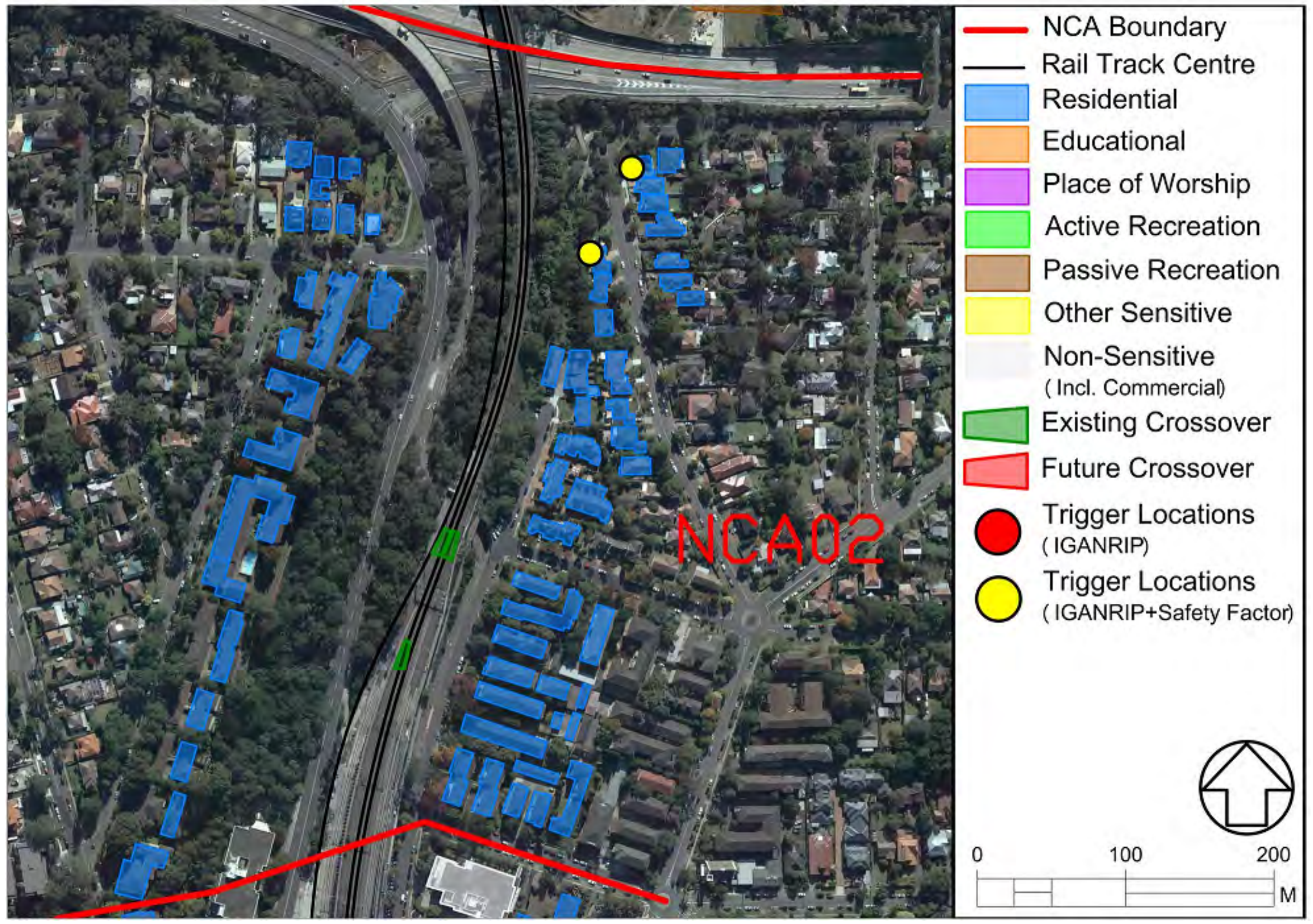
In NCA01, it is noted that a new crossover will be constructed to allow freight trains travelling north to transfer onto the new ETTT. This new crossover is not predicted to increase the maximum noise levels due to freight trains, as these are dominated by the freight exhaust rather than the noise from the wheel/rail interface. However, the new crossover introduces the potential for subjective noise impacts due to the impulsive noise of wheels impacting on the track at the crossover.

Noise mitigation options for triggered locations in NCA01 are discussed in **Section 8**.

5.9.2 Predicted Noise Impacts NCA02

The locations in NCA02 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 32**.

Figure 22 NCA02 Locations Triggered for Consideration of Noise Mitigation



In NCA02, residential properties on the Down side of the corridor are set back typically around 70 m to 90 m from the railway line. As a result, the predicted rail noise levels typically remain below the overall noise trigger levels. No properties are triggered for consideration of noise mitigation on the Down side in NCA02.

Consideration of mitigation is triggered at two locations on Derby Street at the northern end of NCA02, on the Up side. These properties are also set back around 70 m from the rail corridor, but are predicted to receive night-time L_{Aeq} noise levels of 61 dBA to 63 dBA, and increases of 2.0 to 2.1 dB between 2016 and 2026. These locations are triggered due to the addition of the safety factor, which has been applied to freight traffic travelling in both directions.

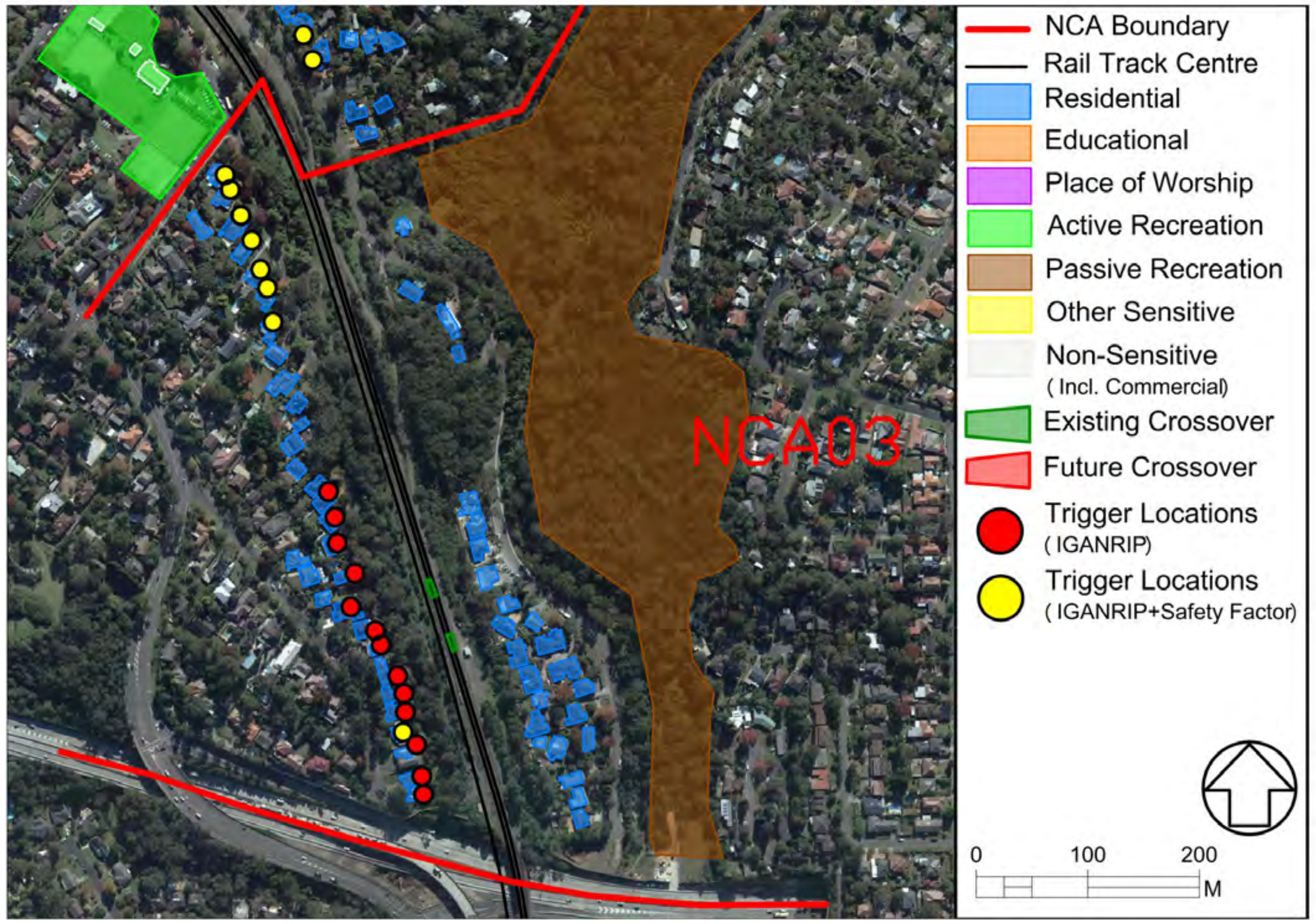
Compliance with the noise trigger levels is predicted at all other sensitive receiver locations in NCA02.

Noise mitigation options for triggered locations in NCA02 are discussed in **Section 8**.

5.9.3 Predicted Noise Impacts NCA03

The locations in NCA03 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 23**.

Figure 23 NCA03 Locations Triggered for Consideration of Noise Mitigation



In NCA03, the nearest residential properties on the Down side of the corridor are set back typically around 40 m to 50 m from the nearest future track. Consideration of noise mitigation is triggered at 21 properties on the Down side:

- between 17 and 33 Old Beecroft Road, inclusive (10 houses)
- between 76 and 88 The Crescent, inclusive (7 houses)
- between 102 and 108 The Crescent, inclusive (4 houses)

Without the safety factor, consideration of mitigation would be triggered at 13 of the houses.

The terrain is undulating through this NCA. The properties on the Down side that are not triggered for consideration are shielded by cuttings and therefore are predicted to receive lower noise impacts. At the triggered locations with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 61 dBA to 63 dBA, with increases in noise due to the project of between 2.0 and 4.0 dB. Maximum noise levels of up to 90 dBA are predicted. The larger than typical predicted increases at some properties in this NCA is the result of changes to the existing shielding provided by cuttings.

No locations are triggered for consideration of mitigation on the Up side in NCA03.

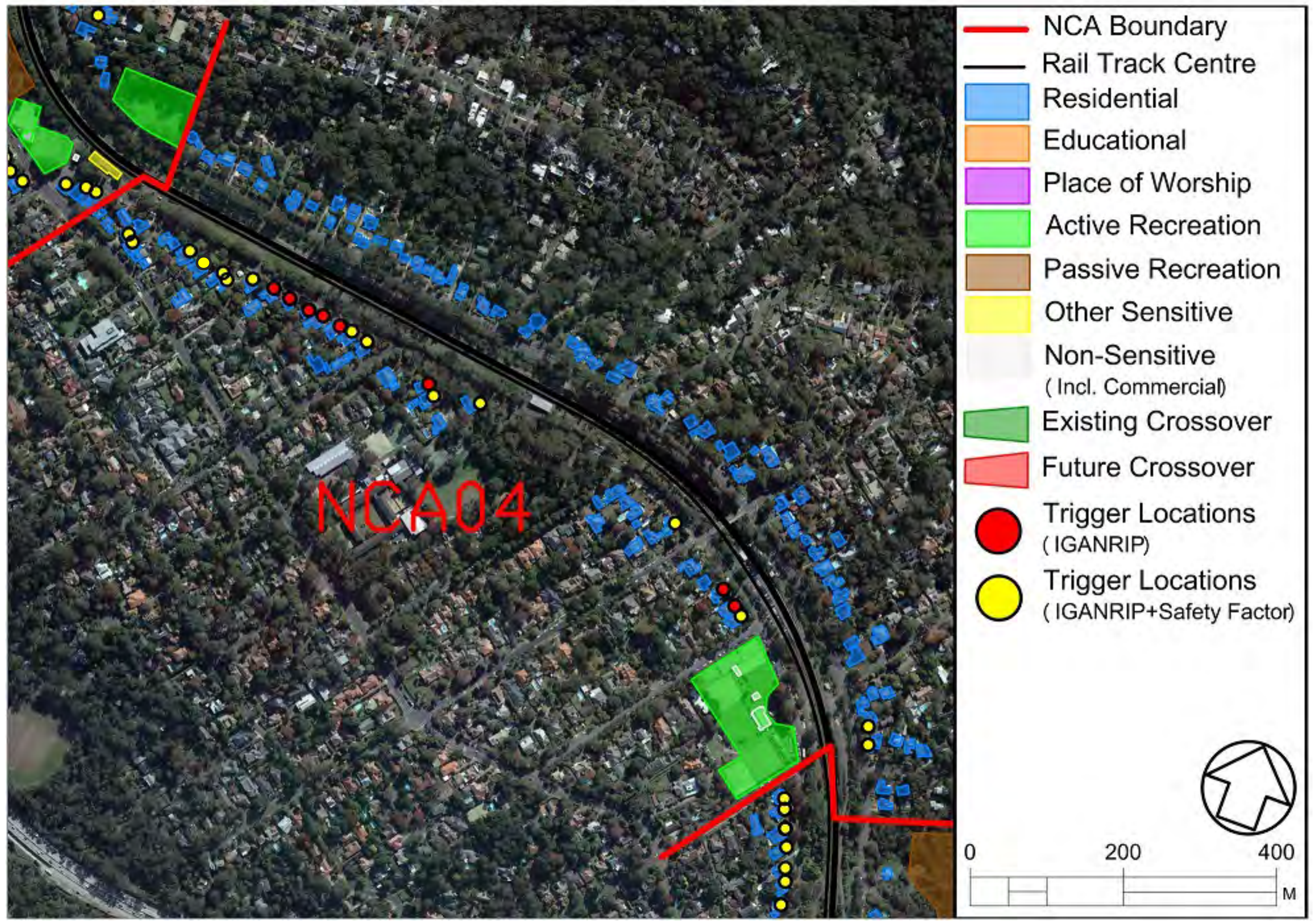
In NCA03, it is noted that freight trains travelling north on the new ETTT will no longer pass over the existing crossover between the Down and Up Main lines. This will reduce the subjective noise impacts in this area as these freight trains will no longer generate impulsive noise at the existing crossover location.

Noise mitigation options for triggered locations in NCA03 are discussed in **Section 8**.

5.9.4 Predicted Noise Impacts NCA04

The locations in NCA04 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 24**.

Figure 24 NCA04 Locations Triggered for Consideration of Noise Mitigation



In NCA04, the nearest residential properties on the Down side of the corridor are set back typically around 40 m to 50 m from the nearest future track. Consideration of noise mitigation is triggered at 21 properties on the Down side and 2 properties on the Up side:

- 125 and 127 Beecroft Road (2 houses)
- 22 Cheltenham Road (1 house)
- 54-58 The Crescent, inclusive (3 houses)
- 8-32 The Crescent (15 houses including 2 Murray Road)
- 1 Cobran Road (1 house on the Up side)
- 2 Sutherland Road (1 house on the Up side)

Without the safety factor, consideration of mitigation would be triggered at only 8 of the above houses on the Down side only.

At the triggered locations with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 61 dBA to 65 dBA, with increases in noise due to the project of between 2.0 and 2.5 dB. Maximum noise levels of up to 92 dBA are predicted at the triggered locations. The highest noise levels are predicted at the western end of this catchment, where curve noise impacts extend beyond the start of the curves.

Noise mitigation options for triggered locations in NCA04 are discussed in **Section 8**.

5.9.5 Predicted Noise Impacts NCA05

The locations in NCA05 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 25**.

Figure 25 NCA05 Locations Triggered for Consideration of Noise Mitigation

Note At the Cheltenham Scout Hall, the two red dots represent two different assessment points on the same building, not two separate exceedances of the noise trigger levels.

In NCA05, the majority of residential properties on the Down side of the corridor are set back around 90 m from the nearest future track, with the exception of the properties immediately south of the Cheltenham Scout Hall which are located at around half that distance from the future ETTT. On the Up side, residences are around 50 m from the nearest track. Consideration of noise mitigation is triggered at 10 residential locations on the Down side and 1 property on the Up side, as well as at the Cheltenham Scout Hall:

- 106-118 Beecroft Road, inclusive (7 houses)
- 115 Beecroft Road (1 house)
- 2D and 2C The Crescent, (2 houses)
- 144 Copeland Road (1 house on the Up side)

Without the safety factor, consideration of mitigation would be triggered at the Cheltenham Scout Hall only. Due to curving noise, predicted levels in NCA05 are higher than in catchments away from the small radius curves. In the unmitigated case, with overall levels above the overall trigger, the requirement to consider mitigation is triggered by the increase in noise due to the project. The increase due to the project is determined by the number of trains and the shift in these trains closer to the receiver locations. The propensity of this section to curve noise does not affect the number of locations triggered for mitigation under the rail noise guidelines. However, mitigation of curve noise is required by the CoA regardless of the rail noise guidelines – see **Section 8.4**.

At the triggered residential locations in NCA05 with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 62 dBA to 67 dBA, with increases in night-time L_{Aeq} noise due to the project of between 2.0 and 2.2 dB. Maximum noise levels of up to 100 dBA are predicted at the triggered residential locations.

It is noted that the single triggered location on the Up side with the safety factor is set back from the rail corridor, behind other houses. The reason this property is triggered but houses in front are not is due to the predicted increase in noise. The house set back from the corridor has a predicted increase of 2.0 dB (at the trigger level), while neighbouring properties (with higher absolute noise impacts) have a predicted increase of 1.9 dB (below the trigger level).

Noise mitigation options for triggered locations in NCA05 are discussed in **Section 8**.

5.9.6 Predicted Noise Impacts NCA06

The locations in NCA06 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 26**.

Figure 26 NCA06 Locations Triggered for Consideration of Noise Mitigation

In NCA06, the majority of properties on the Down side of the corridor are commercial receivers, and therefore mitigation is not required under the Guideline. Consideration of noise mitigation is not triggered at any locations on the Down side, either with or without the safety factor. Consideration of mitigation is triggered on the Up side at 19 residential locations with the safety factor, being the majority of residences immediately adjacent to the rail corridor. Six residences are also triggered for consideration of mitigation without the safety factor:

- 98A, 100, 100A, 102, 104 and 104A Sutherland Road, (6 houses)

This location is unusual along the alignment in that consideration of mitigation is triggered on the Up side without the safety factor, even though the ETTT will shift northbound freight traffic further away from the residences on this side of the corridor. In the EIS, no properties were triggered for consideration of mitigation on this side. With the detailed design noise model the reason these properties are triggered is partly because the re-examination of curve squeal has increased the overall noise level predictions in this area, and partly because of the low passenger speeds through the station. The low speed of passenger trains through stations means the increase in freight numbers translates directly to an increase in the overall L_{Aeq} noise levels (at locations with higher passenger speeds, passenger trains contribute a small but significant amount to starting noise level, meaning the increase with the addition of more freight trains is less).

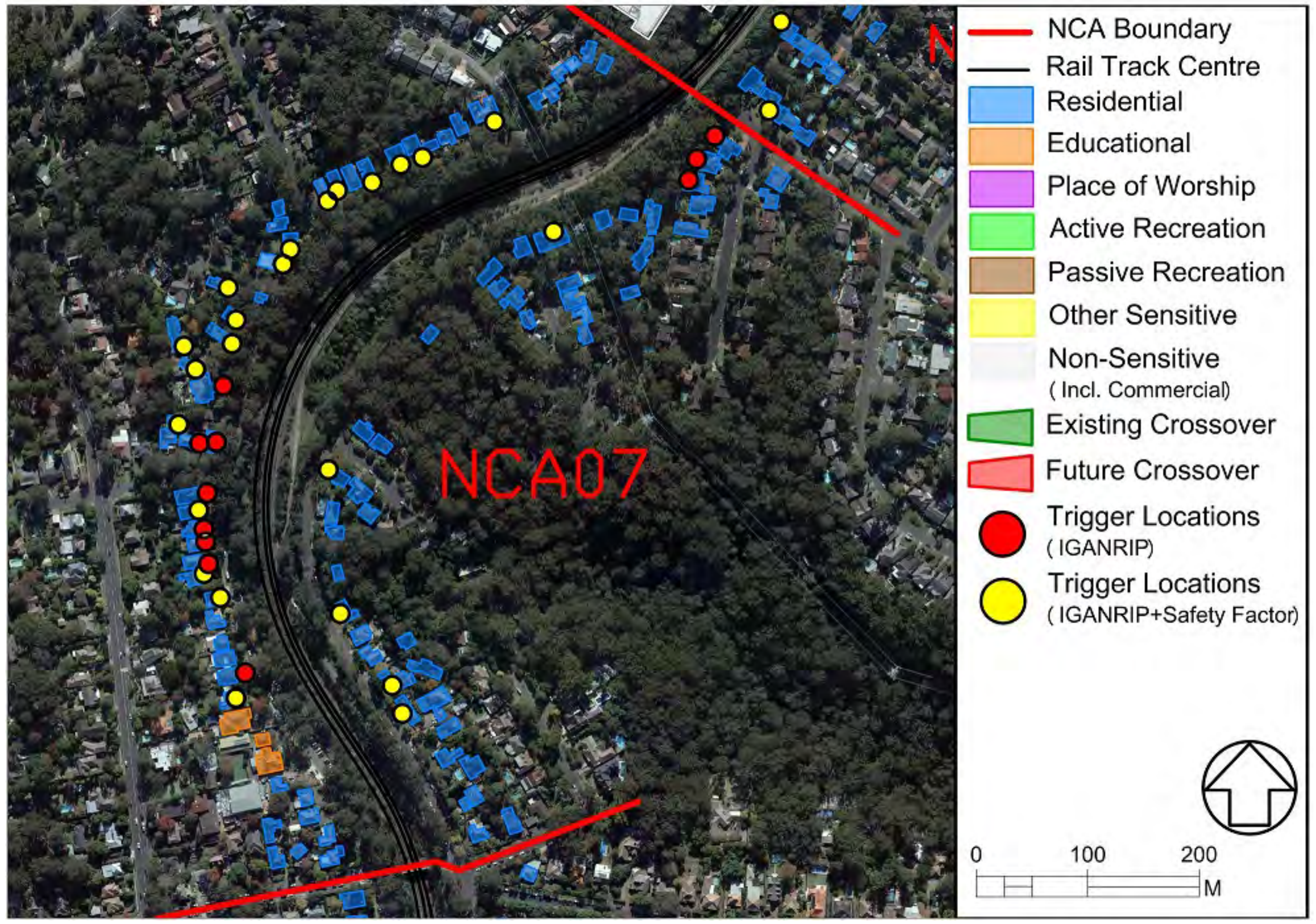
At the triggered residential locations in NCA06 with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be up to 70 dBA, with increases due to the project of between 2.0 and 2.9 dB. Maximum noise levels of up to 104 dBA are predicted at the triggered residential locations, as a result of curve squeal.

Noise mitigation options for triggered locations in NCA06 are discussed in **Section 8**.

5.9.7 Predicted Noise Impacts NCA07

The locations in NCA07 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 27**.

Figure 27 NCA07 Locations Triggered for Consideration of Noise Mitigation



In NCA07, consideration of mitigation with the safety factor is triggered at the majority of residential properties on the Down side of the corridor. Without the safety factor, consideration of mitigation would be triggered at a subset of only 8 residential locations on the Down side in this catchment. On the Up side, an additional 8 locations are triggered for consideration of mitigation with the safety factor, and three locations without the safety factor.

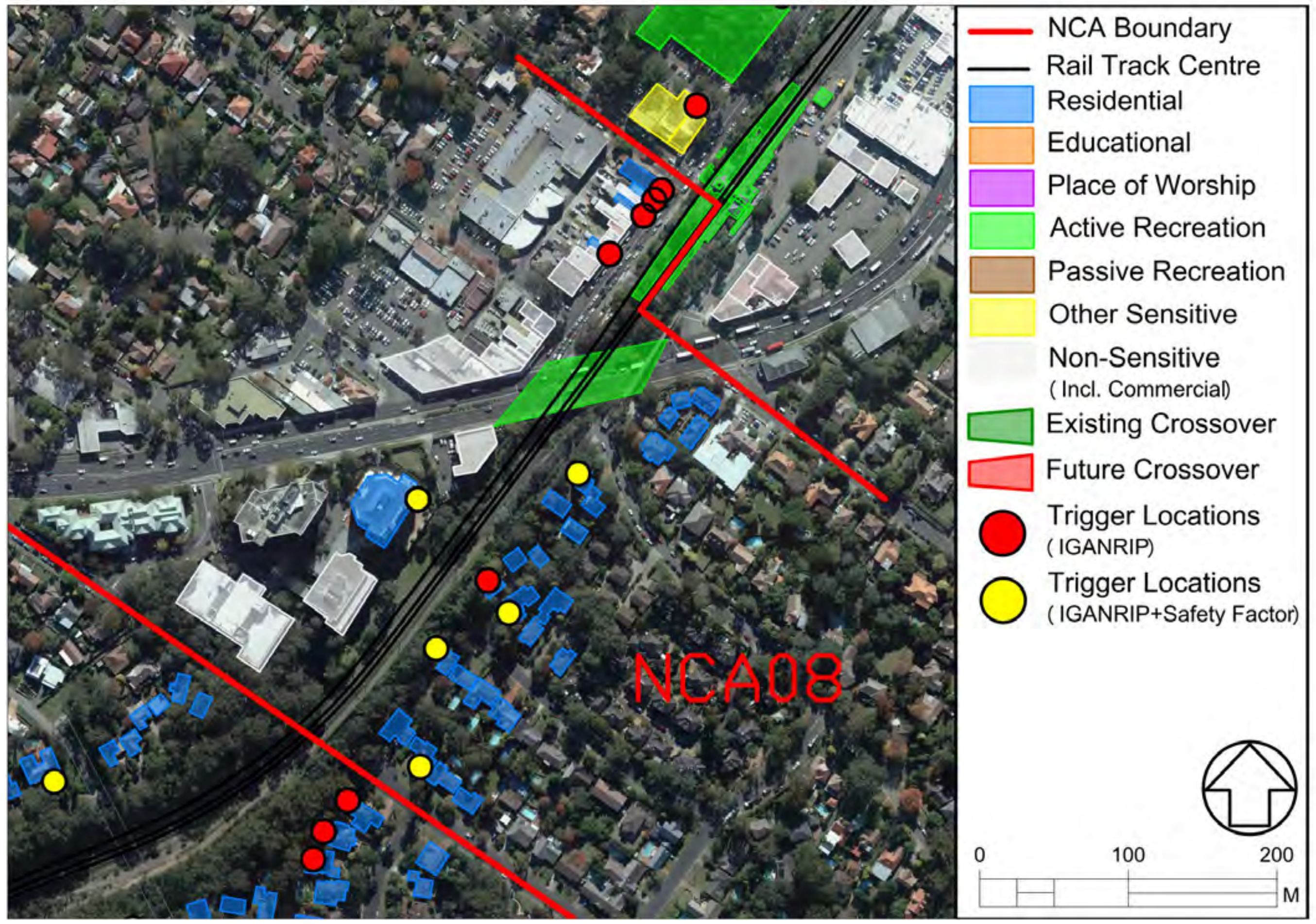
At the triggered residential locations in NCA07 with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be up to 70 dBA, with increases due to the project of between 2.0 and 2.9 dB. Maximum noise levels of up to 104 dBA are predicted at the triggered residential locations. The high predicted noise levels in NCA07 are the result of curve squeal.

Noise mitigation options for triggered locations in NCA07 are discussed in **Section 8**.

5.9.8 Predicted Noise Impacts NCA08

The locations in NCA08 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 28**.

Figure 28 NCA08 Locations Triggered for Consideration of Noise Mitigation



In NCA08, the only residential properties on the Down side of the corridor are the apartment building at 5 City View Road, and the residences above the shops in the Pennant Hills shopping precinct. These properties are set back typically around 25 m to 30 m from the nearest future track. Consideration of noise mitigation is triggered at both the residences above the shops (without the safety factor) and the apartment building (with the safety factor). Consideration of mitigation is also triggered at five locations on the Up side, most being triggered only with inclusion of the safety factor.

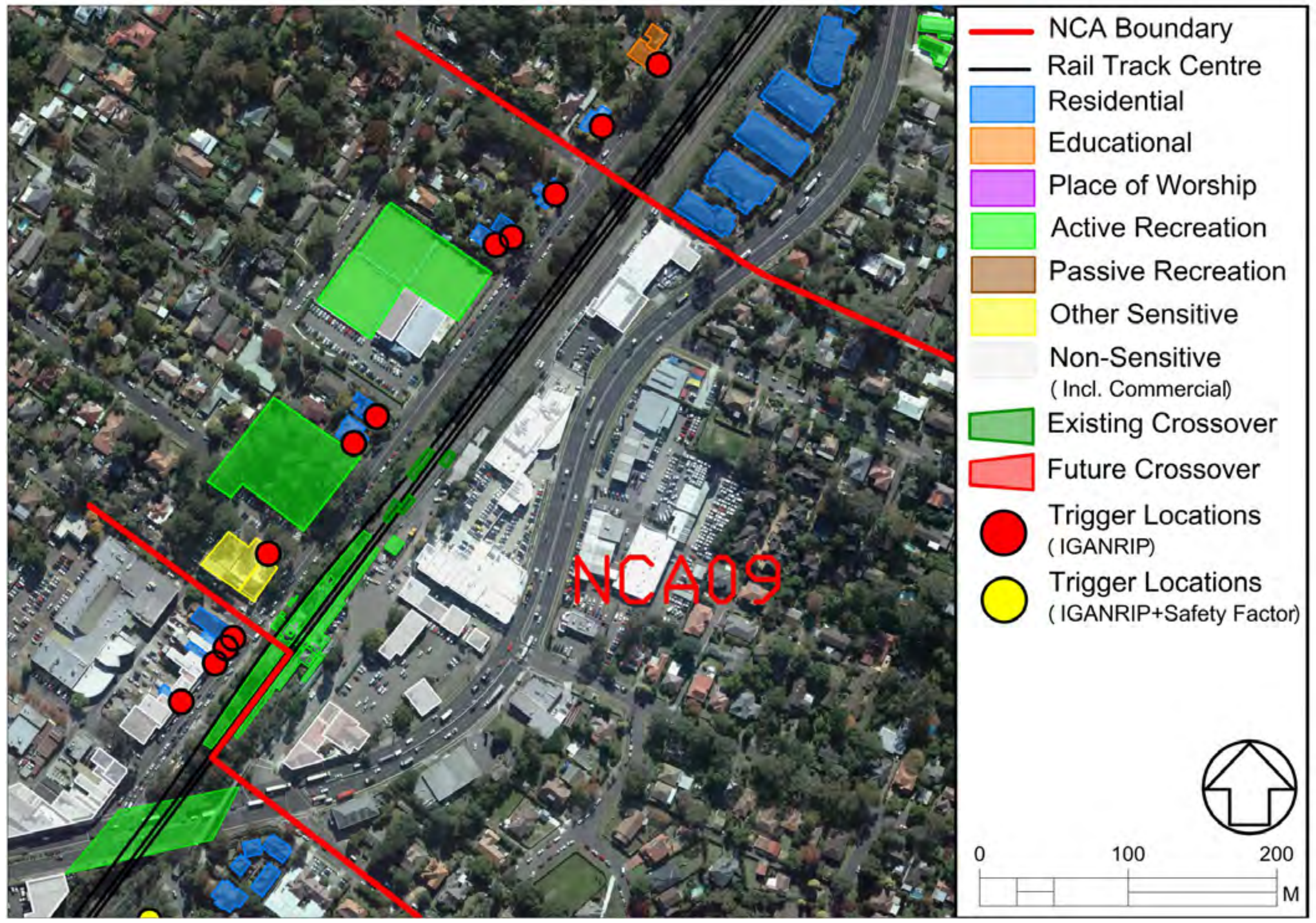
At the triggered locations with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 61 dBA to 65 dBA, with increases in noise due to the project of between 2.0 and 4.5 dB. Maximum noise levels of up to 92 dBA are predicted at the triggered locations. The greatest increase in noise levels is predicted at residences above the shops, as at this location the freight trains will be moving around 10 m closer to the facade in order to pass through the station. This distance shift is proportionally greater at this location than elsewhere in the project area.

Noise mitigation options for triggered locations in NCA08 are discussed in **Section 8**.

5.9.9 Predicted Noise Impacts NCA09

The locations in NCA09 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 29**.

Figure 29 NCA09 Locations Triggered for Consideration of Noise Mitigation



Consideration of noise mitigation is triggered in NCA09 at all sensitive building locations, both with and without the safety factor. Consideration of mitigation is not triggered for the active recreation areas in this catchment. The sensitive buildings in NCA09 are all on the Down side, and include five residences as well as the Pennant Hills Library and Community Centre.

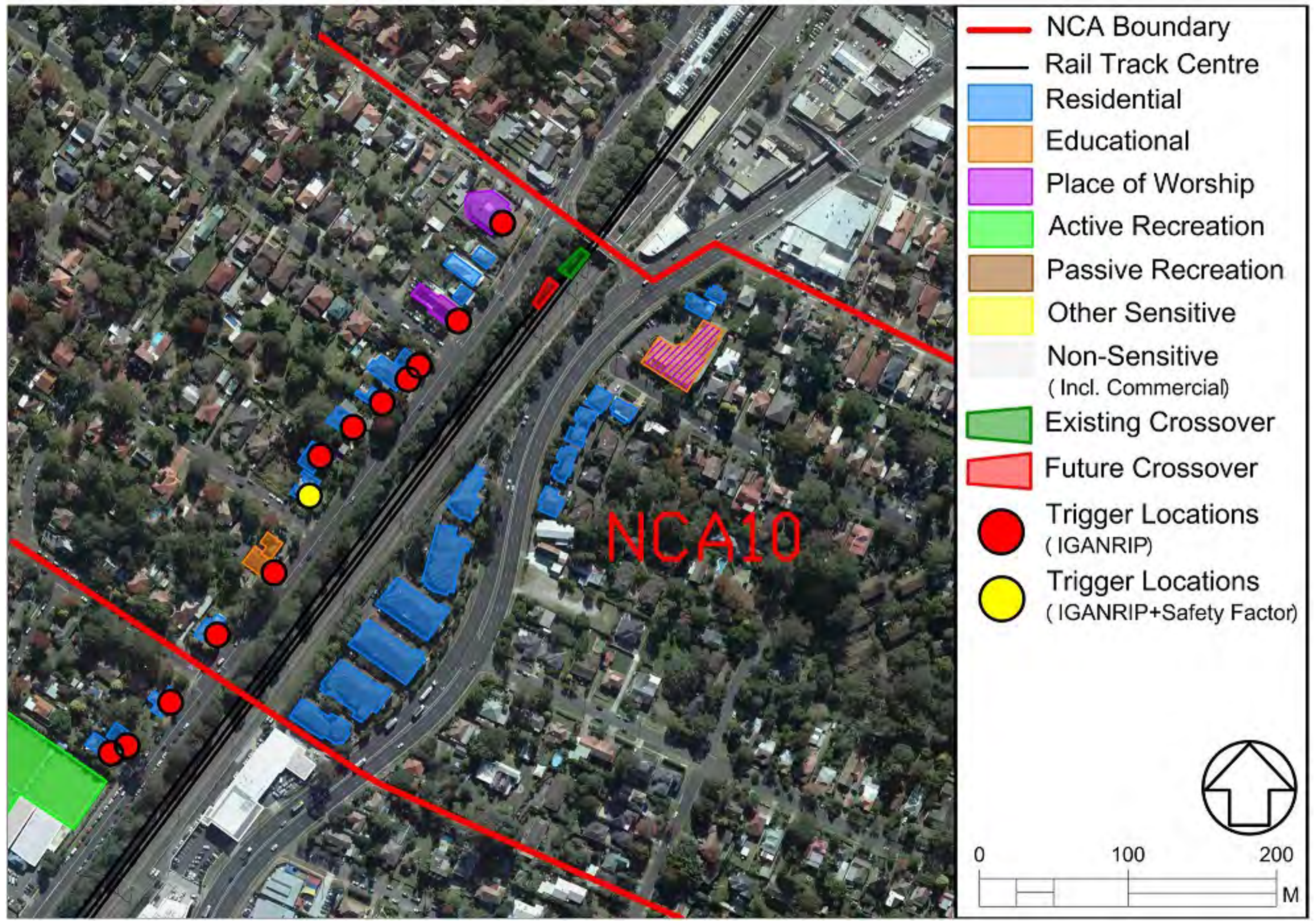
At the triggered residential locations with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 64 dBA to 65 dBA, with increases in noise due to the project of between 2.7 dB and 3.2 dB. Maximum noise levels of up to 91 dBA are predicted at the triggered residential locations.

Noise mitigation options for triggered locations in NCA09 are discussed in **Section 8**.

5.9.10 Predicted Noise Impacts NCA10

The locations in NCA10 that are triggered for consideration of noise mitigation following consideration of impacts and the increase in noise due to the project in both the assessment timeframes are shown in **Figure 30**.

Figure 30 NCA10 Locations Triggered for Consideration of Noise Mitigation



Consideration of noise mitigation is triggered in NCA10 at seven residences on the down side, all south of Pritchard Street. The other sensitive building locations in this catchment on the Down side (the childcare centre and both places of worship) are also triggered for consideration of mitigation. Almost all these receivers are triggered, both with and without the safety factor, the exception being one residence. No properties are triggered for consideration of mitigation on the Up side.

The triggered properties are offset by around 30 m from the new track. They are in the southern section of the catchment where the track is on embankment. At the northern end, the tracks move into cutting resulting in increased shielding to the sensitive receivers nearer the Wells Street overbridge.

At the triggered residential locations with the safety factor, night-time L_{Aeq} noise levels in 2026 are predicted to be 61 dBA to 64dBA, with increases in noise due to the project of between 2.0 dB and 3.9 dB. Maximum noise levels of up to 91 dBA are predicted at the triggered residential locations.

At the two places of worship in this catchment external daytime L_{Aeq} noise levels in 2026 with the safety factor are predicted to be 58 dBA to 60 dBA, up to 5 dB above the external trigger level under the assumption of open windows. At the childcare centre external daytime L_{Aeq} noise levels in 2026 with the safety factor are predicted to be up to 63 dBA, or 8 dB above the external trigger level under the assumption of open windows.

In NCA10, it is noted that a new crossover will be constructed to allow an emergency run-out at the end of the new ETTT. This new crossover is not predicted to increase the maximum noise levels due to freight trains, as these are dominated by the freight exhaust rather than the noise from the wheel/rail interface. However, a new crossover introduces the potential for subjective noise impacts due to the impulsive noise of wheels impacting on the track at the crossover. At this location, there is an existing crossover on the Down Main. The new crossover will be an additional source, but the noise generated at this crossover would occur at the same time as the existing crossover noise. For this reason, the additional crossover will not result in a large change in the noise character. Furthermore, both the existing and new crossovers are located in the section of cutting, with the wheel-rail interface shielded from the nearby sensitive receivers.

Noise mitigation options for triggered locations in NCA10 are discussed in **Section 8**.

5.10 Summary of Locations Triggered for Consideration of Noise Mitigation

Table 24 provides a summary of the locations triggered for consideration of noise mitigation under the IGANRIP, both with and without the safety factor on train numbers.

Table 24 Summary of Locations Triggered for Consideration of Noise Mitigation

NCA	Side	Number of Sensitive Locations Triggered[1]				Comments
		Residential		Other Sensitive		
		Base Case	Safety Factor	Base Case	Safety Factor	
01	Down	0	1	0	1	Large apartment building at 74 Rawson Street, and Epping Baptist Church. No exceedances without safety factor. Consideration of subjective factors around noise from new crossover required.
	Up	0	0	0	0	n/a
02	Down	0	0	0	0	n/a
	Up	0	2	0	0	Two residential buildings with exceedances of trigger levels with the safety factor – compliance at all locations predicted without safety factor. The triggered locations are not the locations with the highest absolute noise impacts in this catchment.
03	Down	13	21	0	0	With the safety factor, the noise trigger levels are exceeded at residential locations except where shielding is provided by the terrain. The safety factor means more locations are triggered than would be otherwise. The locations with the highest absolute noise levels are triggered in this catchment.
	Up	0	0	0	0	n/a
04	Down	8	21	0	0	With the safety factor, the noise trigger levels are exceeded at residential locations immediately adjacent to the tracks, except where shielding is provided by the terrain. The safety factor means more locations are triggered than would be otherwise. The locations with the highest absolute noise levels are triggered in this catchment.
	Up	0	2	0	0	Two residential buildings with exceedances of trigger levels with the safety factor – compliance at all locations predicted without safety factor. The triggered locations are not the locations with the highest absolute noise impacts in this catchment.
05	Down	0	10	1	1	The safety factor, in combination with the curve squeal impact, controls the requirement to consider mitigation in this catchment. Consideration of mitigation is also triggered at the Cheltenham Scout Hall.
	Up	0	1	0	0	One house exceeds the trigger levels with the safety factor – compliance at all locations predicted without safety factor. The triggered location does not have the highest absolute noise impacts in this catchment.
06	Down	0	0	0	0	n/a
	Up	6	19	0	0	Curve squeal impacts in conjunction with low passenger train contributions near Beecroft Station determine the need to consider mitigation in this catchment.
07	Down	8	26	0	0	The safety factor, in combination with the curve squeal impact, controls the requirement to consider mitigation in this catchment.
	Up	3	8	0	0	The safety factor increases the requirement to consider mitigation in this catchment, in combination with the curve squeal impact.
08	Down	4	5	0	0	With only a small number of residential buildings in this catchment, the safety factor means mitigation is required to be considered at all residences on the Down side.
	Up	1	5	0	0	The safety factor increases the requirement to consider mitigation in this catchment. The triggered locations do not all have the highest absolute noise impacts in this catchment.
09	Down	5	5	1	1	Consideration of mitigation is triggered by the relative shift in distance between source and receiver, where the freight trains travel past the station.
	Up	0	0	0	0	n/a
10	Down	6	7	3	3	Consideration of mitigation is triggered by the relative shift in distance between source and receiver.
	Up	0	0	0	0	n/a
Total	Down	44	96	5	6	Consideration of mitigation is required at many of the locations on the Down side with the highest predicted noise impacts. The safety factor extends the locations where consideration of mitigation is triggered, by amplifying the "increase in noise due to the project" component of the criteria.
	Up	10	37	0	0	The safety factor also results in some locations being triggered on the Up side. Some of these are on small radius curves and the resulting higher noise levels are a factor. At most other locations, the triggered locations on the Up side are due to the increase creeping up to 2.0 dB with the safety factor. In many cases, the triggered locations on the Up side do not correspond to the locations with the highest absolute noise levels.
	Overall	54	133	5	6	The safety factor triggers consideration of mitigation at significantly more locations than would otherwise be the case.

Note 1: The number of locations triggered counts addresses once only, in the event that more than one facade or level of the building is triggered. This number will be less than the number of individual properties triggered, for example where buildings contain multiple apartments.

6 VIBRATION FROM TRAINS

6.1 Introduction

Railway vibration is generated by dynamic forces at the wheel-rail interface and will occur, to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness of the surfaces and elastic deformation). Significantly higher vibration levels can occur due to rail and wheel surface irregularities.

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

6.2 Operational Vibration Metrics

The primary metrics used to describe ground-borne vibration from train passbys are as follows:

LVmax the "Maximum Vibration Level" occurring during a train passby event. This is normally defined as the maximum rms vibration level during the train passby averaged over a one second interval. The vibration level is usually expressed in dBV re 10^{-9} m/s.

VDV the "Vibration Dose Value" is used to indicate the total vibration exposure during the daytime or night-time period. It is a cumulative measure and indicates the combined effect of all train passby events within the daytime or night-time period.

Use of the LVmax vibration level is advantageous as it allows the variation in individual train passby events to be examined. The LVmax metric can also be compared directly with human response curves to determine whether the train passby vibration levels are likely to be perceived by building occupants.

The VDV metric is the preferred method of determining the total vibration exposure from train passbys at residential and other sensitive receiver locations.

In order to evaluate the potential impact from intermittent rail vibration in the ETTT area, the NSW Government's *Assessing Vibration – a Technical Guideline* provides a methodology to assess vibration in terms of the Vibration Dose Value (VDV). This assessment parameter takes into account such factors as the overall vibration level, the duration of vibration events and number of vibration events in each assessment period (day and night). The acceptable VDV criteria from the above guideline are described in **Table 25**.

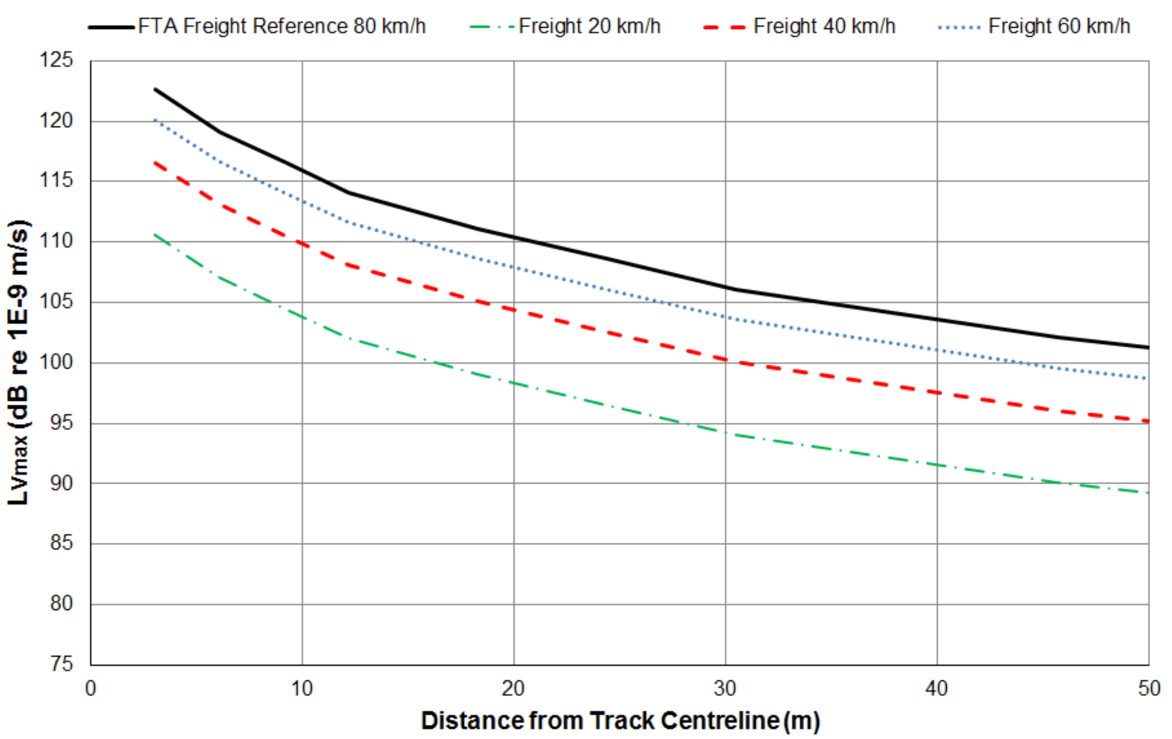
Table 25 Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Location	Daytime (7 am – 10 pm)		Night-time (10 pm – 7 am)	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Residence	0.2	0.4	0.13	0.26
Offices, Schools, Educational Institutions and Places of Worship	0.4	0.8	0.4	0.8

6.3 Source Vibration Levels

The US Federal Transit Administration's (FTA's) *"Transit Noise and Vibration Impact Assessment"* report provides indicative vibration levels versus distance for a variety of transport systems, including freight and passenger systems. **Figure 31** shows the indicative freight vibration levels at various speeds, assuming a "20log" speed relationship. Passenger train vibration levels are typically around 12 dB less than the freight levels shown in **Figure 31.**

Figure 31 Indicative Freight Vibration Level at Speeds 20 km/h to 80 km/h



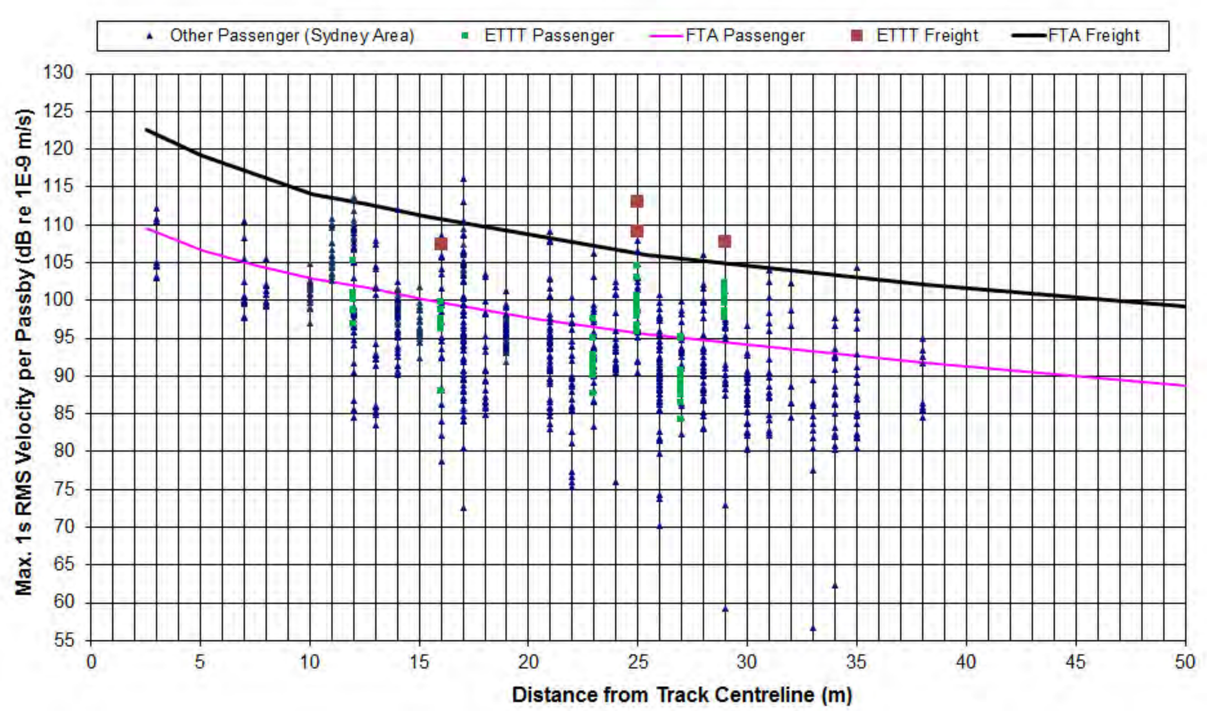
Vibration propagation characteristics can be highly variable depending on the ground conditions at a given location. Vibration measurements of passenger and freight train passbys were undertaken at three locations in the ETTT project area during preparation of the EIS. The EIS vibration measurement results for train passbys in the ETTT project area are presented in **Figure 32** for comparison with the FTA vibration vs distance curves (adjusted for speed to the 80 km/h reference). Vibration measurements undertaken by SLR for passenger trains adjacent to the Sydney metropolitan network on other projects are also included in **Figure 32** to demonstrate the variability of results according to train and location characteristics. The vibration levels are expressed in terms of the rms vibration velocity level in dB (re 10^{-9} m/s). The measurement data obtained as part of the ETTT EIS represent the maximum 1 second rms vibration level observed during each train passby.

At two out of the three EIS measurement locations the vibration levels measured from each of the existing lines were similar to or less than the levels that would be expected according to the FTA indicative curves, shown in **Figure 32**. At one of the three locations, vibration levels from both existing tracks were typically higher than the FTA indicative curves.

On the basis of the EIS measurements, it is concluded that the FTA indicative curves are a reasonable indicator of the typical vibration levels due to passenger and freight trains, and are suitable for calculating VDV. It is acknowledged that due to variability in local ground conditions and between different trains, some passbys may result in higher levels, with LVmax levels up to around 10 dB above the FTA indicative curves.

Figure 32 Ground Surface Vibration Levels Versus Distance at 80km/h

(adapted from Figure 10-1 in FTA's Transit Noise and Vibration Impact Assessment Report)



Note 1: Vibration velocity depicted in dB re $1x10^{-9}$ m/s, where 0.01 mm/s is equivalent to 80 dB, 0.1 mm/s is equivalent to 100 dB and 1 mm/s is equivalent to 120 dB. All measured vibration levels have been adjusted to 80 km/h for comparison with the FTA curves using a 20log relationship.

6.4 Assessment of Ground-Surface Vibration Levels

Section 2.4.1 of the DECC vibration guideline provides a calculation procedure for determining the Vibration Dose Values (VDV) on the basis of frequency weighted acceleration levels. As an alternative, Section B2.3 of the DECC vibration guideline provides a calculation procedure for determining the estimated Vibration Dose Values (VDV) on the basis of the measured (or predicted) rms vibration velocity levels.

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

$$eVDV = 0.07 \times V_{rms} \times t^{0.25} \ (m/s^{1.75})$$

Where: t represents the time period for the train passby

V_{rms} is the rms vibration level of the passby expressed in mm/s.

It is noted that using vibration velocity to estimate eVDV is an approximation, and that it is preferable to use overall weighted rms acceleration to calculate the VDV. The attended measurement data collected during the EIS stage has been reviewed to determine the difference between eVDV and VDV for vibration generated by train passbys. This review indicates that the use of eVDV underestimates VDV by around 25% for both freight and passenger train passbys. A factor of 25% has therefore been added to eVDV values in the following assessment.

The average eVDV per passby has been determined for train passbys on all three tracks (including the proposed third track) from the FTA freight and passenger vibration vs distance curves, adjusted as needed for train speed. This vibration assessment assumes a freight speed of 60 km/h and a passenger speed of 80 km/h throughout. These speeds are considered to be conservative, being above the typical speeds throughout the project area as described in **Section 5.6.6.**

The eVDV per passby has been converted to VDV by addition of a 25% factor (determined by measurement of train passby vibration in the project area). The resulting predicted VDV at the closest sensitive receivers in future is based on the anticipated average daily capacity train numbers shown in **Table 8**.

Based on future numbers of both freight and passenger train passbys, the predicted VDVs at the closest receiver to the tracks in each NCA are presented in **Table 26** for the daytime and night-time periods. The corresponding minimum distances to the nearest track centreline for each receiver type and catchment are also given in **Table 26**.

Table 26 Maximum VDV by Receiver Type and NCA 10 Years After Opening

NCA	Receiver Type	Distance to Facade (m)	Daytime VDV ($m/s^{1.75}$)		Night-time VDV ($m/s^{1.75}$)		Complies
			Predicted	Preferred Criterion	Predicted	Preferred Criterion	
NCA 01	Residential	26	0.09	0.2	0.09	0.13	Yes
	Other	30	0.08	0.4	0.08	0.4	Yes
NCA 02	Residential	23	0.11	0.2	0.10	0.13	Yes
NCA 03	Residential	39	0.06	0.2	0.06	0.13	Yes
NCA 04	Residential	39	0.06	0.2	0.06	0.13	Yes
NCA 05	Residential	46	0.05	0.2	0.05	0.13	Yes
	Other (Scout Hall)	5	0.38	0.4	0.35	0.4	Yes
	Other	26	0.09	0.4	0.08	0.4	Yes
NCA 06	Residential	45	0.05	0.2	0.05	0.13	Yes
	Other	39	0.06	0.4	0.06	0.4	Yes
NCA 07	Residential	42	0.06	0.2	0.05	0.13	Yes
	Other	52	0.05	0.4	0.05	0.4	Yes
NCA 08	Residential	23	0.11	0.2	0.10	0.13	Yes
	Other	13	0.19	0.4	0.18	0.4	Yes
NCA 09	Residential	35	0.07	0.2	0.06	0.13	Yes
	Other	25	0.10	0.4	0.10	0.4	Yes
NCA 10	Residential	24	0.10	0.2	0.10	0.13	Yes
	Other	34	0.07	0.4	0.07	0.4	Yes

The predicted total VDV values at the closest residences to the tracks are predicted to be below the vibration trigger level of 0.13 $m/s^{1.75}$ and 0.20 $m/s^{1.75}$ for the night-time and daytime respectively. The predicted VDV values at other vibration sensitive receiver types are also predicted to comply with the preferred values from the guideline.

The vibration guideline indicates that the threshold of perception for most people is approximately 0.14 mm/s rms (103 dB). From the source levels presented in **Figure 31**, it is anticipated that for some train passbys at the upper end of the typical speed range, vibration levels would be perceptible at buildings located within approximately 40 m from the nearest track.

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

6.5 Ground-borne Noise from Rail Operations

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

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

If of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be experienced in buildings adjacent to many urban underground rail systems.

For surface rail projects, the effect of ground-borne noise tends to be less of an issue than for underground rail projects. This is because the airborne noise emissions in most circumstances are much higher than the ground-borne noise levels. For this reason ground borne noise will not be significant for the ETTT project and further assessment is not warranted.

7 NOISE MITIGATION MEASURES CONSIDERED

Condition of Approval C4 (c) requires the Project to, among other things, assess all feasible and reasonable noise and vibration mitigation measures, and requires the feasible and reasonable analysis to be transparent and fully justified. In order to meet this requirement the following assessment approach was adopted:

(a) Brainstorming potential mitigation measures;

(b) Elimination of potential mitigation measures based on feasibility;

(c) Modelling of feasible extents of mitigation measures; and

(d) Finalisation of mitigation measures based on predicted effectiveness, cost and other factors.

Items (a) and (b) are described in **Sections 7.1** and **7.2** below. Items (c) and (d) are described in **Section** 8.

7.1 Brainstorming

The ONVR seeks to identify as many potential noise mitigation measures as possible, to ensure that the broadest possible suite of options is considered. To this end a brainstorming process was carried out, in which potential measures were identified and listed without any regard to their likely feasibility, cost or other impacts. Various sources were called upon to generate this list including community consultation feedback; a brainstorming workshop; and the Conditions of Approval. This culminated in the list shown in **Table 27** below.

Table 27 Complete list of potential mitigation measures considered

Reference	Potential Mitigation Measure	Source
1	Rail dampers	NSFC noise mitigation strategy and ETTT Conditions of Approval
2	High Rail Pad Stiffness	NSFC noise mitigation strategy
3	Swing Nose Crossings in turnouts and catchpoints	NSFC noise mitigation strategy
4	Upgrade property boundary fence	NSFC noise mitigation strategy
5	Noise Barriers on at-grade track	NSFC noise mitigation strategy and ETTT Conditions of Approval
6	Noise Barriers on embankment track	NSFC noise mitigation strategy and ETTT Conditions of Approval
7	Noise Barriers on cuttings	NSFC noise mitigation strategy and ETTT Conditions of Approval
8	Earth mounds	NSFC noise mitigation strategy and ETTT Conditions of Approval
9	Rail Grinding	NSFC noise mitigation strategy
10	Building treatments (need to determine specific reasonable measures and their hierarchy, then inspect eligible properties to determine feasibility)	NSFC noise mitigation strategy and ETTT Conditions of Approval
11	Low-height noise barriers	ETTT Conditions of Approval
12	Signal relocation	ETTT Conditions of Approval
13	Composite sleepers	ETTT Conditions of Approval
14	Gauge face lubricators for curve track (note: broaden to consider gauge corner lubricators and any other potential lubricator types)	ETTT Conditions of Approval
15	Vegetation – trees	Community
16	Tunnel	Brainstorming
17	Modify track geometry and grade (gradients, curves etc)	Brainstorming
18 & 19	Electric locos	Brainstorming, community
20	Lower the third track	Brainstorming
21	Bank engines	Brainstorming, community
22	Softer rail pad stiffness. Eg modified track support system (softer rubber pads between rail and sleeper)	Brainstorming
23	Other rail fastening system changes eg Delkor eggs	Brainstorming
24 & 25	Concrete slab track (with closer low-height barriers)	Brainstorming
26	Loco exhaust system modifications	Brainstorming
27	Skirts to rolling stock	Brainstorming
28	On-board lubrication	Brainstorming
29	Wheel dampers	Brainstorming
30	Articulated bogies	Brainstorming
31	Altered / improved wagon maintenance	Brainstorming
32	In-service monitoring for noisy trains (on trains or on track)	Brainstorming
33	Time of day limitations, operational restrictions (may include speed, weight, time of day, length, class of loco)	Brainstorming
34	Improved wagon design, eg self-steering bogies	Brainstorming
35	Improved track maintenance, eg tamping to maintain geometry, rail grinding	Brainstorming
36	Ballast gluing	Brainstorming
37	Additional property treatments	Brainstorming
38	Operate freight trains on the centre track instead of the third track	Community, brainstorming
39	Leverage project activities to broaden and accelerate property treatments for existing noise issues	Brainstorming
40	Apply any of the above as relevant to existing tracks	Brainstorming
41	Build the third track without mitigation	Brainstorming
42	Noise barriers that curve out and over the track	Brainstorming
43	Lightweight noise barriers, eg sturdy timber fences	Brainstorming
44	At-receiver noise barriers	Brainstorming
45	Noise attenuation that targets specific frequency bands, eg lightweight boundary treatment to target high frequency noise	Brainstorming
46	Noise cancelling equipment	Brainstorming
47	Engineer noise barrier shape (non-conventional barrier) to reduce specific noise frequencies	Brainstorming
48 & 49	Create noise impact buffer area along corridor	Brainstorming
50	Alternative lubricants – on-board or track	Brainstorming
51	Alternative materials to avoid steel-on-steel noise (alternative metal rail?)	Brainstorming, community
52	Alternative rail profile that improves wheel steering	Brainstorming
53	Gauge widening (separate rails by additional mm around sharp curves)	Brainstorming
54	Alternative wheel profiles to alter contact band	Brainstorming
55	Smaller wheels	Brainstorming
56	Truck freight to a point outside of metropolitan area – eg intermodal terminal at Hornsby	Brainstorming

7.2 Elimination of potential mitigation measures

All potential mitigation measures were assessed against the following criteria:

- Likely noise level reduction;
- Wider benefits;
- Alignment with community feedback;
- Speed of benefit realisation;
- Cost;
- Environmental impacts; and
- Degree of difficulty

Individual mitigation measures were then eliminated where they were found not to be feasible for this project. A detailed reason for each of those potential mitigation measures found not to be feasible for this project is included in **Table 28** below.

The remaining shortlisted mitigation measures were assessed further and are detailed in **Section** 8.

Table 28 Shortlist of potential mitigation measures

Reference	Potential Mitigation Measure	Shortlisted? (YES / NO)	Reason
1	Rail dampers	NO	Research indicates that there is no reason why rail dampers should have any influence on curve squeal.
2	High Rail Pad Stiffness	NO	High rail pad stiffness would target general rolling noise minimisation only. Given the Sydney rail system already typically uses very stiff rail pads there is little more to be gained. In terms of wheel squeal, stiffer pads are not expected to make any improvement.
3	Swing Nose Crossings in turnouts and catchpoints	YES	Refer to Section 8.11.1 for further details.
4	Upgrade property boundary fence	NO	1) Only a very limited number of properties actually back onto the rail corridor – typically there is a road between houses and the corridor. Barriers are most effective when located close to either the source or the receiver. In this case, a barrier in the rail corridor would be more effective. 2) Boundary fences of acceptable/reasonable height would not be high enough to address noise effectively.
5	Noise Barriers on at-grade track	YES	Refer to Sections 8.6 and 8.8 for further details.
6	Noise Barriers on embankment track	YES	Refer to Sections 8.6 and 8.8 for further details.
7	Noise Barriers on cuttings	YES	Refer to Sections 8.6 and 8.8 for further details.
8	Earth mounds	NO	Insufficient space exists within the rail corridor to construct earth mounds.
9	Rail Grinding	YES	Targeted rail profile grinding on sharp curves has potential benefits for curve squeal by optimising lubricator effectiveness. Refer to Section 8.11.2 for further details.
10	Building treatments (subject to inspection of eligible properties to determine what treatment is feasible)	YES	Refer to Section 8.7.
11	Low-height noise barriers	YES	Refer to Section 8.5.
12	Signal relocation	NO	Other than in emergency or breakdown scenarios, there is only one location that trains on the new third track will be required to stop at a signal - at the end of the new third track at Thornleigh. This signal cannot be moved further north as this would be beyond the end of the track. The signal cannot be moved further south, due to the need to maximise the length of freight trains on the lesser gradient between Pennant Hills and Thornleigh. Therefore there are no opportunities to implement signal relocation to influence operational noise.
13	Composite sleepers	NO	There is published research that curve squeal is worsened by replacing wooden sleepers with concrete sleepers. It is hypothesised that one reason for this may be a change in the lateral stiffness / receptance of the track. If this is the case, there is a potential for composite sleepers or alternative sleeper designs to have a benefit in reducing curve squeal. The research required to investigate this and understand the root causes would take several years. The outputs would be available too late for implementation on the ETTT project. Investigations of composite sleepers are ongoing as part of longer term noise mitigation projects (see Section 8.11.2)
14	Gauge face lubricators for curve track (note: broaden to consider gauge corner lubricators and any other potential lubricator types)	YES	Refer to Section 8.4 for further details.
15	Vegetation – trees	NO	1) Trees provide little acoustic benefit. There is a commonly held belief that vegetation can be a noise barrier. Typically vegetation is not an effective noise barrier as an attenuation of only 3dB(A) per 30 metres of densely wooded bushland is possible. The role of vegetation in reducing noise is mostly psychological (if you cannot see the source it reduces the perception of noise), however this can be a powerful mitigation tool in itself. 2) Opportunities to plant trees have already been maximised in the project's urban design and landscape plan, and no further opportunities exist. Trees within the rail corridor compromise rail safety and reliability due to the risk of branches and trees falling on overhead wiring and track.
16	Tunnel	NO	A tunnel option was investigated during the project development phase and found not to be feasible due to: 1) Incompatibility of tunnels with diesel trains 2) Significant additional costs which would not be justified
17	Modify track geometry and grade (gradients, curves etc)	NO	The new track needs to follow the geometry of the existing track. A new track with broadened curves would not fit within the existing corridor and would necessitate extensive private property acquisition and demolition.
18 & 19	Electric locos	NO	Provision of electric locos would require electrification from Sydney to Brisbane as well as implementation of a 25kV AC voltage system, neither of which are currently planned, funded or part of the ETTT project scope. Changing locos at the boundaries of the electrified system is not feasible for freight operators due to the time delays incurred and the significant costs involved in operating an additional locomotive fleet.
20	Lower the third track	NO	The significant additional rock excavation required to deepen existing cuttings, as well as the increased length of the third track (to get back to surface level at the allowable gradient) make this mitigation measure extremely costly and therefore not feasible.

Reference	Potential Mitigation Measure	Shortlisted? (YES / NO)	Reason
21	Bank engines	NO	Operation of bank engines would require significant new infrastructure, due to the need to have additional sidings and turn-back tracks for the bank engines. Attaching and re-attaching bank engines would require freight trains to stop, thereby increasing travel times, reducing the competitiveness of rail freight and causing disruption to passenger trains. These consequences are the opposite of the objectives of the ETTT project.
22	Softer rail pad stiffness. Eg modified track support system (softer rubber pads between rail and sleeper)	NO	Further research would be required to determine whether any noise benefits would result, and to confirm whether the likely increase in rolling noise would be offset by a reduction in curve noise. The research required to investigate this and understand the root causes would take several years. The outputs would be available too late for implementation on the ETTT project.
23	Other rail fastening system changes eg Delkor eggs	NO	As above.
24 & 25	Concrete slab track (with closer low-height barriers)	NO	Slab track would significantly increase project costs, but without any certainty of providing operational noise benefits. Slab track actually risks increasing operational noise due to the higher reflectivity of concrete compared with ballast and the need to use softer rail fastening systems which would increase rolling noise. Instead, low height barriers adjacent to ballasted track have been used as a shortlisted mitigation measure (Reference 11 below).
26	Loco exhaust system modifications	YES	The ETTT Project could document the potential benefits, but does not have the authority to implement such modifications to privately-owned trains. However Transport for NSW is working with operators to reduce the noise from older locomotives. This work is not particular to the ETTT Project but will provide benefits to the residents within the project area. Refer to Section 8.11.3 for further details.
27	Skirts to rolling stock	NO	This is not a feasible measure as it would involve retrofitting all rolling stock and wagons (which are not of uniform design).
28	On-board lubrication	NO	The ETTT Project is already required to implement curve lubrication, which is a measure more targeted to specific problem areas (the Beecroft curves). On-board lubrication would involve retrofitting existing locos. The likely benefits will be obtained far more simply using track lubrication on curves.
29	Wheel dampers	NO	Not a feasible measure for the ETTT project. There is some potential benefit for curve squeal, but would require retro-fitting of wheel dampers to the entire freight fleet.
30	Articulated bogies	NO	Not a feasible measure for the ETTT project. There is some potential benefit for curve squeal, but would require retro-fitting of articulated bogies to the entire freight fleet.
31	Altered / improved wagon maintenance	YES	The ETTT Project will upgrade the existing prototype noise monitoring station at Beecroft to facilitate wagon noise monitoring, but does not have the authority to implement such modifications to privately-owned trains. Refer to Section 8.11.4 for further details.
32	In-service monitoring for noisy trains (on trains or on track)	YES	Refer to the Source Noise Monitoring Plan in Section 14 for further details.
33	Time of day limitations, operational restrictions (may include speed, weight, time of day, length, class of loco)	YES	This is generally opposite to the objectives of the ETTT project, which seeks to increase the number of paths available for freight trains to operate. While most additional paths facilitated by the project are during the day, some are at night. The ETTT Project could document the potential benefits of restricting access for the noisiest classes of locos, for implementation by others as part of ongoing noise abatement or regulatory programs. Refer to Section 8.11.3 for further details.
34	Improved wagon design, eg self-steering bogies	YES	The ETTT Project upgrade the existing prototype noise monitoring station at Beecroft to facilitate wagon noise monitoring, but does not have the authority to implement such modifications to privately-owned trains. Refer to Section 8.11.4 for further details.
35	Improved track maintenance, eg tamping to maintain geometry, rail grinding	NO	These activities are already carried out regularly – minimal further benefits are considered possible.
36	Ballast gluing	NO	Latest research indicates this measure would be ineffective for noise control.
37	Additional property treatments	YES	In accordance with the Conditions of Approval, additional property treatments will be implemented if the track lubricators are found to be ineffective.
38	Operate freight trains on the centre track instead of the third track	NO	This would require all-stops passenger trains to use the new third track. Therefore a new platform would be required at Beecroft, resulting in the demolition of the station gardens and playground. Additional infrastructure would also be required at Epping to allow trains to turn back without blocking the centre track.
39	Leverage project activities to broaden and accelerate property treatments for existing noise issues	NO	The ETTT Project does not include funding to treat properties affected by existing operational noise.
40	Apply any of the above as relevant to existing tracks	YES	Applicability depends upon which mitigation measure is being considered. However in principle mitigation measures that would provide reductions in noise levels at properties predicted to exceed trigger levels will not be restricted to just the new track. For example, a noise barrier could be constructed on either side of the corridor; track lubricators could be installed on all tracks. Refer to Section 8 for further details.
41	Build the third track without mitigation	NO	Consideration of reasonable and feasible mitigation measures is required as part of the project's Conditions of Approval.
42	Noise barriers that curve out and over the track	NO	1) Cost is significantly higher than conventional noise barriers and therefore prohibitive. 2) Cannot be maintained effectively as they would sit over the track.
43	Lightweight noise barriers, eg sturdy timber fences	YES	Various construction materials will be investigated during detailed design, for proposed noise barriers. Refer to Section 8.6 for further details.
44	At-receiver noise barriers	YES	These would be considered for properties found to be eligible for building treatment. However such a barrier is likely to significantly affect the amenity of individual properties due to its solid nature and the likely height required.
45	Noise attenuation that targets specific frequency bands, eg lightweight boundary treatment to target high frequency noise	NO	Already covered by conventional barriers – there would be no benefit in limiting the effectiveness of barriers to specific frequencies.
46	Noise cancelling equipment	NO	This technology is only effective in an enclosed environment of limited size (for example headphones). Noise cancelling that worked at one property would actually increase noise levels at other properties.
47	Engineer noise barrier shape (non-conventional barrier) to reduce specific noise frequencies	NO	Noise barrier shape will be optimised in the detailed design of conventional barriers. However there is limited benefit to be gained by targeting specific frequencies.
48 & 49	Create noise impact buffer area along corridor	NO	This would require significant private property acquisition, which is not considered reasonable

Reference	Potential Mitigation Measure	Shortlisted? (YES / NO)	Reason
50	Alternative lubricants – on-board or track	YES	None have been identified at this stage but if alternative lubricants are available these could be used in existing or proposed track lubricators. Refer to Section 8.4 for further details.
51	Alternative materials to avoid steel-on-steel noise (alternative metal rail?)	NO	Alternative rail types are not feasible – existing rail materials have been refined over years for their important wear and strength properties. Use of alternative wheel types such as rubber tyres are only feasible on rail systems with light axle loads such as a metro system.
52	Alternative rail profile that improves wheel steering	NO	The time required for research and trials to establish whether any benefits could be obtained will extend beyond the ETTT Project construction phase.
53	Gauge widening (separate rails by additional mm around sharp curves)	YES	Gauge widening is sometimes used on passenger transit rail systems to reduce curving noise. However, these systems normally operate with a restricted rolling stock fleet, and the track and wheel profiles can be readily optimised. The issue is more complicated for a mixed freight line and insufficient test data is available to determine whether any benefit could be gained for the ETTT. Investigations of gauge widening fall into the remit of longer term noise mitigation projects being progressed outside of the project (see Section 8.11.2)
54	Alternative wheel profiles to alter contact band	NO	This would require re-railing / re-profiling / re-grinding of the East Coast standard gauge rail network, and would require all trains operating on these networks to have new wheels fitted. These measures are simply not feasible.
55	Smaller wheels	NO	This would require a full retrofit or more likely replacement of the entire wagon fleet. This is not a reasonable or feasible measure.
56	Truck freight to a point outside of metropolitan area – eg intermodal terminal at Hornsby	NO	This is the opposite of the objectives of the ETTT project to eliminate truck movements from major roads.

8 INVESTIGATION OF SHORTLISTED MITIGATION MEASURES

8.1 Introduction to "Reasonable and Feasible" Considerations

Section 3.1 of IGANRIP provides guidance in relation to determining feasible and reasonable mitigation measures. *Feasibility* relates to engineering considerations and what can practically be built or modified, given the opportunities and constraints of a particular site. *Reasonableness* relates to a judgement which takes into account the following factors:

- Noise-mitigation benefits - noise reduction provided, number of people protected
- Cost of mitigation - total cost and cost variation with level of benefit provided
- Community opinion
- Aesthetic impacts
- Track maintenance and access requirements
- Noise levels for affected land uses - existing and future levels, expected changes in noise levels
- Benefits arising from the development or its modification.

Source control measures are typically more cost effective to implement in terms of the resulting noise benefit compared with path and receiver controls respectively. On this basis, the hierarchy of noise control is to give preference to source control measures, then to path control measures and finally receiver controls. The identified shortlisted mitigation measures in **Section 7** include a mix of source, path and receiver controls. The source control measures are divided further into measures in the control of the project, and measures that require longer term changes that would need further research, or to be implemented by regulatory authorities or programs outside of the ETTT project.

In this chapter, the investigation of shortlisted mitigation measures considers firstly source measures in the control of the project (track lubrication), and then path controls which are also implementable by the ETTT project (barriers close to the track, and conventional barriers). Mitigation opportunities with subjective benefits are then discussed. In many cases these opportunities would need to be implemented over the longer term, they are not in the control of the ETTT project. However, in many cases these measures have significant potential to reduce perceived impacts at all locations (not just locations with exceedances of the trigger levels).

Finally, receiver controls are discussed at triggered locations where path controls (barriers) are not reasonable or feasible. Property treatments are proposed only at locations that are triggered by the project, without the addition of the safety factor. Treatments of locations that are triggered with the safety factor but where barriers are not reasonable and feasible are not proposed at this stage. Treatment of these properties would be triggered only if future compliance measurements indicate that freight train numbers are growing faster than anticipated.

It is recognised that some locations in the project area experience extremely high existing rail noise levels. In many cases, these locations with the highest existing rail noise impacts are not triggered for consideration of mitigation as a result of the ETTT project.

8.2 Contribution of Freight Exhaust vs Freight Wheel/Rail Sources

Noting that freight traffic controls the overall L_{Aeq} and L_{Amax} noise levels throughout the project area, it is useful to understand the contribution of the locomotive engine / exhaust sources vs the wheel / rail sources when considering noise mitigation measures.

At the majority of locations where receivers have a clear line of sight to the tracks, both the wheel / rail interface and the exhaust contribute to the overall L_{Aeq} noise levels in the future scenarios. Typically, the exhaust contribution is slightly higher (by around 1 dB) than the wheel/rail contribution. At most locations, the L_{Amax} noise level is produced by the freight locomotives, with levels around 8 dB higher than the L_{Amax} due to the wheel/rail at typical speeds.

The exception to these patterns is around the small radius curves at Beecroft, where the increased noise levels due to squeal increase the contribution of the wheel/rail source to dominate both L_{Aeq} and L_{Amax}.

This relative contribution of freight sources and wheel/rail sources means that mitigation measures at most locations need to target both the wheel/rail and exhaust sources to reduce overall L_{Amax} and L_{Aeq} noise levels. However in areas where curve squeal is a problem, mitigation measures targeting the wheel/rail source have the potential to be effective. Mitigation measures that target the wheel/rail source specifically are track lubrication systems, and low-height noise barriers close to the track.

Barriers targeting the wheel/rail interface would also have a benefit in mitigating noise from wagons after the locomotives have passed. For this reason, mitigation measures that target the wheel/rail source alone may also be of benefit even away from the Beecroft curves. By targeting the wheel/rail source, future improvements to locomotive noise emissions as a result of longer term programs would have a greater effect on the overall noise levels.

8.3 Process for Reasonable and Feasible Assessment of Noise Barriers

Noise barriers are most effective when they can be located close to either the source or the receiver. In situations where the source is the wheel/rail interface a low-height noise barrier constructed close to the noise source can provide a similar noise reduction to a higher noise barrier located at the corridor boundary, but at a much cheaper cost. Care must be taken to ensure the noise barrier does not obstruct safe maintenance access to the track. In other situations, a conventional barrier located nearer to the receivers may be more effective. This study considers both low-height barriers close to the track, and conventional noise barriers. Barriers are considered only at locations where more than three closely grouped properties are triggered for consideration of mitigation.

The steps undertaken to determine whether barriers are a reasonable and feasible mitigation measure for ETTT are as follows:

1. Determine potential barrier locations in noise catchment areas where consideration of mitigation is triggered. This step includes a review of the engineering constraints on barrier locations. For example, noise barrier foundations are not able to be constructed in locations where soil nails or rock bolts are used to stabilise cuttings or embankments. In these situations, the barrier would need to be located outside the area containing the soil nails or rock bolts.

2. Determine the maximum potential barrier height to be considered, with reference to engineering constraints. In the absence of any site-specific constraints, an upper limit on conventional barrier height of 8 m has been applied. For road applications, barriers of greater height than 8 m are considered to be visually unacceptable[2]. This limit on acceptable height is also considered applicable to the ETTT situation. It is noted that this upper limit on height is twice the height of barriers normally considered on rail upgrade projects, and that construction of barriers of these heights would have significant visual impacts and adverse urban design outcomes.

3. Calculate the noise benefit achieved at all sensitive receivers for barriers of increasing height up to the maximum feasible height, in each noise catchment area. In some cases, sub-catchments are considered where the terrain and source-receiver geometry varies throughout a noise catchment. The calculation of noise benefit considers both overall noise (wheel/rail sources and locomotive exhaust sources), and the wheel/rail noise sources in isolation.

[2] As described in the Roads and Maritime Services *Environmental Noise Management Manual* (ENMM, December 2001) Practice Note IV(a) Noise barrier heights.

4. To be effective (and therefore to warrant consideration as a viable noise treatment), noise barriers should provide a reduction of at least 5 dB in either L_{Aeq} or L_{Amax}. This test is applied to avoid constructions with little or no acoustic benefit, and construction of a noise barrier is generally not considered if this minimum performance standard is not achieved. This test is applied to the L_{Amax} and $L_{Aeq(9hour)}$ parameters, recognising the increased sensitivity of the night-time period. The minimum benefit test is considered to be achieved if at least one property triggered for consideration of mitigation would receive a 5 dB benefit. For barriers which are 5 m high or more, the barrier should provide a reduction of at least 10 dB for at least one property triggered for consideration of mitigation, to justify the increased cost and negative visual impacts of very high barriers.

5. Cost estimates for each barrier height are developed. Estimates include the cost of design, the cost of vegetation offsets where additional tree clearing is required to construct a barrier, the cost of construction, and the cost of ongoing maintenance such as graffiti removal.

6. Barrier options are reviewed for overall cost-effectiveness and value for money. For rail infrastructure projects, there is no formalised method to assess cost-effectiveness. Two different approaches have been used for this project. The primary approach used is based on actual estimates of the barrier cost, relative to the benefit provided (using units of dB per $Million). The second approach assumes cost is directly proportional to barrier surface area, and assesses relative cost-effectiveness in units of dB per m^2. This second approach has been applied on other NSW rail infrastructure projects and is used in this case as a check to confirm that reasonable and feasible barriers are not ruled out on the basis of an excessive cost estimate, and that the benefit provided per m^2 of barrier is comparable to other rail noise barriers. See **Section 8.8** for a description of the two approaches for assessing cost-effectiveness.

7. Determine the minimum barrier height, the target barrier height and the acoustic optimum barrier height. The minimum height is the height required to achieve the minimum benefit requirements. The target height is the height required to achieve the target noise levels at all triggered locations (the overall IGANRIP trigger levels). The acoustic optimum height is the height (above the minimum height) with the maximum benefit-cost ratio above 100 dB per $1 Million. See **Section 8.8** for a description of how the acoustic optimum height is calculated and for a description of the two approaches for assessing cost-effectiveness.

8. If an option or options are found to meet the minimum benefit requirement and be cost-effective, a recommended barrier is proposed. If both the acoustic optimum height and the target barrier height are cost-effective, the greater of the target height and the acoustic optimum barrier height would be recommended, with both these taking precedence over the minimum height.

9. Residual impacts are identified at locations where the recommended barriers do not meet the target noise levels.

10. The adverse impacts of the recommended barriers are identified. Adverse impacts of barriers include additional vegetation clearing requirements, loss of open aspect and breezes, loss of views, potential for vandalism and need for graffiti removal, general reduction in visual amenity and constrained maintenance access to the rail corridor.

11. Directly affected property owners provide feedback on the recommended noise barriers, following exhibition of the draft ONVR. This feedback is documented and responded to in the final ONVR confirming the mitigation measures to be applied.

8.4 Track Lubrication Systems

Track lubrication systems are recognised as a cost effective means to minimise curving noise. In recognition of the existing curve squeal problem at Beecroft, a Proof of Concept track lubrication project was implemented in July 2013 which includes all existing tracks.

8.4.1 Lubrication System Trials and Optimisation

The Proof of Concept (PoC) project utilised state of the art wayside lubrication for railway systems. This includes modern electronic lubricators, as shown in **Figure 33**, and lubricants developed specifically for noise suppression on railway curves. The utility of a combination of electronic lubricators and specific lubrication products has been proven in the USA and elsewhere. The electronic lubricators were also equipped with an internet based remote monitoring system to ensure peak performance. The placement, set-up and performance of the units have been reviewed by rail lubrication experts to optimise their performance.

In addition, Transport for NSW has installed a Rail Noise Monitoring Station (see also **Section 14**) at the site which captures the noise from each passing freight train on either track. This data is regularly reviewed and the results shared with the lubrication maintainer to ensure the best noise outcome is achieved and sustained.

Figure 33 Modern Electronic Lubricators with Remote Monitoring

8.4.2 Installed Lubrication System

There are six lubrication units installed on the two existing tracks in the Pennant Hills – Beecroft - Cheltenham section. Locations are shown on the maps included in **Part 1 of the ONVR** document. The units serve both rails of each track to ensure that the entire track is well lubricated.

8.4.3 Noise Benefit of Lubrication

The noise benefit achieved by the lubrication system has been determined by analysis of freight train noise measurements taken over two months (October 2013 and January 2014) at the Beecroft Rail Noise Monitoring Station (see **Section 14** for details of the measurement system). The measurements are summarised in **Table 29**. During these two months, the lubrication systems are considered to have been operating as intended. Between October and January, changes to the system including rail re-profiling reduced the effectiveness of the system and hence these time periods have not been used to determine the benefit of lubrication.

Table 29 Lubricated Track Freight Noise Measurements

Time Period	Number of Freight Trains		Average Speed (km/h)		Measured Noise Levels (dBA) Both Directions	
	Down	Up	Down	Up	Logarithmic Average L_{AE}	$L_{Amax, 95\%}$
October 2013	304	315	37	42	106	103
January 2014	234	236	36	40	107	104

To establish the noise benefit of the lubrication systems to include in the noise model, comparison is made between the unmitigated model predictions at the Beecroft Rail Noise Monitoring Location, and the measured noise levels with mitigation in **Table 30**.

Table 30 Lubricated Track Noise Benefit

Scenario	Noise Levels (dBA)		
	Daytime $L_{Aeq(15hour)}$	Night-time $L_{Aeq(9hour)}$	$L_{Amax, 95\%}$
Modelled unmitigated	73	72	111
Measured with lubrication	71	71	103
Benefit due to lubrication	2	1	8

On the basis of the measured effectiveness of the lubrication system, the model for mitigated cases incorporating lubrication of the Beecroft curves incorporates the following allowances for curving noise:

- +5 dB passenger L_{AE} (no change from unmitigated case)
- +8 dB passenger L_{Amax} (6 dB reduction from unmitigated case)
- +8 dB freight L_{AE} (1 dB reduction from unmitigated case)
- +13 dB freight L_{Amax} (8 dB reduction from unmitigated case)

In achieving an 8 dB reduction in $L_{Amax,95\%}$ curve squeal noise levels, it is concluded that the lubrication system is an effective mitigation measure. In addition to the reduction in L_{Amax} levels, the PoC project has reduced the number of extreme wheel squeal events occurring through the Beecroft - Cheltenham section by approximately 50%. Transport for NSW is seeking to further reduce curve noise by working with freight operators to improve the performance of their wagons so that they are less likely to generate curve squeal (see **Section 8.11.4**).

8.5 Low-Height Noise Barriers Close to Tracks

Low-height barriers would need to be installed as close as possible to the tracks, but outside the zone in which there is the potential for them to be struck by a train or by maintenance equipment such as automated ballast cleaning machines. On tight curves, this means the dynamic envelope of all train types using the track must be considered. Sydney Trains Standard *ESC 215 Transit Space Version 4.9 April 2013* (the Transit Space Standard) has been used to determine a minimum offset distance of 2250 mm from the track centre as the closest a barrier of height up to 1 m above the top of rail could be installed.

There are many potential designs for low-height barriers in various situations. Some examples are shown in **Figure 34**. From an acoustic perspective, a barrier with an absorptive facing is preferred. Otherwise, safety considerations control the detail of the design of a low-height barrier close to the track. Consultation with track maintainers has raised the following safety and track access issues for consideration:

- Refuges / egress points spaced every 20m will be required.
- Consideration must be given to where safe places will be. Where the track centres between Down Main and Down Relief are 6.4m, there is a safe place in the 6-foot, so a low-height barrier could be located on the outside of the new third track and there would be a safe place on the other side of the track. However, this would not be the case if a low-height barrier were installed on both sides of the new track.
- If a low-height barrier were installed on the outside of the Up main, no safe place would be available as track centres between Up and Down mains are typically only 3.9m.
- Warning lights may be required around curves if sighting is insufficient.
- Reflectivity of the low-height barrier and consequential effect on signal sighting should be considered. Barrier materials would need to be non-reflective and preferably a dark colour.
- Drainage would need to be considered – it would be preferable for barriers not to be solid concrete, in order to ensure water can drain away properly from the track structure. Maintaining good drainage is critical to track maintenance.
- Sydney Trains is transitioning to automated track patrol system, so maintaining safe access for visual track inspection by maintenance staff will be less of an issue in the future than it is currently.

Figure 34 Examples of Low-Height Barriers

First five barrier example images reproduced from DB Netze Report *Innovative Massnahmen zum Larm- und Erschutterungsschutz am Farhweg Schlussbericht*, dated 15 June 2012. Sixth barrier example is a location near Stockholm, Sweden.

It is noted that the low barrier examples in **Figure 34** are installed on only one side of the tracks in all cases. The example with another barrier on the far side incorporates gaps in the low concrete barrier to permit a refuge or egress point.

8.5.1 Low-Height Noise Barrier Modelling

Low-height barriers have been introduced to the noise model of the future situation, to determine the benefit that would be expected at receivers in the Beecroft area. Three barrier heights have been considered, starting with a barrier of height 0.5 m above the top of rail. Heights of 0.75 m and 1 m above top of rail have also been assessed. Barriers greater than 1 m are considered to be unlikely to be acceptable close to the track due to increasing safety and visibility concerns at greater heights. For safety reasons, low-height barriers have been considered only on the western side of the new ETTT track, and on the eastern side of the existing Up Main (the easternmost track). These locations target noise from freight wagons.

Modelling the acoustic benefit to be achieved by a low-height barrier close to the source is not straightforward. To confirm that the model is representative of the low barrier performance, a series of tests were conducted to determine if the model could reproduce the findings of a German measurement study, described in DB Netze Report *Innovative Massnahmen zum Larm- und Erschutterungsschutz am Farhweg Schlussbericht*, dated 15 June 2012. The German study was part of a program “Konjunkturprogramm II” examining the performance of noise and vibration mitigation measures. As part of the German study, measurements were made of the attenuation provided by low-height noise barriers of heights up to 0.78m above top of rail, with four measurement positions 25m from the nearest track at elevations from 1.5m up to 9.1m. The following conclusions were reached as to the suitability of the ETTT model to predict low-height barrier performance:

- The model underpredicts the barrier benefit at 9.1m high receivers by approximately 2 dB (potentially due to lack of shielding by the train body in the model).
- The model predictions match well with the DB Netze measurements at a 6.3m receiver height.
- The model overpredicts the benefit at a 3.5m receiver height, for traffic on the near track, by up to approximately 2 dB.
- Overall, the model predictions for low-height barriers were found to match the expected attenuation from previous SLR studies and the literature of a benefit of 8 dB to 10 dB for a 1m barrier above top of rail, at receivers 1.5m to 3.5m above top of rail.

The model predictions indicate that maximising the height of the low-height barriers would maximise the noise benefit. For this reason, barriers of height 1 m above top of rail are preferred, being the height that would shield noise emitted from wheels most effectively.

For low height barriers which are located close to the near track, there is potential for reflected noise to build-up in the small gap between the train and the barrier and reduce the noise benefit at receivers on the same side of the track. For this reason, an absorptive facing is recommended on the track-side of the low height barriers.

8.5.2 Benefits / Negative Effects of Low-Height Noise Barriers

A benefit of low-height noise barriers is that they provide noise mitigation benefits to all residents in the area, including those that have noise impacts below the IGANRIP trigger levels. Barriers also improve external amenity by targeting noise before it reaches the receiver.

Low-height noise barriers have less negative effects than conventional barriers due to their minimal size and visual impacts. Negative effects of conventional barriers such as overshadowing, loss of open aspect, potential for vandalism, and visual impacts are all minimised with a low barrier close to the track. The negative effects of low-height barriers are in the areas of track access and safety. These issues would need to be worked through in consultation with track maintenance staff, risk assessors and other stakeholders.

Low-height noise barriers close to the track have the potential to reduce noise from the wheel/rail interface only. Noise from other parts of the train would not be reduced by low-height barriers. Noise from freight locomotive engines and exhausts, which can be a cause of annoyance to residences, would remain untreated.

Noise barriers including low-height noise barriers do not necessarily satisfy all expectations. They will reduce, but not eliminate noise from freight wagons and electric passenger vehicles. For example, the noticeable “clunking” character of a wheel with a flat spot rolling past would remain audible with low-height barriers, albeit at a lower volume. Subjective annoyance due to freight wagon noise and squeal noise would not be eliminated by low-height noise barriers close to the track.

8.6 Conventional Noise Barriers

To have a noticeable effect, noise barriers must break the line of sight between the source and receiver. The acoustic performance depends on the degree to which the noise propagation path is interrupted. The topography (ground elevation) must be taken into account in the noise barrier design as this has a direct effect on the geometry of the source, barrier and receiver. Some examples of conventional noise barriers are shown in **Figure 35**.

Conceptual noise barrier locations have been proposed throughout the project area on the basis of a high level review of engineering constraints identifying the maximum feasible height at each particular location, compatibility with civil works and structures, operational compatibility, access, drainage and constructability.

The noise benefit of conventional barriers has been determined using the ETTT model for a range of barrier heights defined in 0.5 m increments above the local ground height at the barrier location, for heights from 1 m up to 8 m (except where the height is limited by engineering constraints).

For conventional barriers, the potential for reflected noise to increase noise levels on the opposite side of the track has been considered as part of the detailed assessment. This assessment identified that the noise level increase would be negligible on the basis of the additional propagation distance and since the reflected noise would be shielded by the train itself for receivers on the opposite side of the track. The addition of absorptive treatments to the noise barrier would not provide a material noise benefit to sensitive receivers.

8.6.1 Benefits / Negative Effects of Conventional Noise Barriers

A benefit of conventional noise barriers is that they maximise the noise mitigation benefits to all residents in the area, including those that have noise impacts below the IGANRIP trigger levels. Barriers also improve external amenity. Conventional barriers can be constructed to greater heights than low barriers close to the tracks.

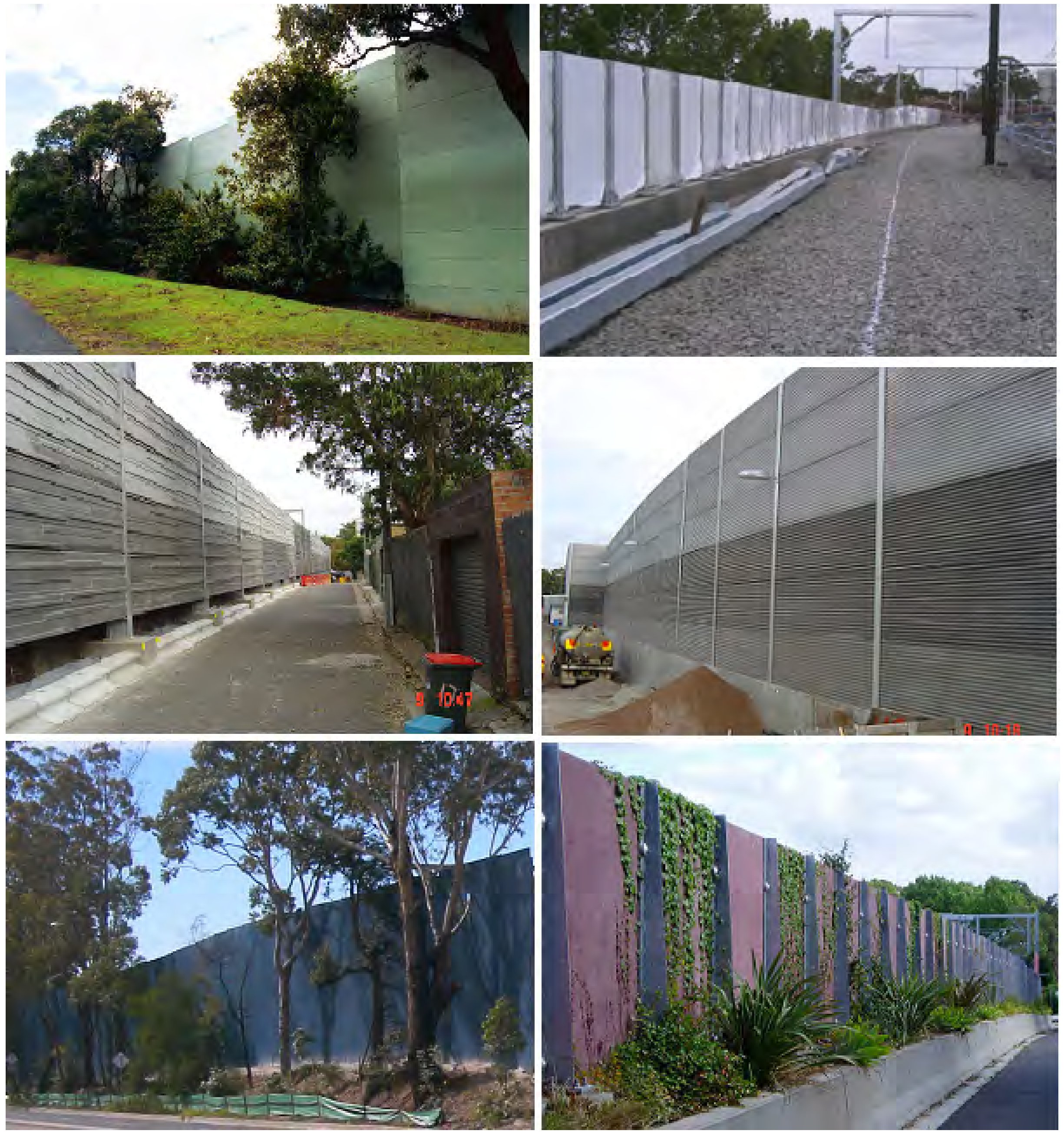
Conventional noise barriers do not necessarily satisfy all expectations. Residents may also possibly be affected by negative aspects of conventional barriers such as:

- Loss of open aspect and breezes
- Potential for vandalism and need for graffiti removal
- Reduction in visual amenity of urban landscape
- Loss of views and vistas
- Removal of vegetation

Conventional noise barriers do not necessarily satisfy all expectations. Conventional noise barriers will reduce, but not eliminate noise from the relevant source. In some cases, it may not be feasible to construct a conventional barrier targeting noise from freight locomotives engines and exhaust. Even if a barrier can be constructed to the height required to break the line of sight from this noise source to a receiver, the low frequency character of locomotive exhaust noise means it will tend to diffract around the barrier. For this reason, it is likely that locomotive exhaust noise would remain clearly audible and noticeable (albeit reduced in volume) at residential properties near the tracks, even after construction of a high noise barrier.

Subjective annoyance due to freight locomotive noise would not be eliminated by conventional noise barriers.

Figure 35 Examples of Conventional Noise Barriers



8.7 Property Treatments

Treatments to building facades usually involve higher performance windows, doors and seals to keep noise out. Facade treatments effectively require occupants to keep their windows and doors closed and hence alternative ventilation is usually required to maintain adequate air flow.

If the facade condition is reasonable from an acoustic point of view (ie no significant gaps, etc) and residents already close their windows because of noise issues, then closing them as a mitigation measure and providing alternative ventilation does not improve their acoustic environment. In this instance, it is preferable to provide air conditioning rather than ventilation only.

Windows provide little attenuation of low frequency noise. Since locomotive engine and exhaust noise is dominated by low frequency noise, closing windows and providing air conditioning may not reduce noise levels significantly. It may be necessary to install heavier glazing, laminated glazing or double glazing to provide a noticeable benefit. Glazing may not be the only issue, as the entire facade determines the acoustic transmission into a residence. Lightweight buildings (eg of weatherboard construction) are limited by the underlying construction and attenuation of low-frequency noise requires significant mitigation measures.

Upgrading property boundary fences is sometimes an option, where the existing fence is low or has gaps. The property fence then forms a noise barrier. However, the height of fence required to form an effective barrier to locomotive noise is unlikely to be acceptable at residential boundaries.

Building treatments are considered as a noise mitigation option for the ETTT project only as a final measure, for existing receivers that are triggered in the base case (without the safety factor), and at locations where a noise barrier is not constructed. If windows are closed as a noise mitigation measure, the resulting noise reductions are likely to be clearly beneficial from a quantitative and subjective perspective. If heavier glazing, laminated glazing or double glazing is provided, the additional noise benefit (quantitative and subjective) could be beneficial in some circumstances, depending on the overall facade construction of individual dwellings.

The scope and suitability of property facade treatments would depend on the existing conditions at each property and consultation with the affected receivers. The cost of property treatments will vary from case to case, but is typically around $20,000 per property.

8.8 Noise Barrier Reasonable and Feasible Analysis by NCA

Barriers are investigated only at locations where more than three closely grouped properties are triggered for consideration of mitigation. This situation occurs on the Down side in all catchments except NCA02 and NCA06 (where no sensitive receiver properties are triggered for consideration of mitigation). On the Up side, the third track is moving some freight traffic further away from the sensitive receivers. Consideration of noise barriers for receivers on the Up side is required in NCA06, NCA07 and NCA08.

The analysis of all barriers uses the noise model of the 2026 “IGANRIP plus safety factor” scenario.

As described in Section **8.3**, two approaches have been used to assess barrier cost effectiveness. The primary approach is based directly on the ratio of the cost of the barrier to the benefit provided to all properties behind the barrier. The second approach does not rely on a specific barrier cost estimate, but instead assumes barrier cost is proportional to the surface area.

8.8.1 Primary Approach to Assessing Barrier Cost-effectiveness

Overall cost-effectiveness is assessed by summing the L_{Amax} and $L_{Aeq(9hour)}$ noise benefit at all levels of all noise affected properties behind the barrier (for both wheel rail noise, and for overall noise). The sum includes all modelled residential buildings, not just triggered properties. To be considered cost-effective in an absolute sense for this project, a barrier must provide a total benefit of at least 100 dB per $1 Million cost, where the benefit is the sum of the L_{Amax} and $L_{Aeq(9hour)}$ benefit. This means a barrier would be considered cost effective if on average a clearly noticeable benefit (5 dB in each of L_{Aeq} and L_{Amax}) is achieved at one level of a sensitive receiver at a cost of $100,000. This cost is five times the typical cost to treat one property. It is noted that there is precedence in road infrastructure projects to set a cost-effectiveness cut-off at twice the cost of property treatments[3], since barriers provide for outdoor amenity as well as indoor amenity (so double the cost is justified). The higher cost factor of barriers relative to property treatments is considered justified for this project in light of the benefit achieved in reducing subjective annoyance factors such as curve squeal.

[3] As described in the Roads and Maritime Services *Environmental Noise Management Manual* (ENMM, December 2001) Practice Note IV Selecting and designing ‘feasible and reasonable’ treatment options for road traffic noise from ‘new’ and ‘redeveloped’ roads affecting residential land uses.

8.8.2 Alternative Approach to Check Barrier Cost-effectiveness

The second method used to check barrier cost-effectiveness considers the total noise benefit per unit area, as well as the increase in benefit with increasing barrier area. This approach has been used on other rail infrastructure projects and is described in detail in Weber and Atkinson (2008)[4]. The noise barrier optimisation approach is consistent with the requirements of the “reasonability” requirements in the IGANRIP and RING, and is broadly similar with the approach described in the *Environmental Noise Management Manual* (RMS, formerly RTA, 2001). In both cases, the most cost-effective noise barrier takes into consideration the Total Noise Benefit, the Noise Benefit per Unit Area, the number of properties protected, incremental noise barrier heights of 0.5 m and minimum performance requirements to provide a “noticeable” benefit.

In order for noise barriers to have been considered cost-effective on other infrastructure projects including the Cronulla Line Duplication and Kingsgrove to Revesby Quadruplication projects, both the total noise benefit per unit area and the increase in benefit with incrementing area have been greater than 0.2 dBA/m^2. For this project, this check has been applied to both wheel-rail noise in isolation, and to overall noise.

This alternative approach is used as a check on the cost-effectiveness of the recommended barriers identified using the primary approach above:

- To confirm that reasonable and feasible barriers have not been excluded under the primary approach on the basis of an excessive cost estimate
- To confirm that the recommended barriers give a benefit relative to their height and area that is comparable to other noise barriers constructed on rail infrastructure projects in the Sydney area

This alternative approach arrived at the same conclusions as the primary method of assessment, endorsing the three proposed barrier lengths and confirming that the other potential barriers considered would not be cost effective. Detailed results of both methods of analysis are provided in Appendix E.

8.8.3 Parameters used in the Assessment of Noise Barriers

The following parameters are used in the analysis to inform the determination of the minimum height, the target height and the acoustic optimum barrier height:

- Minimum Barrier Height – the minimum height that achieves a 5 dB reduction in noise (either $L_{Aeq(9hour)}$ or L_{Amax}) for at least one residence triggered for consideration of mitigation. If the barrier height considered is 5 m or more, the minimum reduction required is changed to 10 dB. For barriers targeting the wheel/rail source, the minimum benefit applies to the wheel/rail source in isolation.
- Target Barrier Height – the height that achieves the overall noise target, being the IGANRIP $L_{Aeq(9hour)}$ and L_{Amax} trigger levels at all triggered locations. Since the night-time controls the L_{Aeq} assessment, achieving the $L_{Aeq(9hour)}$ goals means the daytime $L_{Aeq(15hour)}$ goals would also be met. This barrier height is not relevant for barriers targeting the wheel/rail sources only.
- The “Total Noise Benefit” (TNB) for each barrier height option is the sum of the dB reductions (L_{Amax} plus L_{Aeq}) achieved at modelled residences within each catchment for the barrier height. The dB reductions are only summed whilst the noise levels are above a cut-off, set 5 dB below the IGANRIP trigger levels. This means additional benefit to the community is not included in the justification for noise barriers once the predicted noise levels are no longer considered to be excessive. Individual floors of residential properties are counted as individual points in calculating TNB.
- The “Total Noise Benefit per unit Barrier Area” (TNBA) is the TNB divided by the total area of the barrier in the section being examined. TNBA has units of dBA/m^2.

[4] *A systematic approach for arriving at reasonable heights and locations for noise barriers adjacent to railway lines.* C. Weber and K. Atkinson (2008) p243-249 Noise and Vibration Mitigation for Rail Transport Systems: Proceedings of the 9th International Workshop on Railway Noise.

- The "Marginal Benefit Value per unit Area" (MBVA) for a particular barrier height option is the increase in TNB divided by the increase in barrier area. MBVA also has units of dBA/m^2.
- Cost effectiveness (dB per $1M) is calculated by dividing the TNB by the barrier cost estimate.
- Acoustic Optimum Barrier Height – this height meets the minimum benefit requirement and maximises cost-effectiveness for either wheel rail noise or overall noise, compared with the other barrier height options being considered.

Appendix E summarises the investigation of different barrier heights and cost-effectiveness (by both approaches), and documents the determination of the acoustic optimum barrier height for each location considered.

8.8.4 Barrier Assessment NCA01 Down

In NCA01 on the Down side, the northern end of the apartment building at 74 Rawson Street is triggered for consideration of mitigation. Being apartments, there are more than three closely grouped properties and noise barriers are therefore considered. Both low-height barriers close to the track and a conventional barrier on the existing rail corridor fence line have been examined.

The height of a conventional barrier at this location is not subject to any particular engineering constraints. There is an existing access gate to be maintained, located approximately 20 m from the end of the Epping Station platforms, near the limit of the ETTT project area. This constraint defines the southern end of a potential barrier extending approximately 150 m in length.

Table 31 Summary of Barrier Assessment for NCA01 Down

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 23+500km to 23+650km Barrier length 150m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	At this location the affected receivers are elevated relative to the tracks and would overlook even a high barrier. For this reason, noise barriers at this location would not provide the minimum acoustic benefit required to justify further consideration of a barrier. Barriers are not reasonable or feasible at this location This conclusion applies to low-height barriers close to the tracks, as well as to conventional barriers.
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	
		Acoustic Optimum		
	Conventional barrier targeting overall noise	Minimum	Minimum benefit not reached	
		Target		
		Acoustic Optimum		

Note: Acoustic optimum height is the most cost-effective height above the minimum height
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA01 Down it is concluded that noise barriers are not a reasonable and feasible mitigation measure.

8.8.5 Barrier Assessment NCA03 Down

In NCA03 on the Down side, there are two groups of receivers triggered for consideration of mitigation. These groups are divided by the high point around 94 The Crescent where the tracks are in a deep cutting, which already provides a noise benefit. The analysis of barriers in NCA03 Down is therefore divided into two sub catchments, A to the south and B to the north. Both low barriers close to the track and conventional barriers on the existing rail corridor fence line have been examined.

Rock bolts and soil nails are used to stabilise the cutting face throughout NCA03. For this reason, foundations for conventional noise barriers could not be constructed on the top edge of the cutting but would need to be offset by 0.5 m beyond the tips of the rock bolts and soil nails. The barrier location considered would therefore be set back a minimum of 3m and a maximum of 8 m from the cutting edge.

At the southern end of the catchment, the barrier would need to tie in with the M2 road noise barriers and the rail corridor access gate at Chainage 24.480km.

There is another access gate at Chainage 24.960km that would also need to be maintained. The barrier considered extends to the northern end of the catchment, at the junction of Lyne Road and the Crescent.

The barrier assessment for NCA03 Down Sub Catchment A is summarised in **Table 32**.

Table 32 Summary of Barrier Assessment for NCA03 Down Sub Catchment A

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 24+440km to 24+880km Barrier length 440m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	The existing cuttings means low-height barriers would not be effective at this location.
		Target		
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	3.0m	The existing cutting means wheel-rail noise is already well attenuated – a barrier of 3m would be required to gain an additional 5 dB reduction in wheel rail noise. Targeting overall noise is therefore preferable at this location.
		Acoustic Optimum	3.5m	
	Conventional barrier targeting overall noise	Minimum	2.0m	A 6.5 m conventional barrier targeting overall noise would meet the noise goals at all receivers. A slightly higher barrier would be more cost-effective.
		Target	6.5m	
		Acoustic Optimum	7.0 m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA03 Down Sub catchment A, the analysis indicates that noise barriers targeting overall noise are potentially reasonable and feasible on the basis of the acoustic benefit provided, but are not cost-effective. The costs and benefits of the barriers considered are summarised in **Table 33.**

Table 33 Barrier Costs and Benefits NCA03 Down Sub Catchment A

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
2.0m	$1.76M	50	69	29	39	No
3.0m	$2.09M	81	120	39	58	No
3.5m	$2.49M	98	154	39	62	No
6.5m	$4.78M	120	378	25	79	No
7.0m	$4.96M	120	396	24	80	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 2 m barrier would meet the minimum noise benefit requirements and would meet the noise goals at 2 out of 13 triggered residences. A barrier up to 6.5 m high would be required to meet the noise goals at all 13 triggered residences in the area, with a cost of $4.78M. None of the barrier heights examined meet the cost-effectiveness requirements described in **Section 8.3**.

In NCA03 Down Sub catchment B, the analysis indicates that conventional barriers targeting the wheel-rail source only are potentially feasible and reasonable on the basis of the acoustic benefit provided. A 3.5 m barrier would provide the necessary minimum reduction in wheel/rail noise for at least one triggered property, and would have subjective benefits in reducing noise from freight wagons. A 4.5 m barrier would be marginally more cost-effective. The barrier assessment for NCA03 Down Sub Catchment **B** is summarised in **Table 34.**

Table 34 Summary of Barrier Assessment for NCA03 Down Sub Catchment B

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 24+900km to 25+120km Barrier length 220m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	The source to receiver terrain means low-height barriers would not achieve the minimum benefit requirements at this location
		Target		
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	3.5m	The acoustic optimum barrier is marginally more cost effective than the minimum height barrier. Higher barriers targeting wheel/rail noise would need to be 7 m high or more to meet the minimum benefit requirements for barriers greater than 5m, and would be less cost-effective for wheel rail noise.
		Acoustic Optimum	4.5m	
	Conventional barrier targeting overall noise	Minimum	8.0m	Barriers targeting overall noise would need to be 8.0 m high to meet the minimum benefit requirements at this location.
		Target	n/a	
		Acoustic Optimum	8.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

The costs and benefits of these barriers are summarised in **Table 35**.

Table 35 Barrier Costs and Benefits NCA03 Down Sub Catchment B

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
3.5m	$1.25M	59	59	48	48	No
4.5m	$1.53M	73	85	48	55	No
8.0m	$3.05M	87	192	29	63	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 3.5 m barrier would not meet the overall noise goals at any triggered residences, leaving 7 residences with residual exceedances. The 4.5 m barrier would meet the noise goals at one triggered residence. An 8.0 m high barrier would be required to meet the minimum benefit requirements for overall noise and would meet the noise goals at all but two triggered residences. None of the barriers considered meet the overall cost-effectiveness requirements described in **Section 8.3**.

In NCA03 Down it is concluded that noise barriers are not a reasonable and feasible mitigation measure.

8.8.6 Barrier Assessment NCA04 Down

In NCA04 on the Down side, there are two groups of receivers triggered for consideration of mitigation. The first group is located adjacent to Cheltenham Station, and the second extends along the Crescent between the Beecroft substation and the Scout Hall. The analysis of barriers in NCA04 Down is therefore divided into two sub catchments, A near Cheltenham Station and B towards Beecroft.

Construction of a barrier would be complicated adjacent to Cheltenham Station in Sub Catchment A. While a barrier up to 2.4m high could be fixed to the top of the retaining wall adjacent to the station, this would not be feasible for a 100 m long section immediately to the south of Cheltenham Road. In this catchment, the barrier is therefore limited to 100 m in length adjacent to the station.

In Sub Catchment B, no engineering constraints on barrier height have been identified between the substation and the Scout Hall, provided the barrier remains outside areas stabilised with rock bolts and soil nails. The barrier ends would tie into the substation and the Scout Hall.

The barrier assessment for NCA04 Down Sub Catchment A is summarised in **Table 36**, and the assessment for NCA04 Down Sub Catchment B is summarised in **Table 37**.

Table 36 Summary of Barrier Assessment for NCA04 Down Sub Catchment A

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 25+280km to 25+380km Barrier length 100m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	The engineering constraints around Cheltenham Station mean that a conventional barrier is not feasible except in a 100m section, with limited height. Conventional barriers meeting these constraints would not provide the minimum acoustic benefit required to justify construction of a noise barrier. Conventional barriers are not reasonable or feasible at this location. Low-height barriers close to the tracks would also not achieve the minimum benefit requirement.
		Target		
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	
		Target		
		Acoustic Optimum		
	Conventional barrier targeting overall noise	Minimum	Minimum benefit not reached	
		Target		
		Acoustic Optimum		

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

Table 37 Summary of Barrier Assessment for NCA04 Down Sub Catchment B

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 25+840km to 26+370km Barrier length 530m	Low-height barrier targeting wheel/rail sources only	Minimum	1m	Low-height barriers close to the track are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	1m	
	Conventional barrier targeting wheel/rail sources only	Minimum	2.5m	Conventional barriers targeting the wheel rail source alone are also potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	3.0m	
	Conventional barrier targeting overall noise	Minimum	2.0m	Conventional barriers targeting overall noise are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Target	6.5m	
		Acoustic Optimum	6.5m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA04 Down Sub catchment B, the analysis indicates that noise barriers targeting either overall noise or wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. Four potential conventional barriers are proposed for further consideration, along with low height barriers. The costs and benefits of these barriers are summarised in **Table 38.**

Table 38 Barrier Costs and Benefits NCA04 Down Sub Catchment B

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
1.0m	$2.85M	92	n/a for low barrier	32	n/a	No
2.0m	$2.40M	98	74	41	31	No
2.5m	$2.60M	146	105	56	40	No
3.0m	$2.80M	190	141	68	50	No
6.5m	$6.05M	258	525	43	87	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 2.5 m barrier would meet the minimum noise benefit requirements for both overall noise and wheel rail noise, and would meet the noise goals at 5 out of 16 triggered residences. A barrier up to 6.5 m high would be required to meet the noise goals at all 16 triggered residences in the area. However, none of the barriers considered meet the overall cost-effectiveness requirements described in **Section 8.3**.

In NCA04 Down it is concluded that noise barriers are not a reasonable and feasible mitigation measure.

8.8.7 Barrier Assessment NCA05 Down

In NCA05 on the Down side, residential receivers are triggered for consideration of mitigation between the Scout Hall and Beecroft Public School. Construction of a barrier would be complicated adjacent to the Scout Hall, and some overlapping areas may need to be provided to maintain access to the rail corridor and parking area immediately west of the Scout Hall. For the majority of this section, barriers would need to be located beyond the embankment retaining wall, but would not be height restricted. A barrier could extend to approximately 100m south of the Copeland Road bridge, to target the triggered residential properties. The barrier assessment for NCA05 Down is summarised in **Table 39**.

Table 39 Summary of Barrier Assessment for NCA05 Down

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 26+420km to 26+690km Barrier length 270m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	Low-height barriers close to the tracks would not achieve the minimum benefit requirement at any triggered receivers.
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	6.5m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	7.0m	
	Conventional barrier targeting overall noise	Minimum	8.0m	Conventional barriers targeting overall noise are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Target	7.0m	
		Acoustic Optimum	8.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA05 Down, the analysis indicates that conventional noise barriers targeting either overall noise or wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. Low-height barriers close to the tracks would not meet the minimum benefit requirement in this area.

Three potential conventional barriers are proposed for further consideration. The costs and benefits of these barriers are summarised in **Table 40.**

Table 40 Barrier Costs and Benefits NCA05 Down

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
6.5m	$3.08M	229	200	74	65	No
7.0m	$3.19M	251	221	79	69	No
8.0m	$3.89M	272	273	70	70	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 6.5 m barrier would meet the minimum noise benefit requirements for wheel rail noise, and would also meet the overall noise goals at 9 out of 10 triggered residences. A barrier up to 7 m high would be required to meet the overall noise goals at all 16 triggered residences in the area; however, this barrier would not meet the minimum benefit requirement for overall noise. An 8 m high barrier would be required to achieve the minimum requirement of a 10 dB reduction in overall noise at one receiver. However, none of the barriers considered meet the overall cost-effectiveness requirements described in **Section 8.3**.

It is concluded that a noise barrier is not a reasonable mitigation measure in NCA05 Down.

8.8.8 Barrier Assessment NCA06 Up

NCA06 on the Up side has multiple levels of receivers triggered for consideration of mitigation in the vicinity of Beecroft Station. A conventional barrier in this area would need to avoid constraints including high voltage power, existing access ways, and the Beecroft Station underpass. A conventional barrier would need to tie in to the Copeland Road and Chapman Avenue road bridges. Construction of conventional barriers in this area may also require additional clearing of otherwise undisturbed sensitive vegetation. However, no specific conventional barrier height constraints have been identified. The barrier assessment for NCA05 Down is summarised in **Table 41**.

Table 41 Summary of Barrier Assessment for NCA06 Up

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Up Side Chainage 26+800km to 27+200km Barrier length 400m (conventional) or 360m (low-height)	Low-height barrier targeting wheel/rail sources only	Minimum	0.5m	Low-height barriers close to the tracks would achieve the minimum benefit requirement.
		Acoustic Optimum	1.0m	
	Conventional barrier targeting wheel/rail sources only	Minimum	1.5m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	3.0m	
	Conventional barrier targeting overall noise	Minimum	1.5m	Conventional barriers targeting overall noise are potentially reasonable and feasible (since the wheel/rail source dominates at this location). Subject to cost-effectiveness and consideration of adverse impacts and community opinion. Two acoustic optimum heights are considered at this location with similar cost-effectiveness.
		Target	>8m	
		Acoustic Optimum	3.0m, 5.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA06 Up, the analysis indicates that noise barriers targeting wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. This location is adjacent to the small radius curves, and the barriers considered have the potential to reduce overall noise by targeting the wheel/rail source. Three conventional barrier heights are proposed for further consideration in this area, along with low-height height barriers close to the tracks.

The costs and benefits of these barriers are summarised in **Table 42.**

Table 42 Barrier Costs and Benefits NCA06 Up

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
1.0m	$1.94M	295	n/a for low barrier	152	n/a	Yes
1.5m	$1.81M	120	113	66	62	No
3.0m	$2.11M	304	273	144	129	Yes
5.0m	$3.16M	416	402	132	127	Yes

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 1.5 m barrier would meet the minimum noise benefit requirements for both overall noise and wheel rail noise, but would not meet the overall noise goals at any triggered locations. It is not feasible to meet the overall noise goals at all triggered residences in the area as the barrier height required would be excessive (more than 8 m). A more cost-effective solution may be the acoustic optimum height for wheel rail noise of 3.0 m. A barrier height targeting overall noise of 5.0 m would also maximise cost-effectiveness. This final option would leave residual exceedances at 4 out of 19 triggered properties, but would maximise the cost-benefit ratio of a conventional barrier.

A low barrier close to the tracks would also be a cost-effective mitigation measure at this location by targeting wheel squeal, and would avoid the issues with conventional barriers which include station access, visual impacts and a requirement to clear otherwise undisturbed vegetation on the Up side near Beecroft Station. The low barrier option close to the tracks is the preferred option at this location as it is cost-effective while minimising the adverse impacts of conventional noise barriers. There would be some residual impacts due to the locomotive noise contribution; these are described in **Section 8.10**.

8.8.9 Barrier Assessment NCA07 Down

In NCA07 on the Down side, residential receivers are triggered for consideration of mitigation between the Arden Anglican School and Brecks Way. In this section, barriers would need to avoid rock bolts and soil nails, as well as drainage systems and retaining walls, but would not be height restricted by these constraints.

The assessment of barriers in NCA07 Down is divided into two sub catchments. Sub catchment A extends from Chapman Avenue to the end of the southern part of Wongala Crescent. The barrier in this area would be located on or near the corridor boundary. Sub catchment B extends north from this point, to the high point near Brecks Way. In this area the barrier footings would be located away from the corridor boundary, but avoiding the various engineering constraints within the rail corridor.

The barrier assessment for NCA07 Down Sub Catchment A is summarised in **Table 43**.

Table 43 Summary of Barrier Assessment for NCA07 Down Sub Catchment A

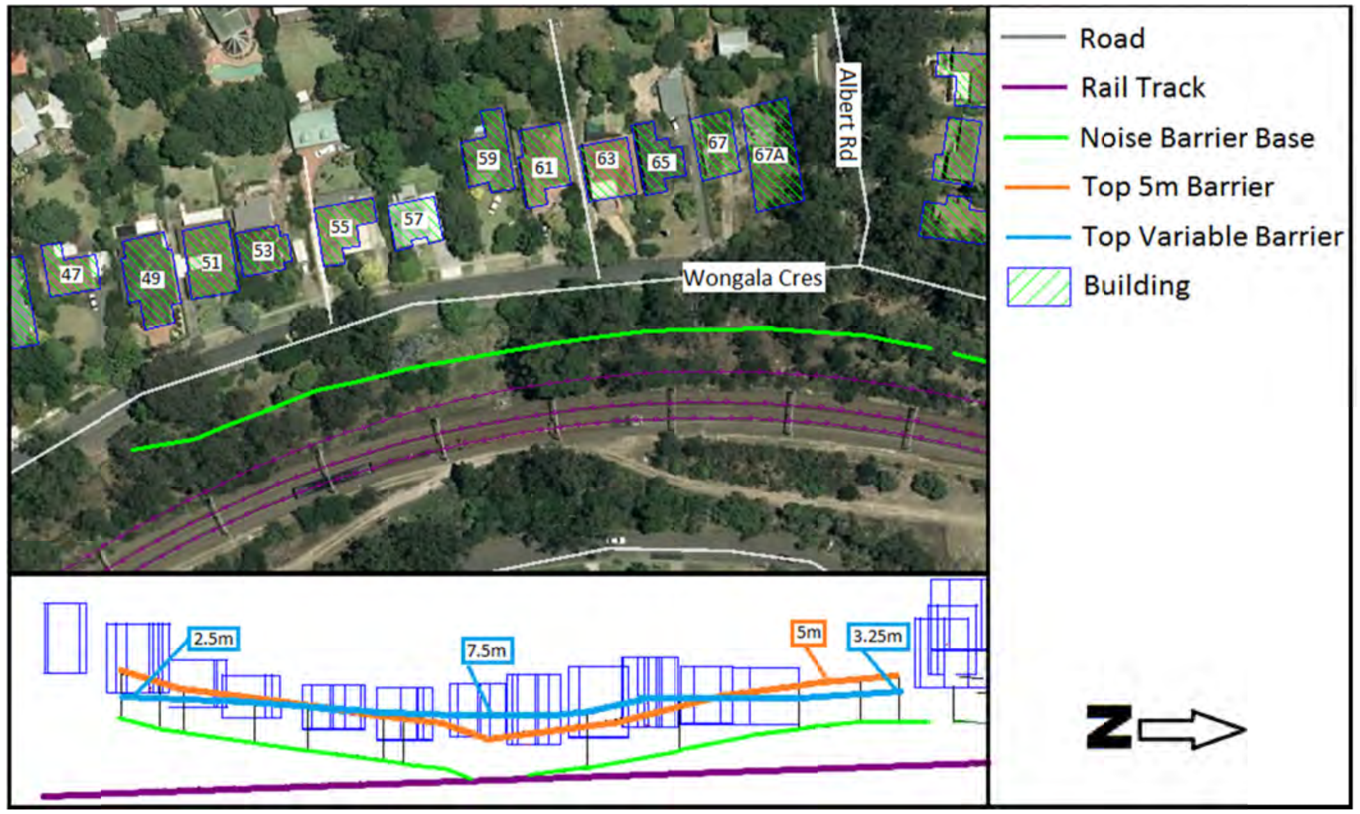
Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 27+400km to 27+640km Barrier length 240m	Low-height barrier targeting wheel/rail sources only	Minimum	Minimum benefit not reached	Low-height barriers close to the tracks would not achieve the minimum benefit requirement at any triggered receivers.
		Acoustic Optimum		
	Conventional barrier targeting wheel/rail sources only	Minimum	2.0m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	5.0m	
	Conventional barrier targeting overall noise	Minimum	2.5m	Conventional barriers targeting overall noise are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Target	>8.0m	
		Acoustic Optimum	5.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA07 Down Sub Catchment A, the analysis indicates that conventional noise barriers targeting either overall noise or wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. Low-height barriers close to the tracks would not meet the minimum benefit requirement in this area.

The terrain in NCA 07 Down A varies significantly in elevation along the length of the noise barrier alignment. In addition to noise barriers which remain at a constant height above the local ground level, an optimised noise barrier has been examined which takes into account changes in topography. In the area where there is a significant drop-off in topography (near 59 Wongala Crescent), the height of the proposed barrier has been increased from 5 m to up to 7.5 m. In areas where the track is located within a cutting, the height of the proposed barrier has been reduced from 5 m to a minimum of 2.5 m. In an overall sense, the total surface area of the noise barrier remains unchanged, but provides greater equity in the overall noise levels achieved at sensitive receivers within the noise catchment. Details of the proposed variable height barrier are shown in Figure 36 below.

Figure 36 Details of proposed variable height barrier – NCA 07 Sub Catchment A



Four potential conventional barriers are proposed for further consideration. The costs and benefits of these barriers are summarised in **Table 44.**

Table 44 Barrier Costs and Benefits NCA07 Down Sub Catchment A

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
2.0m	$1.09M	115	107	105	98	Yes
2.5m	$1.18M	163	148	139	126	Yes
5.0m	$1.89M	372	364	197	192	Yes
Variable	$1.89M	372	367	197	194	Yes

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M. Variable height barrier has an average height of 5.0m.

A 2.0 m barrier would meet the minimum noise benefit requirements for wheel rail noise. A 2.5 m barrier would also meet the minimum benefit requirement for overall noise, but neither of these barriers would meet the overall noise goals at any triggered residences. A variable height barrier with an average height of 5 m would be the acoustic optimum considering both wheel rail noise and overall noise, and would meet the overall noise goals at 7 out of 13 triggered residences. Meeting the target levels at all triggered receiver locations is not possible at this location as the barrier height required would be excessive.

Table 45 Summary of Barrier Assessment for NCA07 Down Sub Catchment B

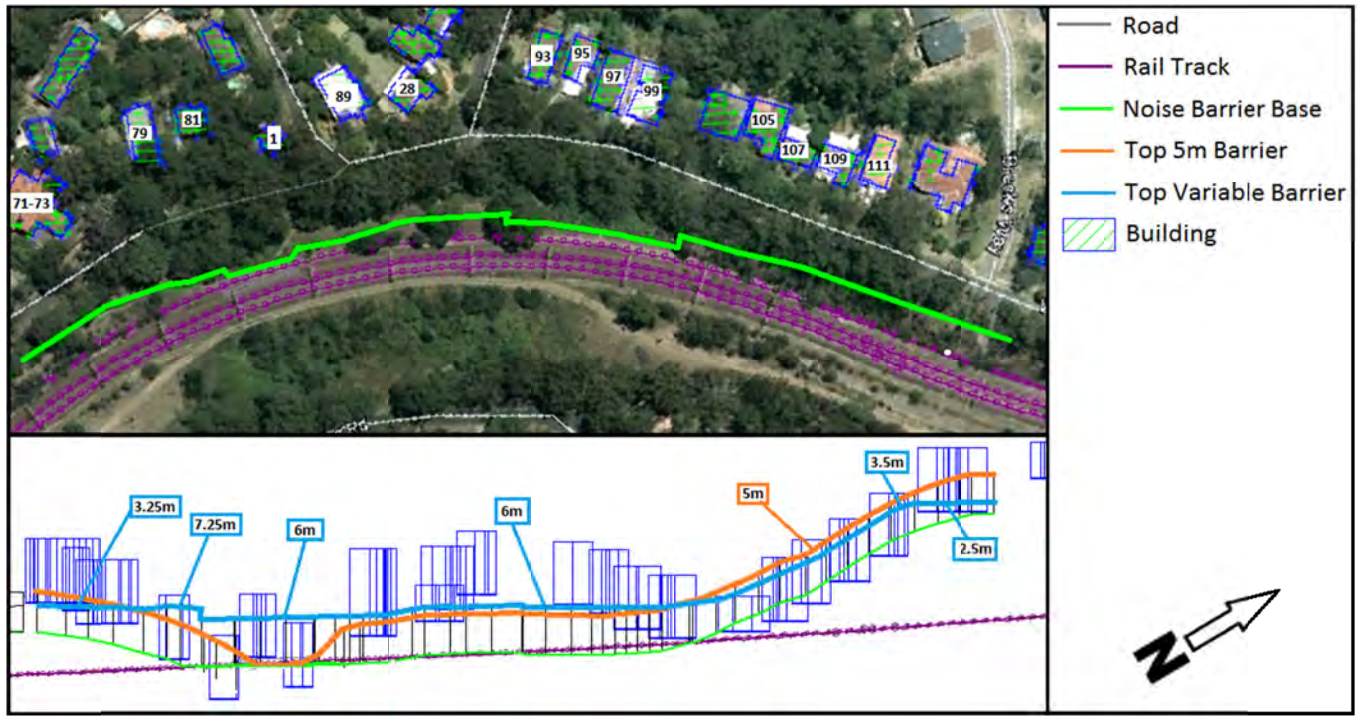
Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 27+640km to 28+000km Barrier length 360m	Low-height barrier targeting wheel/rail sources only	Minimum	1m	Low-height barriers close to the track are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	1m	
	Conventional barrier targeting wheel/rail sources only	Minimum	2.5m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	5.0m	
	Conventional barrier targeting overall noise	Minimum	2.5m	Conventional barriers targeting overall noise are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Target	>8.0m	
		Acoustic Optimum	7.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA07 Down Sub catchment B, the analysis indicates that noise barriers targeting either overall noise or wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided.

Similarly to NCA 07 Down A, the terrain in NCA 07 Down B varies significantly in elevation along the length of the noise barrier alignment. In addition to noise barriers which remain at a constant height above the local ground level, an optimised noise barrier has been examined which takes into account changes in topography. In the area where there is a significant drop-off in topography (near Sherwood Close), the height of the proposed barrier has been increased from 5 m to up to 7.25 m. In areas where the track is located within a cutting, the height of the proposed barrier has been reduced from 5 m to a minimum of 2.5 m. In an overall sense, the total surface area of the noise barrier remains unchanged, but provides greater equity in the overall noise levels achieved at sensitive receivers within the noise catchment. Furthermore the proposed base level of the barrier in the vicinity of Byles Creek (near 81 Wongala Crescent) has been raised significantly in recognition that this barrier would be founded near the top of the rail embankment, rather than part way down the embankment. Details of the proposed variable height barrier are shown in Figure 37 below.

Figure 37 Details of proposed variable height barrier – NCA 07 Sub Catchment B



Three potential constant height conventional barriers are proposed for further consideration. In addition, one variable height conventional barrier and one low-height barrier are also considered. The costs and benefits of these barriers are summarised in **Table 46.**

Table 46 Barrier Costs and Benefits NCA07 Down Sub Catchment B

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
1.0m	$1.94M	132	n/a for low barriers	68	n/a	No
2.5m	$1.77M	155	136	88	77	No
5.0m	$2.84M	421	364	148	128	Yes
7.0m	$4.25M	583	577	137	136	Yes
Variable	$2.84M	517	510	182	179	Yes

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A low barrier close to the tracks or a 2.5 m conventional barrier would meet the minimum noise benefit requirements for both overall noise and wheel rail noise, but would not meet the overall noise goals at any triggered residences. Meeting the overall target levels at all triggered receiver locations is not possible at this location as the barrier height required would be excessive. A variable height barrier with an average height of 5 m would be the acoustic optimum height to target wheel/rail noise, and would meet the overall noise goals at 11 triggered residences.

It is concluded that noise barriers are a reasonable and feasible mitigation measure in NCA07 Down. A variable height barrier with an average height of 5 m is preferred at this location as it has the highest cost effectiveness of the examined options. The variable height barrier with a maximum height of 7.25 m also still mitigates noise levels in the area where a barrier of a consistent 7.0 m height would provide the greatest noise benefit.

8.8.10 Barrier Assessment NCA07 Up

In NCA07 on the up side the properties triggered for consideration of mitigation are not closely spaced in groups of three or more. Noise barriers are therefore not considered in NCA07 on the Up side, except at the northern end of this catchment where three properties are triggered next to additional properties in NCA08. A noise barrier targeting these closely spaced properties is considered in **Section 8.8.12** along with the receivers in NCA08 on the Up side.

8.8.11 Barrier Assessment NCA08 Down

NCA08 on the Down side has two areas of residential receivers. The first is the apartment building at 5 City View Road, with multiple levels of receivers triggered for consideration of mitigation. The second area is the group of residential receivers above shops near Pennant Hills Station.

Immediately opposite 5 City View Road, a 100 m long barrier could be constructed without height constraints. At the Boundary Road end of this barrier, a 2 m high section could be added on top of the retaining wall. Further north of the apartment building a barrier would not be feasible either inside or on the rail corridor boundary due to conflicts with ground stabilisation rock bolts and soil nails.

A noise barrier is also not feasible between the Pennant Hills Road Bridge and the Pennant Hills Station due to soil nails and rock bolts, and limited space in the rail corridor. Therefore, a single noise barrier is considered in NCA08, adjacent to the apartment building at 5 City View Road. The barrier assessment for NCA08 Down is summarised in **Table 47**.

Table 47 Summary of Barrier Assessment for NCA08 Down

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Chainage 28+140km to 28+300km Barrier length 160m	Low-height barrier targeting wheel/rail sources only	Minimum Acoustic Optimum	Minimum benefit not reached	Low-height barriers close to the tracks would not achieve the minimum benefit requirement at any triggered receivers.
	Conventional barrier targeting wheel/rail sources only	Minimum	3.5m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	4.5m	
	Conventional barrier targeting overall noise	Minimum Target Acoustic Optimum	Minimum benefit not reached	Conventional barriers targeting overall noise would not achieve the minimum benefit requirement at any triggered receivers.

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA08 Down, the analysis indicates that noise barriers targeting wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. Two potential conventional barriers are proposed for further consideration.

The costs and benefits of these barriers are summarised in **Table 48.**

Table 48 Barrier Costs and Benefits NCA08 Down

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
3.5m +2.0m	$993K	27	8	27	8	No
4.5m +2.0m	$1.20M	43	16	36	14	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

A 3.5 m barrier would meet the minimum noise benefit requirements for wheel rail noise for at least one apartment, but would not meet the overall noise goals at any triggered apartments. Meeting the overall target levels at all triggered receiver locations is not possible at this location as the barrier height required would be excessive. A barrier up to 4.5 m high would be the acoustic optimum height to target wheel/rail noise, but again this barrier would not meet the overall noise goals at any triggered apartments. None of the barriers considered at this location are cost-effective.

It is concluded that noise barriers are not a reasonable and feasible mitigation measure in NCA08 Down.

8.8.12 Barrier Assessment NCA08 Up

The consideration of barriers in NCA08 on the Up side is extended to include the triggered residences at the northern end of NCA07. In this area (extending from Clement Close and Azalea Grove to the Pennant Hills Road bridge), a conventional barrier could be located outside the existing access road, and avoiding combined services routes. No constraints on conventional barrier height have been identified. The barrier assessment for this location is summarised in **Table 49**.

Table 49 Summary of Barrier Assessment for NCA07 and NCA08 Up

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Up Side Chainage 28+050km to 28+400km Barrier length 350m	Low-height barrier targeting wheel/rail sources only	Minimum	0.5m	Low-height barriers close to the tracks would achieve the minimum benefit requirement for wheel rail noise.
		Acoustic Optimum	1.0m	
	Conventional barrier targeting wheel/rail sources only	Minimum	1.5m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	2.5m	
	Conventional barrier targeting overall noise	Minimum	3.0m	Conventional barriers targeting overall noise are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Target	5.0m	
		Acoustic Optimum	5.0m	

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA07 and NCA08 Up, the analysis indicates that noise barriers targeting wheel rail noise or overall noise are potentially reasonable and feasible on the basis of the acoustic benefit provided. Four potential conventional barriers are proposed for further consideration, along with low-height barriers. The costs and benefits of these barriers are summarised in **Table 50.**

Table 50 Barrier Costs and Benefits NCA07 and NCA08 Up

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
1.0m	$1.88M	193	n/a for low barriers	103	n/a	Yes
1.5m	$1.59M	151	85	95	54	No
2.5m	$1.72M	203	171	118	100	Yes
3.0m	$1.85M	215	220	116	119	Yes
5.0m	$2.76M	225	477	81	173	Yes

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

Low-height barriers close to the track would meet the minimum noise benefit requirements for wheel rail noise, but would not meet the overall noise goals at any triggered residences as maximum noise levels due to locomotives would remain above the noise goals.

A 1.5 m barrier would meet the minimum noise benefit requirements for wheel rail noise for at least one residence, but would not meet the overall noise goals at any triggered apartments. Meeting the overall target levels at all triggered receiver locations would require a 5 m barrier, this would be the acoustic optimum height for overall noise. A barrier up to 3.0 m high would be the acoustic optimum height to target wheel/rail noise in isolation, but would only meet the overall noise goals at 1 triggered residence.

It is concluded that noise barriers are a reasonable and feasible mitigation measure in NCA08 Up, extending into NCA07 Up. The recommended height is 5.0 m throughout this catchment to maximise overall cost-effectiveness by targeting overall noise.

A low height barrier would also be reasonable and feasible in this location, targeting wheel/rail noise only. A low height barrier is an alternative option, which could be proposed in the event that the community considers the adverse impacts of the recommended conventional barrier to be unacceptable.

8.8.13 Barrier Assessment NCA09 and NCA10 Down

The consideration of barriers in NCA09 and NCA10 on the Down side is combined, as the NCA boundaries do not correspond to the distinct geometries and receiver groups in this area. With regard to the first group of receivers, consideration of mitigation is triggered at two residential properties south of Shields Lane, and the Pennant Hills Library. These properties are not closely grouped. Furthermore, the review of engineering constraints indicates that a barrier is not viable south of Shields Lane due to soil nail / rock bolt extents and limited space within or on the corridor boundary.

To the north of Shields Lane, a noise barrier of up to 2m could be added to the retaining wall supporting the new track, extending to the rail corridor access point near Fulbourne Avenue. Between this point and the rail corridor boundary a noise barrier is not feasible as rock bolts and soil nails extend beyond the rail corridor boundary. It is not possible to construct barrier foundations through these areas of ground stabilisation.

These constraints restrict the potential for a conventional barrier to the section between Shields Lane and Fulbourne Avenue, which includes 5 properties triggered for consideration of mitigation. A low-height barrier close to the tracks would potentially be feasible over a greater length. The barrier assessment for this location is summarised in **Table 51**.

Table 51 Summary of Barrier Assessment for NCA09 and NCA10 Down

Barrier Location and Length (m)	Description	Identified Height Options	Height for Option (m)	Comments
Down Side Low Barrier Chainage 28+800km to 29+250km (450m)	Low-height barrier targeting wheel/rail sources only	Minimum	0.5m	Low-height barriers close to the tracks would achieve the minimum benefit requirement for wheel rail noise.
		Acoustic Optimum	1.0m	
Conventional Barrier Chainage 28+800km to 29+100km (300m)	Conventional barrier targeting wheel/rail sources only	Minimum	1.0m	Conventional barriers targeting the wheel rail source alone are potentially reasonable and feasible, subject to cost-effectiveness and consideration of adverse impacts and community opinion.
		Acoustic Optimum	1.5m	
	Conventional barrier targeting overall noise	Minimum	Minimum benefit not reached	Conventional barriers targeting overall noise would not achieve the minimum benefit requirement at any triggered receivers, due to the constraint on barrier height at this location.
		Target		
		Acoustic Optimum		

Note: Acoustic optimum height is the height above the minimum height that maximises cost-effectiveness
For low-height barriers close to the track, the height of the barrier is referenced to the top of rail. For conventional barriers, the height of the barrier is referenced to the local ground level.

In NCA09 and NCA10 Down, engineering constraints limit the potential for barriers to be built, and targeting overall noise including locomotive engine and exhaust sources is not feasible. The analysis indicates that noise barriers targeting wheel rail noise in isolation are potentially reasonable and feasible on the basis of the acoustic benefit provided. Two potential conventional barriers are proposed for further consideration, along with low-height barriers. The costs and benefits of these barriers are summarised in **Table 52.**

Table 52 Barrier Costs and Benefits NCA09 and NCA10 Down

Option	Cost Estimate	TNB wheel rail noise (dB)	TNB overall noise (dB)	dB per $1M for wheel/rail noise	dB per $1M for overall noise	Cost-effective?
1.0m	$2.42m	48	n/a for low barrier	20	n/a	No
1.0m	$1.36M	40	7	29	5	No
1.5m	$1.36M	46	9	34	7	No

Note: TNB includes all buildings behind the barrier, not just triggered properties. Each level of multi-storey buildings is considered separately. The cost-effectiveness requirement is 100 dB per $1M.

Low-height barriers close to the track, or a similar height conventional barrier on top of the retaining wall would meet the minimum noise benefit requirements for wheel rail noise, but would not meet the overall noise goals at any triggered residences. The benefit provided by these options would be similar, but there is potential for low-height barriers close to the track to provide a benefit to a larger number of triggered residences than the conventional barrier on top of the retaining wall. For this reason, a low-height barrier close to the track would be preferred. However, none of the barriers considered meet the overall cost-effectiveness requirements.

It is concluded that noise barriers are not a reasonable and feasible mitigation measure in NCA09 and NCA10 Down.

8.9 Recommended Noise Barriers

An assessment of the feasibility and reasonability of noise barriers throughout the project area has been undertaken. This assessment has identified the following noise barriers as being feasible and reasonable at some locations, subject to community and stakeholder feedback on this draft ONVR.

In recommending these barriers for construction, it is noted that residents often have unrealistic expectations of the effectiveness of noise barriers. Noise barriers do not eliminate noise from the rail corridor. Noise barriers would be expected to reduce the volume of noise from the rail corridor, but noise from passing freight trains would remain clearly audible. The low frequency characteristic of some freight locomotives will diffract around even high barriers. This means that although a barrier may result in compliance with the A-weighted noise goals, some annoying characteristics of rail noise will remain noticeable.

Residents may also possibly be affected by negative aspects of barriers such as:

- Loss of open aspect and breezes
- Potential for vandalism and need for graffiti removal
- Reduction in visual amenity of urban landscape
- Loss of views and vistas
- The need for additional vegetation clearing to construct conventional barriers

The use of low-height barriers close to the tracks has been proposed in NCA06 at Beecroft to alleviate these negative aspects, but in many locations throughout the project area low-height barriers would not be effective and conventional barriers are the only feasible path control mitigation option.

The recommended noise barriers are:

- NCA06 on the Up side. Low barrier close to tracks, 1m above top of rail from chainage 26.8 to 27.2km (360m).
- NCA07 on the Down Side. Conventional barrier between 2.5m and 7.5m high (average 5m high) (above local ground level) from chainage 27.4 to 28.0km (600m).
- NCA 07/08 on the Up Side. Conventional barrier 5m high (above local ground level) from chainage 28.05 to 28.4km (350m).

These recommended barriers have been determined to be reasonable and feasible, taking account of:

- Noise-mitigation benefits - noise reduction provided, number of people protected
- Cost of mitigation - total cost and cost variation with level of benefit provided
- Track maintenance and access requirements
- Noise levels for affected land uses - existing and future levels, expected changes in noise levels

Feedback is sought from directly affected property owners on the recommended noise barriers (see **Section 10**).

In NCA 07/08 on the Up Side, a low height barrier targeting only wheel/rail noise on the Up Main is a possible alternative to the recommended conventional barrier in the event that the adverse impacts of the conventional barrier are not considered to be acceptable to the community.

8.10 Residual Noise Impacts With Lubrication and Recommended Barriers

The predicted noise levels with the lubrication system and with the recommended acoustic barriers are summarised in **Appendix F** in tabular form and as noise contours in **Appendix G**. **Appendix F** also indicates the benefit achieved at each location due to the lubrication and recommended barriers.

8.11 Other Mitigation Measures with Subjective Benefits

For the ETTT project, the relevant guidelines require that noise levels be presented and described only in terms of the L_{Aeq} and L_{Amax} noise descriptors. This means that the assessment prioritises noise mitigation measures which have a significant influence on the overall L_{Aeq} or L_{Amax} noise levels. Consequently mitigation is often limited to the construction of noise barriers, which have a clearly predictable and measureable benefit in terms of these parameters, but often do not completely eliminate the noise characteristic that causes the most annoyance.

The overall L_{Aeq} or L_{Amax} parameters do not always correlate with the annoyance experienced by some people living in proximity to a freight railway corridor. Other factors such as the number of events above a certain noise level, or the number of events with annoying characteristics such as low frequency noise, curve squeal or wagons with wheel defects contribute to the perceived impact on people. For this reason, noise mitigation measures which reduce the number or level of particularly annoying events will also be beneficial, even if they are not quantifiable in a noise model or have only a marginal effect on the L_{Aeq} or L_{Amax} parameters. Consideration of other mitigation measures with subjective benefits is also required by CoA C4.

In most cases the following opportunities would need to be implemented over the longer term, they are not in the control of the ETTT project. However, these measures have significant potential to reduce perceived impacts at all locations (not just locations with exceedances of the trigger levels, in the ETTT project area).

8.11.1 Swing Nose Crossings

Turnouts, crossovers and diamond crossings can be significant sources of impulsive noise, and are sometimes audible (although not necessarily intrusive) over a large distance. The principal source of the noise is the discontinuity at the crossing (also known as the "frog"). Impulsive noise from the frog can be largely eliminated by the use of swing-nose crossings (see **Figure 38**).

The use of swing nose crossings in place of conventional crossings involves signalling changes, and changes to maintenance requirements.

Figure 38 Conventional and Swing Noise Crossings

A. Conventional Crossing (ref Esveld)

B. Swing Nose Crossing (ref Esveld)

The reduction in the impulsiveness of the noise (resulting from the removal of the discontinuity) is a benefit in its own right. The reduction in L_{Aeq} levels would be typically less than 1 dB at 30 m, especially at locations where freight locomotive noise contributes to the L_{Aeq}. The overall L_{Amax} level during a passby would also not change significantly if it is controlled by other sources, such as locomotive noise.

From a subjective viewpoint, the noise associated with conventional turnouts and crossings is clearly perceptible and the installation of swing nose crossings in place of conventional crossings would be viewed as beneficial from both a subjective and quantitative viewpoint. To achieve a benefit, a swing nose crossing must be installed and maintained correctly.

The ETTT project is introducing new turnouts at either end of the study area.

A concept design is underway to determine the feasibility of installing swing-nose turnouts instead of conventional turnouts at Epping and/or Thornleigh. This will include consideration of the additional maintenance liability attached to such infrastructure. The potential to utilise wheel / rail profile matching through precision grinding will also be investigated.

8.11.2 Research into Curve Squeal Mitigation by Track Design Measures

A number of track design measures were rated highly in the consideration of alternative mitigation measures to target curve squeal. In particular, use of composite sleepers was identified as having potential to result in a reduction in curve squeal. Rail grinding to optimise the profile is another aspect of track design that has the potential to maximise the effectiveness of track lubrication. Gauge widening could also be investigated.

The phenomenon of curve squeal is not well understood, and research in the field is ongoing. There is published research that curve squeal is worsened by replacing wooden sleepers with concrete. It is hypothesised that one reason for this may be a change in the lateral stiffness / receptance of the track. If this is the case, there is a potential for composite sleepers or alternative sleeper designs to have a benefit in reducing curve squeal. With regard to rail grinding, the lubrication trials undertaken at Beecroft have indicated that optimising the rail profile is key to the effectiveness of the lubricators.

The research required to investigate these factors and their impact on the root causes of curve squeal could take several years, and would require a combination of theoretical investigations and experimental trials.

Transport for NSW recognises that noise and emissions from freight trains is an issue of significant concern for the community. In response to community concerns over the impact that freight rail noise has on the community, Transport for NSW is working with the Department of Planning and Environment, the EPA, and NSW Health to deliver a comprehensive approach to managing its impacts.

A Strategic Noise Action Plan was developed in 2012 to address and manage freight rail noise and is a key task in the NSW Freight and Ports Strategy. A primary objective of the Plan is to reduce noise at source, in particular curve noise. Some of the measures Transport for NSW and its partners are implementing to reduce curve noise include:

- Installing electronic gauge face lubricators on curves that are noise hot spots. Lubrication systems have been installed at seven sites between Epping and Newcastle.
- Installing noise monitoring equipment at sites with upgraded lubrication systems.
- Providing operators with information on the performance of their rolling stock on curves, including data on angle of attack and noise. Assisting operators to analyse this data to identify wagon classes with poor performance and to identify measures to improve performance.
- Continuing research on the effect of all factors on curve noise, including wagon design and maintenance; lubrication systems; track system design; track and wheel profiles and rail grinding.
- Disseminating the results of research and trials through presentations, technical papers and face-to-face meetings with industry.

8.11.3 Measures Targeting High-Noise Locomotives

A fact sheet prepared by the Australian Railway Association[5] states that the average age of Australia's freight locomotives is around 21 years. In the USA it is eight years, and in the UK it is 11.5 years. The age and design of some locomotives in the fleet is one factor in the variation in maximum noise levels between locomotives. This variation can be 20 dB or more between the quietest and noisiest examples operating through the ETTT project area. Such large variations are very clearly noticeable and can cause significant disturbance, particularly during night-time periods.

Some locomotives also produce particularly high levels of low-frequency noise. The human ear is less sensitive to low frequency noise than noise at higher frequencies, and low frequency noise emissions are not captured in the A-weighted parameters that the NSW rail noise guidelines use to assess the noise impact of infrastructure projects. However, this low frequency noise can be highly annoying, and can give rise to vibration in houses that causes (for example) windows to rattle as the locomotives pass. Occupants can sometimes confuse this structural vibration response to airborne noise with ground-borne vibration, although it is not transmitted through the ground.

High freight noise levels are often caused by a relatively small number of locomotives, which pass through the project area over and over again. A large benefit in perceived noise impacts would be achieved by reducing noise levels from the few noisiest locomotives.

There are currently no national or state-based standards which limit noise emissions from trains. Whilst criteria are applicable in NSW for new and upgraded locomotives to be introduced to the network, these are not applicable to locomotives that commenced operating on the network prior to the introduction of Environment Protection Licence (EPL) limits.

There are significant challenges associated with limiting noise emissions from freight operators in a competitive environment void of enforceable noise regulations. Since freight services through the ETTT project area are supplied by different operators, ownership and availability of quieter locomotives is likely to be an issue for some operators.

In order to achieve the proposed growth freight traffic across the ETTT project area, a large number of additional trains will be required. The noise emissions from new or upgraded/refurbished locomotives are required to comply with the relevant EPL requirements. This means that the noise due to additional freight movements facilitated by the project would be at the lower end of the range of existing freight locomotive noise emissions. It is anticipated that older locomotives would be phased out over time, and replaced with quieter locomotives, providing a subjective benefit. However, this benefit may not be noticeable if it occurs over a long period.

Accelerating the upgrading or rate of retirement of noisy locomotives is not within the control of the ETTT project, and would require action from the regulator (the EPA).

Regulatory options to limit noise emissions from locomotives include strategies such as differential track charge incentives to provide a financial incentive to minimise noise emissions, or restrictions on track access times for locomotives that do not comply with designated noise levels. Restrictions would be introduced gradually in phases to give operators time to adapt.

In order to facilitate a reduction in the number of high-noise locomotives, the ETTT project is committed to the following actions:

- Preparation of a paper documenting the potential benefit that would be achieved by targeting high noise locomotives (considering both subjective factors and quantitative measures). This paper would summarise existing measurement data. The paper would be publicly available, with the aim of informing the community and government of the benefit in targeting high noise locomotives.

[5] Australian Railway Association – A Greener Future Leveraging on rail's green credentials –www.ara.net.au/fact-sheets

Transport for NSW is also, as part of its Strategic Noise Action Plan, developing strategies for the management of locomotive noise.

8.11.4 Measures Targeting High Noise Wagons (Wheel Flats and Squeal)

For similar train types, the noise associated with train passbys is reasonably consistent, with only minor variations in noise character and level. However, there are a number of conditions which can give rise to larger variations in noise levels or unusual characteristics. From a community viewpoint, these variable noise emissions may be more intrusive, may be viewed as unnecessary and are likely to generate an increase awareness and negative response to the noise emissions.

There are a number of defects which can result in increased noise emission or unusual characteristics. The most common defect type related to freight wagons is wheel flats. Other defects can include misaligned axles/bogies or sticking brakes which can generate a high-pitched squeal noise even away from small radius curves. Around curves, there is evidence that misaligned axles/bogies give rise to higher squeal levels than would otherwise be the case. Squeal from these wagons is not eliminated by track lubrication.

For wagons with audible wheel defects, L_{Amax} noise levels can be 10 dB to 15 dB higher than for adjacent wagons without audible wheel defects. However, at the relatively low average speeds observed in the ETTT project area due to the steep grades, these wheel flats are not likely to influence the overall L_{Aeq} or L_{Amax} noise level parameters used in the assessment of noise in accordance with IGANRIP. This is because the maximum noise levels associated with diesel locomotives are higher than the freight wagon maximum noise levels, even if wheel defects are present.

Nevertheless, these sources represent an important part of the railway noise environment, and may be responsible for the increased annoyance experienced by some people living in proximity to a freight railway corridor.

From a subjective viewpoint, the presence of wheel defects on freight wagons is clearly perceptible. If a wheel maintenance program was introduced which halved the number of audible wheel defects on freight wagons, it is likely that the overall reduction in L_{Aeq} and average L_{Amax} noise levels would be small (probably less than 1 dB). From a community perception viewpoint, however, it is likely that the benefit of this change would be much greater than indicated by the quantitative noise levels.

The following mitigation measures have the potential to target high noise wagons:

- **Identify wagons with wheel flats and enhance maintenance** –This option involves identifying wheel defects and removing them from service or scheduling them for maintenance within defined time periods.
- **Identify wagons with misaligned axles/bogies and enhance maintenance** – This option involves identifying problem wagons and removing them from service or scheduling them for maintenance within defined time periods.

Both these options would require a permanent noise monitoring station to identify problem wagons. An enforceable regulatory strategy is also necessary to either require or encourage operators to rectify problem wagons.

To facilitate the introduction of these mitigation measures in the longer term, the ETTT project is committed to:

- Upgrading the prototype noise monitoring station (installed by FRD at Beecroft) to become a permanent noise monitoring station for ongoing use by FRD in targeting high noise wagons (see **Section 14**).

Also refer to details of Transport for NSW's Strategic Noise Action Plan described in **Section 8.11.2** above.

8.12 Proposed Individual Property Treatments

Property treatments are proposed only at locations that are triggered by the project, without the addition of the safety factor, where noise barriers are not a reasonable and feasible mitigation measure. Treatments of locations that are triggered only with the addition of the safety factor are not proposed at this stage. There are an additional 75 properties predicted to exceed trigger levels once the safety factor is included in the modelling. Of these 75 properties, approximately half (37) will be treated by the proposed noise barriers, leaving 38 properties triggered by the safety factor which are not proposed to be eligible for property treatment at this stage.

Construction of noise barriers requires a civil construction team to be in place and has significant mobilisation and design costs involved. Therefore in areas where noise barriers are cost effective it has been decided to take a conservative approach and extend the barriers to provide mitigation to properties that exceed trigger levels with and without the safety factor. Property treatments require much less design and mobilisation and so can be carried out at any time in the future on a case by case basis if the operational monitoring indicates noise levels exceed the modelled levels.

Property treatments are proposed for investigation at the 40 locations identified in Table 53. Offers of property treatments are subject to an inspection of each affected property to confirm that treatments would be of benefit, and to determine the recommended treatment for each property on a case by case basis.

Although the ETTT Project's CoA do not require this, an assessment was made of which properties are predicted to be 'acutely affected' before and after the project. 'Acutely affected' refers to those properties at which LAeq noise levels (ie average noise levels) are predicted to exceed guideline target levels by 5dB(A) or more. That is, regardless of any increase due to the project, the noise levels are predicted to be 5dB(A) higher than IGANRIP / RING target levels. It was found that without the ETTT Project, in 2016, 50 properties would be acutely affected. As a result of the project, in 2026 (10 years after commencement of operation), this is forecast to reduce to 35 properties (due to ETTT installing noise barriers). Without the proposed ETTT noise barriers, this figure would have increased to 80 properties. These figures are based on an assessment that does not include a safety factor on train numbers.

Transport for NSW has a program of works underway to reduce existing rail noise. The program of works includes:

- Working with freight operators to improve the design and maintenance of their rolling stock to reduce wheel squeal and locomotive noise;
- Installing modern electronic lubricators throughout the Beecroft and Cheltenham area;
- Using dedicated maintenance teams to ensure the lubricators are always fully operational; and
- Working with Sydney Trains to improve track maintenance practices.

Table 53 Locations of Property Treatments

NCA	Side	Number of Sensitive Locations Triggered[1]				Proposed property treatments	
		Residential		Other Sensitive			
		Base Case	Safety Factor	Base Case	Safety Factor		
01	Down	0	1	0	1	n/a	
	Up	0	0	0	0	n/a	
02	Down	0	0	0	0	n/a	
	Up	0	2	0	0	n/a	
03	Down	13	21	0	0	17 Old Beecroft Rd 19 Old Beecroft Rd 21 Old Beecroft Rd 23 Old Beecroft Rd 25 Old Beecroft Rd 25A Old Beecroft Rd 29 Old Beecroft Rd	31 Old Beecroft Rd 33 Old Beecroft Rd 102 The Crescent 104 The Crescent 106 The Crescent 108 The Crescent
	Up	0	0	0	0	n/a	
04	Down	8	20	0	0	16 The Crescent 18 The Crescent 20 The Crescent 22 The Crescent	24 The Crescent 26 The Crescent 54 The Crescent 56 The Crescent
	Up	0	2	0	0	n/a	
05	Down	0	10	1	1	Scout Hall	
	Up	0	1	0	0	n/a	
06	Down	0	0	0	0	n/a	
	Up	6	19	0	0	Low height noise barrier close to tracks recommended	
07	Down	8	26	0	0	5.0m average height conventional barrier recommended	
	Up	3	5	0	0	5.0m conventional barrier recommended	
08	Down	4	5	0	0	72 Yarrara Rd 74 Yarrara Rd 78 Yarrara Rd	94 Yarrara Rd (Residences above shops)
	Up	1	5	0	0	5.0m conventional barrier recommended	
09	Down	5	5	1	1	1-3 Stevens St 26 Yarrara Rd 28 Yarrara Rd	56 Yarrara Rd 58 Yarrara Rd 70 Yarrara Rd (Library)
	Up	0	0	0	0	n/a	
10	Down	6	7	3	3	2 Stevens St 1 Fulbourne Av (child care) 2 Yarrara Rd (church) 10 Yarrara Rd (church) 12 Yarrara Rd	14 Yarrara Rd 16 Yarrara Rd 18 Yarrara Rd 22 Yarrara Rd
	Up	0	0	0	0	n/a	

Note 1: The number of locations triggered counts addresses once only, in the event that more than one facade or level of the building is triggered. This number will be less than the number of individual properties triggered, for example where buildings contain multiple apartments.

9 SUMMARY OF NOISE MITIGATION MEASURES ADOPTED

The noise mitigation measures adopted are summarised in Table 54 below and in each of the following sections in terms of whether they are source control measures, path control measures or receiver control measures. Mitigation measures are also summarised in Table 54 by NCA. The locations of the adopted mitigation measures are also shown on the maps in **Part 1 of the ONVR document.**

Table 54 Summary of Location-Specific Project Mitigation Measures Adopted by Catchment

NCA	Side	Location Specific Project Mitigation Measures Adopted
01	Down	Investigation of swing nose crossing to reduce subjective impacts due to impulsive noise over turnout
	Up	n/a
02	Down	n/a
	Up	n/a
03	Down	Treatments to 13 properties triggered by project impacts
	Up	n/a
04	Down	Treatments to 8 properties triggered by project impacts
	Up	n/a
	Both	Lubricators have been installed on existing tracks and will also be used on the new track. Ongoing work into curve squeal noise minimisation is being undertaken by FRD, including investigation of track design measures and rolling stock measures.
05	Down	n/a
	Up	n/a
	Both	Lubricators have been installed on existing tracks and will also be used on the new track. Ongoing work into curve squeal noise minimisation is being undertaken by FRD, including investigation of track design measures and rolling stock measures.
06	Down	n/a
	Up	Low height noise barrier close to tracks recommended
	Both	Lubricators have been installed on existing tracks and will also be used on the new track. Ongoing work into curve squeal noise minimisation is being undertaken by FRD, including investigation of track design measures and rolling stock measures.
07	Down	Variable height conventional barrier with average height of 5.0m recommended
	Up	5.0m conventional barrier recommended at northern end of catchment.
	Both	Lubricators have been installed on existing tracks and will also be used on the new track. Ongoing work into curve squeal noise minimisation is being undertaken by FRD, including investigation of track design measures and rolling stock measures.
08	Down	Treatments to 4 properties triggered by project impacts
	Up	5.0m conventional barrier recommended
09	Down	Treatments to 6 properties triggered by project impacts (including library)
	Up	n/a
10	Down	Treatments to 9 properties triggered by project impacts (six residential, three other sensitive) Investigation of swing nose crossing to reduce subjective impacts due to impulsive noise over turnout
	Up	Investigation of swing nose crossing to reduce subjective impacts due to impulsive noise over turnout
Throughout	Both	ETTT to prepare a paper documenting potential benefits of targeting particularly noisy locomotives, to inform the community and government. Implementation of measures targeting noisy locomotives would need to be implemented by regulatory authorities.

9.1 Source Control Measures

A total of six lubrication units have been installed on the two existing tracks in the Pennant Hills – Beecroft - Cheltenham section. The performance of these "proof of concept" lubricators is being monitored on an ongoing basis through noise measurements at the prototype Beecroft Rail Noise Monitoring Station. Research to optimise and maintain the performance of the lubricators on the existing tracks is ongoing. Lubricators will also be installed and maintained on the new track.

The existing prototype noise monitoring station will be upgraded as part of the ETTT Project to become a permanent noise monitoring station for ongoing use in targeting high noise wagons. Results from this permanent noise monitoring station will be made publically available as per the requirements of the Source Noise Monitoring Plan defined in the CoA.

Swing Nose Crossings are being investigated for installation in the new rail turnouts at Epping and at Thornleigh. This type of crossing has subjective benefits in minimising impulsive noise as trains pass over crossing points.

Measures targeting high noise locomotives are outside the control of the project and would require regulatory changes. ETTT will however prepare a paper documenting the potential benefits of targeting high noise locomotives. This paper will be made publically available, to inform the community and government of the issue and possible benefits.

Outside of the project, ongoing work into curve squeal noise minimisation is being undertaken by Transport for NSW's Freight and Regional Development (FRD) Division, including investigation of track design measures and rolling stock measures.

9.2 Path Control Measures

Path control measures in the form of three lengths of noise barriers are proposed.

The recommended noise barriers are:

- NCA06 on the eastern side. Low barrier close to tracks, 1m above top of rail from kilometrage 26.82 to 27.18km (360m).
- NCA07 on the western side. Conventional barrier between 2.5m and 7.5m high (average 5m high) from kilometrage 27.40 to 28.00km (600m).
- NCA 07/08 on the eastern side. Conventional barrier 5m high from kilometrage 28.05 to 28.40km (350m).

These barriers are significantly longer than the extent that would have been required in order to mitigate noise if a safety factor on train numbers were not included. That is, only short lengths of noise barrier would have been required without the safety factor, however the proposed lengths have been significantly extended (where still shown to be cost effective) as a result of including a safety factor in the noise level predictions.

The proposed barriers are predicted to be effective in noticeably reducing noise levels due to freight trains, at residential properties behind the barriers. However in recommending these barriers for construction, it is worth noting that residents often have unrealistic expectations of the effectiveness of noise barriers. Noise barriers do not eliminate noise from the rail corridor. Noise barriers would be expected to reduce the volume of noise from the rail corridor, but noise from passing freight trains would remain clearly audible. The low frequency characteristic of some freight locomotives will diffract around even high barriers. This means that although a barrier may result in compliance with the A-weighted noise goals, some annoying characteristics of rail noise will remain noticeable.

Residents may also possibly be affected by negative aspects of barriers such as:

- The need for additional vegetation clearing to construct conventional barriers
- Loss of open aspect and breezes

- Potential for vandalism and need for graffiti removal
- Reduction in visual amenity of urban landscape
- Loss of views and vistas

The use of low-height barriers close to the tracks has been proposed on the eastern side of the corridor at Beecroft to alleviate these negative aspects. At this location low-height barriers will be effective given that the affected properties are generally lower than track level and the most significant noise issue is curve squeal. However use of low-height barriers does mean that there will be no reduction in locomotive exhaust noise.

In NCA 07/08 on the eastern side, a low height barrier targeting only wheel/rail noise on the Up Main is a possible alternative to the recommended 5m high conventional barrier in the event that the adverse impacts of the conventional barrier are not considered to be acceptable to the community.

A low-height barrier in lieu of the proposed 600m long, 2.5m to 7.5m high conventional noise barrier on the Down side would not be effective. For this noise barrier the only alternative would be property treatment for those properties predicted to exceed guideline trigger levels in the base-case assessment.

9.2.1 Additional vegetation clearance

The two proposed 5m high conventional noise barriers would result in additional vegetation clearance being required. The exact extent of clearance would be determined during design and construction planning, which have not yet commenced. However a preliminary estimate is that up to an additional 0.5 hectares of vegetation may potentially need to be cleared in order to construct the proposed noise barriers. This estimate is based on the assumption that construction space would be required on both sides of the new barrier, totalling approximately 6m in width. The noise barrier would likely be constructed along the rail corridor property boundary in order to maximise its acoustic effectiveness and minimise impacts to the stability of rock cuttings. This would mean much of the existing corridor screening vegetation in the vicinity of the proposed noise barriers would need to be removed. Minimisation of vegetation clearing will be prioritised in the detail design, including consideration of different panel types that would minimise construction footprint. In addition opportunities for landscaping will be developed and consulted on with visually affected properties.

The vegetation type to be cleared would be predominantly Blue Gum High Forest – an Ecologically Endangered Community (for more details refer to maps in the Flora and Fauna Management Plan, available on the Transport for NSW website). The CoA require the ecological value lost as a result of removal of this vegetation to be offset, which would be implemented in accordance with the approved biodiversity offset strategy. A source of offsets for the project, including Blue Gum High Forest, has already been identified and a procurement pathway established. This includes sufficient offset credits for the worst-case clearing estimate above.

Vegetation removal in order to construct the proposed low-height barrier between Copeland Road and Chapman Avenue would be minimal as this barrier would be immediately adjacent to the existing track.

9.2.2 Noise barrier urban design and landscaping

As described above, the two proposed lengths of 5m high conventional noise barrier are likely to have visual and vegetation impacts on nearby properties. These impacts are not described in the currently-approved Urban Design and Landscape Plan (UDLP), as the location and extent of noise barriers had not been determined at the time that document was published.

In order to describe and consult on the likely visual impacts of the proposed barriers, an information package will be provided to residents adjacent to and those likely to have a direct visual impact from the proposed barriers. The information package will include options for the look and feel of the proposed barriers including colour, texture and opportunities for vegetation planting. Feedback arising from the consultation process will be incorporated into an addendum to the UDLP for approval by DP&E. The addendum document will be published on the Transport for NSW website once approved.

9.3 Receiver Control Measures

Property treatments are proposed only at locations that are triggered by the project, without the addition of the safety factor, where noise barriers are not a reasonable and feasible mitigation measure. Treatments of locations that are triggered only with the addition of the safety factor are not proposed at this stage. Treatment of these properties would occur only if future compliance measurements indicate that freight train numbers are growing faster than anticipated.

There is a total of 54 properties predicted to exceed trigger levels without inclusion of the safety factor. Of these 54 properties, 14 will be treated by the proposed noise barriers, leaving 40 properties to be assessed for property treatment.

There are an additional 75 properties predicted to exceed trigger levels once the safety factor is included in the modelling. Of these 75 properties, approximately half (37) will be treated by the proposed noise barriers, leaving 38 properties triggered by the safety factor which are not proposed to be eligible for property treatment. For these 38 properties further assessment will be carried regarding their eligibility for property treatment, if post-operation validation measurements indicate that freight traffic is increasing at a faster rate than predicted in the NSFC business case.

Property treatments are proposed at the 40 locations identified in Table 53.

10 COMMUNITY CONSULTATION

The NSW Minister for Planning and Infrastructure approved the ETTT Project on 17 July 2013 under Part 5.1 of the Environmental Planning and Assessment Act 1979.

In accordance with the Epping to Thornleigh Third Track (ETTT) Project Environmental Impact Statement (EIS), Submissions Report, and Conditions of Approval (CoA), this Operational Noise and Vibration Review (ONVR) has been developed in consultation with the NSW Environmental Protection Agency and Hornsby Shire Council. The ONVR outlines the noise and vibration controls and measures that will be implemented for the ETTT Project. These are developed after identifying appropriate noise and vibration objectives, predicting impacts based on the final design, and assessing all feasible and reasonable mitigation measures.

The ONVR was released for public display and to obtain feedback from directly affected property owners on the noise and vibration mitigation measures proposed. Following closure of the consultation period the document was updated to address feedback received and submitted to DP&E for approval.

10.1 Early consultation

It is acknowledged that to date, strong community feedback has been received regarding existing and future operational noise and vibration concerns. During the EIS exhibition phase, a total of 426 submissions were received from the community with majority of the submissions mentioning noise including:

- existing noise concerns (341 submissions)
- questions in relation to the noise assessment methodology (309 submissions)
- operational noise mitigation (114 submissions)
- operational noise (62 submissions)
- construction noise (15 submissions)
- construction vibration (12 submissions)
- operational vibration (10 submissions)
- construction noise mitigation (8 submissions)
- existing vibration concerns (6 submissions)
- operational vibration mitigation (4 submissions)
- construction vibration mitigation (2 submissions)
- construction traffic noise (1 submission)

Responses to these concerns were provided in the Mach 2013 ETTT Project Submissions Report with a commitment to produce an ONVR following completion of detailed design.

Concerns about existing and future operational noise and vibration matters have also been strongly voiced by the community after the EIS exhibition, including being mentioned in 43 of the community submissions received during the Urban Design and Landscape Plan (UDLP) consultation in late 2013 (despite operational noise not being the subject of the UDLP). Some of the key issues raised by the community, and the ETTT Project's responses, are listed in the table below:

Table 55 Key community concerns

Issue	How the draft ONVR has responded
The mitigation measures proposed in the EIS are not adequate	Proposed mitigation measures have changed since the time of the EIS as a result of the detailed design being completed and the ONVR being prepared in line with the more stringent requirements included in the CoA, which require us to consider higher curve squeal levels and a safety factor on train numbers.
Noise barriers should be installed	Several noise barriers are now proposed in the ONVR. Two conventional noise barriers (5m high) and one low-height noise barrier (immediately adjacent to the existing track) are proposed to be installed as part of the ETTT Project. For details of these noise barriers please refer to **Section 8.9** and maps in **ONVR Part 1**.
Existing noise levels are unacceptable	Existing noise levels at some properties along the corridor already exceed IGANRIP and RING guidelines, due to existing rail traffic. However these guidelines only relate to new and upgraded infrastructure and are not intended to define noise mitigation for existing noise problems. The ETTT Project has only considered – and is only required to consider – mitigation measures for properties where guideline trigger levels are predicted to be exceeded due to the project, in line with the Conditions of Approval.
Request for independent third party audit of the ONVR process	The ONVR has been independently verified by a noise and vibration specialist, Renzo Tonin and Associates (under subcontract to MWH). This organisation has been approved by DP&E as per the ETTT Project's CoA requirements.
The IGANRIP and RING guidelines are not adequate	The ETTT Project's Conditions of Approval, which are set by the Minister for Planning, require compliance with these guidelines. The ETTT Project is not in a position to influence or change these guidelines.

10.2 May / June 2014 consultation

The ETTT Project's Conditions of Approval require the ONVR to include a consultation strategy to seek feedback from "directly affected" property owners on the noise and vibration mitigation measures.

The ETTT Project adopted an expanded approach to this and developed a draft ONVR document that was put on public exhibition from 26 May to 16 June 2014 to seek feedback from the community. regarding the proposed noise mitigation measures.

The objectives of this community consultation were to:

- Fulfil the requirements of the ETTT Project's Conditions of Approval regarding operational noise and vibration
- Explain how community concerns relating to operational noise and vibration have been addressed.
- Create community awareness of the ONVR requirements and process undertaken to develop it.
- Outline proposed mitigation measures.
- Give directly affected property owners an opportunity to provide feedback on the proposed mitigation measures before the ONVR is submitted to DP&E for approval
- Outline next steps in ONVR development, approval and implementation.

The table below outlines key engagement tools and activities that were implemented as part of the consultation process:

Table 56 Community engagement tools

Engagement tool/activity	Purpose and activity
Project community newsletter	The May 2014 project newsletter was distributed to approximately 5.700 properties living along the corridor and sent to the ETTT Project's e-mailing list. The newsletter: • Outlined the ETTT Project requirements regarding operational noise and vibration; • Explained the process undertaken to develop the ONVR; • Advised the ONVR is available for review • Summarises the proposed mitigation measures; • Invited residents to attend 2 drop in community information sessions to speak with our acoustic and vibration specialists and the project team. • Outline next steps in ONVR development, approval and implementation.
Letter and feedback form to properties deemed eligible for treatment	A specific letter was sent to the 131 properties identified as triggering the requirement for consideration of mitigation measures (with and without the safety factor). The letter outlined what the proposed mitigation measures are; explained the processes that will be followed to implement the ONVR; and asked for feedback on the proposed mitigation measures relevant to them via a feedback form. Also included with this letter was a CD copy of the ONVR document.
Community information sessions	Two staffed drop-in community information sessions were held on Saturday 30 May 20114 (at Beecroft Community Centre) and on 4 June 2014 (at Pennant Hills Community Centre) to provide opportunities for members of the community to discuss the ONVR with the project team and acoustic and vibration specialists and ask any questions or obtain clarification on the ONVR process. Approximately 120 residents attended the two community drop in information sessions. Items that were available at the information sessions included: • ONVR factsheets • Printed and CD copies of the ONVR • Various posters outlining the ONVR development process, mitigation measures, typical noise levels etc. • ONVR newsletter • Maps showing triggered properties and proposed mitigation measures
Unstaffed displays	Copies of the ONVR and the newsletters were available at Pennant Hills Library, Epping Library and the Cheltenham Recreation Club during the display period.
Advertisements	Advertisements were placed in the Northern District Times and the Upper North Shore Advocate advising the community that the ONVR is on public display and providing details about the community information crop in sessions.
Posters	Posters were placed at each railway station between Epping and Thornleigh advising the ONVR is on public display and providing details about the community information drop in sessions.
Website	Created a section on the project website titled 'Operational Noise and Vibration Review' where the ONVR document, ONVR newsletter , ONVR FAQ and various other ONVR information posters are available to view (http://www.transport.nsw.gov.au/projects-northern-sydney-freight-corridor-program/epping-thornleigh-third-track/current-works)
Community group briefings	ONVR-related briefings were provided to the Pennant Hills District Civic Trust and the Beecroft Cheltenham Civic Trust.
Councillor and MP briefings	ONVR-related briefings were provided to Hornsby Shire Councillors, the State Member for Epping and The Federal Member for Berowra.
Other briefings	ONVR-related briefings were also provided to NSW Department of Planning & Environment, the NSW Environment Protection Agency and Hornsby Council.

10.3 Feedback summary

During the public exhibition period, the ETTT Project team received 54 detailed written submissions; 31 from property owners who were sent a specific letter and another 23 from residents not identified in the ONVR as triggering consideration of mitigation (with or without the application of a safety factor).

Feedback received was about various items including:

- Conventional noise barrier – mainly support for – but with some opposition to – noise barrier construction; requests for more conventional noise barriers; and questions about noise barrier heights including requests for higher barriers.
- Low height barrier – General feedback on the proposed low height barrier; and questions on whether this will make a difference.
- Noise reflection from barriers – Concern about the potential for noise to reflect off walls and affect properties on the opposite side.
- Opposition to noise barrier – One submission strongly opposed the proposed noise barrier at Wongala Crescent, a number of others raised the issue of the noise barrier being a potential eyesore if not managed properly.
- Property treatment – Support for property treatment; requests that properties identified as triggering the requirements for consideration of mitigation only with the safety factor should be included; confusion as to how some properties could be offered treatment and neighbouring properties not; requests to have property reviewed for treatment; questions about what treatment can be installed for older style properties; comments that air conditioning homes is expensive and environmentally unsound.
- Freight noise – Concern about existing and increased freight rail noise, wheel squeal, and suggestions about rolling stock maintenance.
- Visual amenity – Some residents requesting barriers to screen the rail line and carriages; concern that a noise barrier will be ugly and attract graffiti; 'eyesore' was used to describe the noise barriers, need to have considerable thought around the landscaping and urban design of the area if the noise barriers are incorporated.
- Vegetation – Concern about losing vegetation, particularly EEC Blue Gum High Forest; requests for adequate replanting; screening of the walls such as native shrubs in front of the barrier to soften the visual appeal,
- Noise modelling and monitoring – Not accepting the explanation and methodology used; claims noise levels at individual properties are higher than is noted in the model; claims it should not be based on predicted impacts; comments that noise monitoring is flawed; requests for monitoring at individual properties; rejection of the applicability of the EPA guidelines used to determine trigger level exceedances.
- Safety factor – Comments around a lack of understanding why adjacent properties have different predictions and some trigger without while others trigger only with the safety factor.
- Health - Health concerns from noise and vibration; comments it is above WHO standards; impacts on sleep resulting in anxiety.
- Suggestion - Suggestions for further investigation of /wheel squeal; suggestions that barriers be included at key location where the new third track will end and merge into the single track as well as adjacent to Beecroft Station/ Village/ Playground,
- Other comments – consultation; property values; dust; construction noise; industry standards/legislation as well as feedback rejecting the report on the basis of methodology used, guidelines that are applicable and derived outcomes..

10.4 Consideration and adoption of feedback received

All of the feedback received from the community was considered by the project team. Wherever possible, suggestions were adopted including the following:

- Optimising the noise barrier height along Wongala Crescent to vary along its length to suit the varying topography. This has resulted in the noise wall now ranging in height, between 2.5m at the top of some cuttings and 7.5 metres at the low points of gullies. Previously the noise barrier was proposed as a consistent 5m height. For exact changes please refer to Section 8.8.9.
- Remodelling the earthworks arrangement just to the north of the M2 motorway. During excavation it was found that part of what was thought to be an existing sandstone formation was in fact a man-made earth mound. This earth mound has had to be lowered and made significantly less steep than a rock cutting during the widening for the third track. This shallower angle is needed in order to ensure the stability of the earth mound. Noise predictions for nearby properties – along the southern end of The Crescent, and behind Old Beecroft Road, at Cheltenham – have been updated accordingly to take into account the change in design. The original plan to maintain the height of the earth mound (originally assumed to be a rock cutting) would have also retained much of the existing noise shielding however the actual construction has required its lowering. The mound cannot be raised as this would involve filling in part of an existing drainage culvert inlet critical to the safe operation of the railway. This remodelling has resulted in six additional properties being proposed to receive property treatment (17, 19, 21 and 23 Old Beecroft Road and 106 and 108 The Crescent). The ETTT Project will contact these property owners to explain what the change in identification means for them directly. The noise barrier cost effectiveness assessment has also been reassessed and has confirmed a barrier at this location is still not cost effective.
- Confirming that the safety deflection wall behind the Scout Hall is included in the noise model and if it has any impacts on the proposed mitigation. It was determined that the deflection wall did not alter the Scout Hall's proposed eligibility for potential property treatment as shown in the draft ONVR.
- There were a lot of comments and requests about providing an explanation/clarification of how noise barrier sound reflection has been addressed in the model and results. Noise barrier reflection was considered in the modelling process and was assessed as not resulting in any material increases in noise levels. This is due to two main factors: 1) the presence of the train itself shielding properties on the opposite side from the barrier at the time the noise is generated; and 2) the path distance, a key determiner of noise levels, was calculated to be significantly longer in a reflected path from a train to a barrier to a property on the other side of the corridor, compared with the direct path between the train and the property. It was therefore concluded that there is no need for absorptive treatment on the proposed conventional barriers. However, due to the proximity of the low height barrier to the train, and the potential for noise to be reflected between barrier and train and back out to properties, it is recommended to confirm whether absorptive treatment is required on the low height barrier during detailed engineering design once further details of proposed construction materials is known.
- Providing an explanation for possible reasons why there are differences in predicted noise levels at adjoining properties. In several areas, there are two or more adjacent properties where one receiver has a red coloured dot, and the adjacent receiver may have a yellow dot, or no dot at all. In these circumstances, there may be little or no difference in the overall noise levels, however the change in noise levels as a result of the project may be slightly below or above the relevant noise increase trigger level. In the extreme example, one property may have a predicted LAeq noise level increase of 1.9 dB as a result of the project (with no coloured dot) and the adjacent receiver may have a predicted LAeq noise level increase of 2.0 dB (with a yellow or red dot). In the latter case, mitigation measures would be considered for the property with the yellow or red dot. The noise modelling results are therefore very sensitive to small changes in the noise level increase as a result of the project. Some of these factors are described below:
  - **Noise transmission path:** Small differences in the noise transmission path between the railway corridor and adjacent residences can influence the change in noise level as a result of the project.

Where the track is located in a cutting, the relative influence of locomotive engine/exhaust noise and wheel/rail noise from freight wagons and electric passenger trains changes. As the ETTT alignment traverses undulating terrain for the majority of the alignment small changes in the noise transmission paths between adjacent receivers can explain why one property is slightly below or above the noise increase trigger level.

- **Height of Sensitive Receiver:** The relative height of a receiver compared to neighbouring properties is analogous to a change in the noise transmission path and may therefore alter the change in noise levels as a result of the project.
- **Change in operating conditions:** Within the noise model, the speed of trains, the engine notch settings, the presence of curves and other track features alter the relative contribution of the noise sources at various locations throughout the project area. In some areas where these parameters are changing, the noise level increase as a result of the project may be different for adjacent receivers. These changes may therefore alter the change in noise levels as a result of the project.
- [Notwithstanding the above factors the ONVR includes consideration of a safety factor. For properties whose predicted average noise level increase would otherwise have been close to – but just below – the 2dB(A) EPA guideline trigger level this means: 1) for properties at which noise barriers are proposed, the noise barrier extent has been increased to include nearby grouped 'yellow dot' properties, and 2) properties not near a proposed noise barrier but that trigger due to the safety factor have been clearly identified as candidates for further mitigation measures such as property treatment, should validation measurements indicate that operational noise levels are higher than predicted. Therefore the safety factor provides a 'buffer' for noise level predictions.]

- Several errors on the maps and street address labels have been fixed.

The ONVR has now been updated to reflect these changes and submitted to DP&E for approval. All the feedback received during the consultation period is included in a table in Appendix H.

It is very important to note that as the proposed mitigation measures were developed based on mandated guidelines and cost effectiveness considerations, there was limited scope to alter the proposed measures. Feedback that conflicts with guidelines / standards and items that go outside the outlined assessment process and associated science could not be implemented. Examples of this include:

- Various suggestions to construct noise barriers where they have been deemed not required (either due to not exceeding trigger levels or being deemed as not cost effective). This includes suggestions of increase noise wall heights or extents of proposed noise walls.
- Assessing additional individual properties that have been deemed as ineligible for 'at receiver' noise treatment.
- Extending the proposed mitigation measures to address properties with existing noise issues but not triggering the requirement for consideration of mitigation measures or those triggering it with the application of the safety factor only. The ETTT Project has to comply with the requirements of the ETTT Project's Conditions of Approval which require compliance with the more stringent of the EPA's Interim Guidelines for the Assessment of Noise from rail Infrastructure Projects (IGANRIP) or Rail Infrastructure Noise Guidelines (RING) but with a focus on addressing project impacts rather than existing noise concerns.

The ETTT Project received multiple requests from property owners for noise monitoring to be undertaken at individual properties to confirm the predictions in the ONVR. This request could not be met as individual property measurements are not undertaken for these types of assessments. Operational noise assessments on infrastructure projects are based on predicted noise levels from the acoustic model created by the noise consultants and verified by the independent acoustic specialist approved by Department of Planning and Environment. This model takes into consideration topography of the land, track geometry, distance nearby properties are from the corridor, height of dwellings, existing and modified cuttings, number of trains that are predicted to use the line as well as data from the 17 locations where monitoring was done beforehand to calibrate the model. It then produces noise predictions for 2016 (when the project will be completed) and 2026 (10 years after operation) to compare the predicted difference as a result of the operation of the third track. Completing monitoring now would not prove or disprove the predictions from the noise model.

Some property owners have indicated that they believe the ONVR maps are showing properties still trigger the requirement for consideration of mitigation measures (with and without the safety factor) even when the noise walls are installed. We would like to confirm that is not the case, the maps in the draft ONVR were showing the locations of all properties that trigger the requirement for consideration of mitigation measures (with and without the safety factor) via yellow and red dots as well as the proposed treatment for those properties which in this instance is a noise wall. The maps in the final ONVR have been updated to make this distinction clear, by highlighting those properties treated by the noise barrier and for which no property treatment is offered.

Transport for NSW will undertake noise and vibration compliance monitoring and assessments to confirm the predictions in the ONVR as well as the proposed mitigation measures. The noise and vibration compliance assessment will be undertaken at twelve months, 5 years and 10 years after the commencement of operation of the ETTT Project.

This ONVR is available on the project website.

10.5 Noise barrier visual appearance consultation

The ETTT Project received numerous submissions about impacts the proposed noise walls will have on vegetation and appearance of the barriers (how they will affect the existing environment).

Consultation about the appearance of proposed noise barriers will be undertaken with directly affected community members after completion of the ONVR consultation phase, most likely during late 2014. This includes those properties directly in front of the proposed noise barriers and those that will have a direct visual impact from them. The noise barrier consultation will be centred about the look and feel of the barriers and its findings will become an addendum to the already-approved Urban Design and Landscape Plan (UDLP).

10.6 At-receiver (property treatment) consultation

Properties identified as eligible for property treatment will be contacted directly by the project team once the ONVR has been approved, expected to be in late 2014 / early 2015.

The first step in this process will be to send an engineer or building surveyor to the property to assess its condition and confirm eligibility for treatment. If eligibility is confirmed, a proposed plan of treatment will be offered to the property owner for agreement.

While details of the treatments cannot be confirmed until an inspection and assessment has taken place, they have on other projects generally included items such as provision of fresh air ventilation (to allow windows to be kept closed) or facade treatments such as window and door seals or window glass upgrades. Specific treatment measures will depend upon factors like the level of predicted noise impact, type of construction of the property, and orientation to the rail line.

It is possible that the inspection will determine some properties as not eligible due to all appropriate mitigation measures having already been implemented. For example if a property already has door and window seals and alternative fresh air ventilation already exists on the affected facade/s.

10.7 Ongoing and future communications

The ETTT project team at ETTT will continue to communicate with local residents and stakeholder groups through:

- Monthly notifications
- Regular updates on the project website
- Community information sessions, where required
- Letter box drops
- Individual briefings
- Phone calls

Briefings with Hornsby Shire Council and local Civic Trusts will continue at appropriate intervals until project completion.

11 ONVR INDEPENDENT VERIFICATION

Condition of Approval C4 requires the ONVR (and any subsequent amendment) to be independently verified by a noise and vibration expert. On the basis of the CoA requirements a scope was developed for the role of Independent Verifier (IV) in consultation with the EPA.

Transport Projects Division of Transport for NSW has a panel of preferred noise and vibration consultants based on skills, experience and price. These consultants were reviewed for independence from all stages of the project and discussions with a noise expert from Transport for NSW Freight and Regional Development were undertaken to identify the relative skills and experience of the listed consultants. Discussions were also held to determine which consultants had the right mix of skills and experience to effectively undertake the Independent Verifier role. Cost was not a consideration in determining which of the panel consultants would be most appropriate as the priority was independence and appropriate skills and experience.

Through this process Peter Karantonis of Renzo Tonin and Associates (under subcontract to MWH) was identified as the preferred consultant to undertake the IV role. Glenn Wheatley (also of Renzo Tonin) provided technical support to Mr Karantonis.

Peter Karantonis is a professional engineer with over 26 years of experience in acoustic consulting. Mr Karantonis' fields of special competence include environmental impact assessments, large infrastructure projects, transportation noise (road, rail and aircraft), industrial noise, construction noise & vibration, occupational noise, structural vibration, acoustic research & development, architectural acoustics, building mechanical services and expert representation in legal cases.

Glenn Wheatley has over 10 years experience in acoustic consulting and has worked on a diverse range of acoustic projects. In addition to a broad range of environmental acoustic experience, Glenn is a specialist consultant for licensed premise projects. His role at Renzo Tonin and Associates requires regular site inspections, environmental noise and vibration calculations and computer modelling, attending consultants meetings and providing advice on the control of noise and vibration. Glenn has also developed acoustic computer applications for the analysis of noise measurements and calculation of noise intrusion and emission.

Mr Karantonis was approved as the Independent Verifier by Department of Planning and Environment on 27 November 2013. The EPA was consulted on the scope of the verification exercise prior to finalising it.

The Independent Verifier has been involved throughout development of the ONVR and has endorsed its findings and recommendations. This is documented in the Independent Verifier report, available separately.

12 IMPLEMENTATION OF MITIGATION MEASURES

Once the ONVR is approved by DP&E the process of implementing mitigation measures will be as follows:

- Community consultation will be undertaken regarding the predicted visual impacts of the noise barriers.
- Detailed design of mitigation measures to be finalised.
- Commence installation of sleepers and rail.
- Commence construction of noise mitigation measures including noise barriers.
- Commence discussions with property owners eligible for property treatment.
- Implement the Source Noise Monitoring Plan.

The ETTT Project's target is to complete all noise mitigation measures prior to operation of the new track. If this is not possible, DP&E will be consulted to determine the best course of action.

13 POST-OPERATIONAL TESTING AND VALIDATION

A program of noise and vibration compliance monitoring will be undertaken in accordance with CoA F.2 to confirm the predictions presented in the ONVR and the mitigation requirements. The monitoring will be undertaken within 12 months, five years and ten years of the commencement of operation as required by the CoA and will be developed in consultation with the EPA.

The assessment is required to include the following:

a) Noise and vibration monitoring and compliance assessment, to assess compliance with conditions C1 to C3 of the approval and the ONVR;

b) An assessment methodology and the outcomes of the Source Noise Monitoring Plan and other relevant Rail Noise Initiatives developed and implemented for the SSI (condition F3);

c) Details of any complaints received relating to operational noise and vibration impacts;

d) An assessment of the performance and effectiveness of the applied noise and vibration mitigation measures;

e) Any required recalibration of the noise and vibration model, including consideration of freight train movements should the average number of night time trains exceed the projected value used for the noise mitigation design of the ONVR; and

f) Identification, if required, of further noise and vibration mitigation measures to meet the requirements of C1 to C3 of the approval and objectives identified in the ONVR

Figure 39 provides a flowchart illustrating a summary of the post operational noise process and validation of the predicted noise levels. The monitoring and validation process will generally involve:

- **Validation of the model inputs** (action B in **Figure 39**) – a review of the inputs to and assumptions for the noise model, i.e. the number of trains, mix of trains, the speed of trains and the track alignment. If these inputs are consistent with the assumptions made within the ONVR, this indicates that the noise increase component will be consistent with the predictions.

Should it be observed that one or more of the above design inputs have changed, then additional calculations will be undertaken to determine the variance generated and whether any additional mitigation measures need to be considered.

- **Validation of the predicted noise levels** (action A in **Figure 39**) – on site noise monitoring will be undertaken at representative locations for the purpose of validating the ONVR predictions. Representative locations will be chosen to provide a cross section of different conditions, e.g. varying landforms, curved track and straight sections, and locations with and without new noise barriers. This process will assess the predictions in the noise model and also the predicted performance and effectiveness of the applied noise and vibration mitigation measures.

  The monitoring results will then be compared against the IGANRIP Trigger Levels and ONVR predictions to determine any variance in noise levels between actual noise levels and ONVR predictions. At this point potential outcomes include:

  - Monitoring results indicate levels consistent with predictions, (i.e. within 2 dB). Mitigation measures remain as described in the ONVR.
  - The measured noise levels are higher than the overall IGANRIP Trigger Levels and outside normal measurement tolerances and daily noise level variations at individual (specific) locations (i.e. 2 dBA or more above the ONVR predictions). In this situation the source of the exceedance will be identified and the reason investigated.

    If the exceedance is due to a defect (typically track or the wheel/rail interface), the investigation will explore rectification measures. If this cannot resolve the issue, additional mitigation measures may need to be considered.
  - Monitoring results indicate a clear trend of higher noise levels than predictions, (i.e. by more than 1-2 dBA on average. In this situation consideration will be given to revisiting modelling results to determine if additional management measures are necessary.

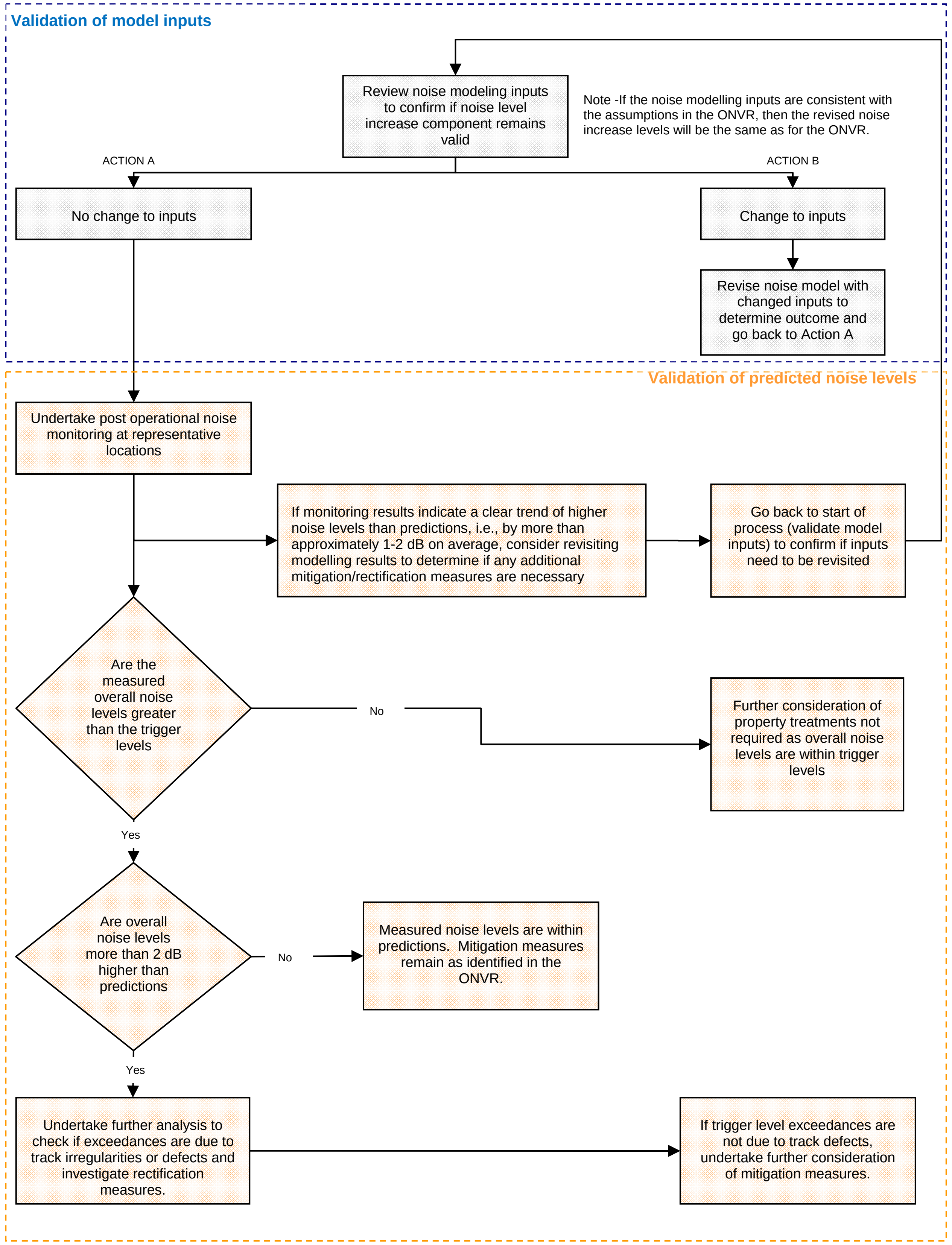
- **Validation of vibration predictions** – on site vibration monitoring will be undertaken at representative locations along the project corridor. The purpose of the monitoring is to determine the change in vibration levels (by comparing the vibration levels from trains operating on new and existing tracks) and comparing the overall vibration levels with the ONVR predictions.

Should the operational testing confirm that the operational noise and vibration levels during operations exceed those predicted in the ONVR, then investigation of further reasonable and feasible mitigation or rectification measures will be undertaken in consultation with affected property owners, EPA and DP&E.

Also if the operational noise monitoring identifies lubricators are not effective in reducing curve squeal, property treatments or other mitigation measures if deemed more practicable, are to be implemented for sensitive receivers immediately adjacent (generally within 50m of the newly constructed track) to rail curves on the downside (western side) of the rail corridor, irrespective of IGANRIP/RING noise trigger level exceedances.

Condition F2 requires the preparation of an Operational Noise and Vibration Compliance Assessment Report which provides the results of the assessment. This must be submitted to the Director General and the EPA within 60 days of its completion and made publicly available.

Figure 39 Post Operational Noise Testing and Validation Process



14 SOURCE NOISE MONITORING PLAN

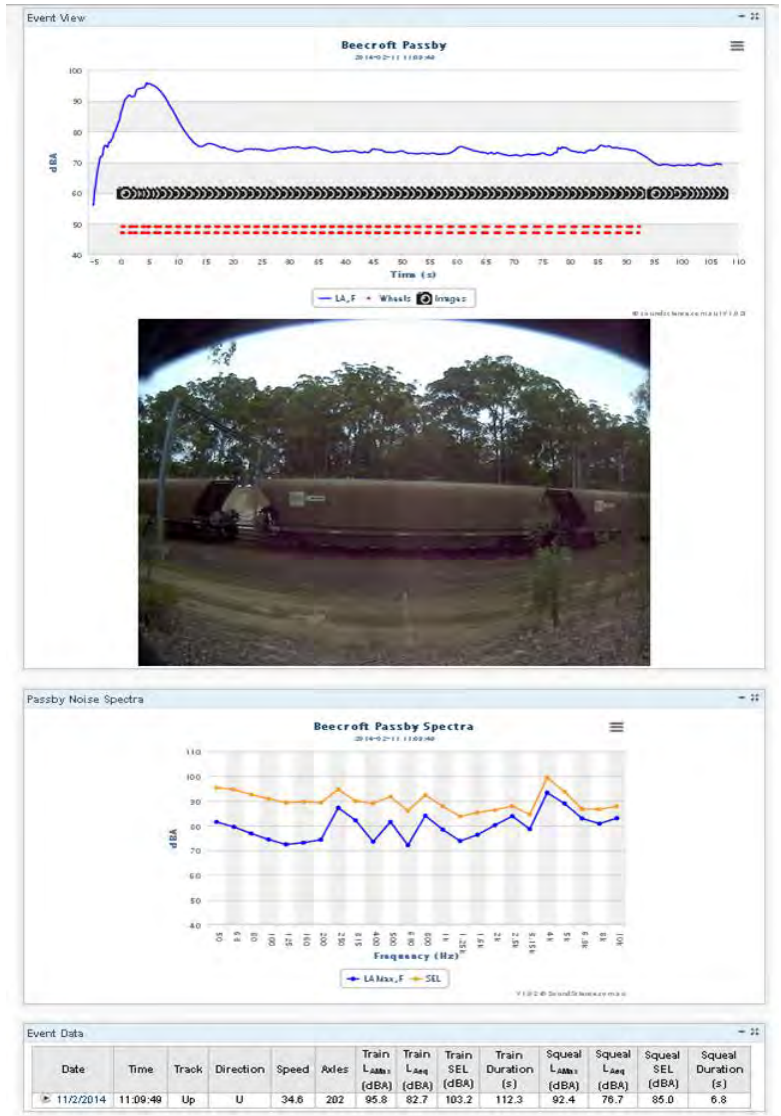
Transport for NSW has installed a prototype noise monitoring station adjacent to the track on the eastern side of the rail corridor, near Narena Close / Sutherland Road, as shown in Figure 40. The system sits atop a small cutting overlooking the tracks such that the microphone is at a similar height above rail to the exhaust of passing locomotives. The microphone is approximately 10m from the nearest track and has a clear line of sight to both tracks. The track at this location is tightly curved and inclined so that the noise measurements capture both wheel squeal and noise from locomotives operating at maximum power.

Figure 40 The location of the noise monitoring station (left)

The unit (shown at right) sits atop a slight rise such that the microphone is at approximately the same height as the locomotive exhaust.

This system measures the noise from each passing freight train on either track, and reports the noise and captures images for every vehicle, as shown in Figure 41.

Figure 41 A sample of data captured by the noise monitoring station



The system is designed to automatically incorporate the third track once this becomes operational. Data from the noise monitoring system will be presented to the public in a form and at a frequency appropriate to meet the requirements of the Minister's Conditions of Approval.

The ETTT Project will upgrade this prototype system to become a permanent noise monitoring station. This will include a concrete foundation, mast, cable routing and associated engineering works to ensure the noise monitoring station is protected from damage and that the requirements of the Source Noise Monitoring Plan are met over the long term.

15 COMPLAINTS MANAGEMENT

During operation of the third track (that is, after construction is complete and the track is in regular use by trains), noise and vibration complaints may be made via the following means:

By Phone: 131 500 (available 24 hours, 7 days a week)

Electronically: complaints may be submitted via the website

Complaints will be investigated and a response provided.

Noise monitoring will be carried out on an ongoing basis, and will include:

Continuous monitoring: as described in the Source Noise Monitoring Plan described in Section 14.

Validation monitoring: 12 months, five years and ten years after operations commence, as described in Section 13.

16 CONCLUSION

This ONVR has been prepared to assess – and propose mitigation measures for – the predicted operational noise and vibration impacts of the Epping to Thornleigh Third Track project. The document has also described the process of validating these predictions and managing impacts during operation.

Exceedances of the guideline trigger levels for operational noise are predicted at various properties along both sides of the project corridor. In summary, proposed mitigation measures to address these exceedances comprise the following:

Noise from trains

- Rail lubricators on the new third track
- Investigation of swing-nose crossings in proposed turnouts at Epping and Thornleigh
- Preparation of a paper documenting the potential benefit that would be achieved by targeting high noise locomotives, to inform community and regulator consideration of this issue
- Three extents of noise barrier in the Beecroft area, with a total length of approximately 1,300m
- Individual property treatments (40 properties eligible to be assessed for suitability)
- Upgrading an existing prototype noise monitoring station to become a permanent noise monitoring station for ongoing use in targeting high noise wagons

Vibration from trains

- None – impacts of proposed design comply with relevant guidelines

Noise from stations

- None – impacts of proposed design comply with relevant guidelines

A public consultation process was carried out, which provided information to the community and an opportunity to provide feedback via email and attend drop-in information sessions. In addition, feedback on the mitigation measures proposed was sought from owners of properties at which trigger levels are predicted to be exceeded, via a hand-delivered letter and CD. All feedback received has been addressed in this version of the ONVR document which has been submitted to the Department of Planning and Environment for approval.

Once the ONVR is approved, it will be published on the Transport for NSW website, and installation of noise mitigation structures and construction of track will commence. The ETTT project is scheduled to become operational in mid 2016.