Transport
Roads & Maritime
Services

OPERATIONAL NOISE REPORT

Banora Point upgrade

AUGUST 2013

Banora Point Upgrade Alliance

OPERATIONAL NOISE REPORT

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A team consisting of RTA, Abigroup, SMEC And Seymour Whyte to upgrade the Pacific Highway at Banora Point

Document History and Status

Revision Status

Revision	Date	Description	Page	Clause	Prepared	Reviewed	Approved
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1 Introduction

On behalf of the Banora Point Upgrade Alliance (BPUA), Renzo Tonin & Associates (NSW) Pty Ltd has prepared this Operational Noise Report (ONR) for the recently completed and now operational Banora Point Upgrade Project (the project).

This ONR has been prepared in accordance with the Minister's Conditions of Approval (MCoA) Conditions 3.2 and 3.3, and the post-construction noise monitoring requirements set out in the NSW Roads and Maritime Services (RMS) 'Environmental Noise Management Manual' (ENMM – RTA 2001).

This ONR presents results of the operational noise monitoring undertaken at selected representative worst-case residential monitoring locations along the length of the project, compares monitored traffic volumes with forecasted traffic volumes used during the design phase of the project and compares monitored noise levels with the modelled noise levels at each corresponding noise monitoring location.

This ONR aims to evaluate the adequacy of the noise mitigation measures as installed on the project by comparing operational noise monitoring results to modelled noise levels at selected representative worst-case locations along the length of the project. Where monitored operational noise levels are equal to or less than those modelled during the detailed design process, then compliance with the project's noise objectives is demonstrated. However, where operational noise levels are measured to be greater than the levels modelled, then steps shall be taken to examine the prediction methodology, review the suitability and adequacy of the installed noise mitigation measures, and assess additional feasible and reasonable mitigation measures.

Annexure A also provides a glossary of relevant acoustic terms.

2 Purpose and Objectives

This ONR has been prepared to meet Commitment No.ON3 as set out in the Statement of Commitments (July 2008) and the requirements set out in the Minister's Conditions of Approval No. 3.2 and 3.3 (February 2009) for the project.

2.1 Purpose

The purpose of the ONR is to:

- outline the objectives of the operational noise monitoring study,
- describe the methodology of the operational noise monitoring study,
- compare monitored traffic volumes with forecasted traffic volumes,
- compare monitored traffic noise levels with modelled traffic noise levels,
- assess the adequacy of the installed traffic noise mitigation measures, and
- present the results, findings and conclusions of the operational noise monitoring study.

2.2 Objectives

The environmental requirements for the design of a large, high speed roadway like the Banora Point Pacific Highway Upgrade need to be comprehensive in order to address the potential environmental noise effects of sensitive noise receivers potentially affected by traffic noise from the roadway. These requirements were addressed during the detailed design phase of the project in consultation with relevant government agencies, including the NSW Department of Planning and Infrastructure (DP&I) and the NSW Environment Protection Authority (EPA), and the community prior to the construction and implementation of noise mitigation measures.

The project's noise objectives and selected noise mitigation measures and design outcomes are all documented in the Operational Noise Management Report (ONMR) addressing the requirements of MCoA 2.15, the NSW 'Environmental Criteria for Road Traffic Noise' (ECRTN – EPA 1999), the NSW Roads and Maritime Services 'Environmental Noise Management Manual' (ENMM – RTA 2001) and Appendix 4 of the Alliance Scope of Work and Technical Criteria (ASWTC). The ONMR provides details on the project's noise objectives, the selected noise mitigation measures and the design outcomes, therefore a brief summary of these are presented in Chapter 4 of this ONR.

As described in the ONMR, the detailed design process involved modelling and assessing noise at all potentially impacted properties along the project in terms of the environmental noise criteria applicable to the project. This ONR aims to evaluate the adequacy of the noise mitigation measures as installed on the project by comparing operational noise monitoring results to modelled noise levels at selected representative worst-case locations along the length of the project.

Where monitored operational noise levels are equal to or less than those modelled from the same noise model used during the detailed design process, then compliance with the project's noise objectives is demonstrated.

Where operational noise levels are measured to be greater than the levels modelled from the design noise model, then the following steps are undertaken:

- an examination of the prediction methodology,
- a review of the suitability and adequacy of the installed noise mitigation measures, and
- an assessment of additional feasible and reasonable mitigation measures at those locations.

Therefore, the primary objectives of the ONR are to:

- present the results and outcomes of operational noise monitoring in accordance with MCoA 3.2 and 3.3, and the post-construction noise monitoring requirements set out in Practice Note viii of ENMM,
- compare actual noise monitoring results against noise level outputs from the noise model used to review and design the noise mitigation measures required by MCoA 2.15 and documents specified under MCoA 1.1, and
- identify areas of exceedance and non-conformance where additional feasible and reasonable noise mitigation measures may be warranted.

3 Environmental and Legal Obligations

3.1 Statement of Commitments

Table 3.1 summarises the Final Statement of Commitments (SoCs) that require consideration during preparation of this ONR. The SoCs listed below are those issued as part of the Environmental Assessment Submissions Report prepared in July 2008.

Table 3.1 – Final Statement of Commitments

SoC No.	Objective	Commitment	Reference this document
ON3	Determine effectiveness of operational noise control measures	Monitoring of operational noise will be undertaken between six months and one year after opening along the proposed Banora Point upgrade. Should the monitoring indicate traffic noise impacts exceeding the relevant noise level criteria in NSW Government's Environmental Criteria for Road Traffic Noise; the RTA will investigate and implement further "reasonable and feasible" mitigation measures. The selection of these measures will be undertaken in consultation with affected property owners. The mitigation measures will be confirmed against predictions of noise levels 10 years after opening.	This document

3.2 Conditions of Approval

Table 3.2 summarises the Minister's Conditions of Approval (MCoA) that require consideration during preparation of this ONR. The conditions of approval listed below are those issued by the Minister for Planning in February 2009.

Table 3.2 – Minister's Conditions of Approval

MCoA No.	MCoA Details	Reference this document
3.2	No later than one year after commencement of operation of the project, or as otherwise agreed by the Director-General, the Proponent shall undertake operational noise monitoring to compare actual noise performance of the project against noise performance predicted in the review of noise mitigation measures required by Condition 2.15 and prepare an Operational Noise Report. The Report shall include, but not necessarily be limited to:	This document
a)	Noise monitoring to assess compliance with the operational noise levels predicted in the review of operational noise mitigation measures required under Condition 2.15 and documents specified under Condition 1.1 of this approval;	Section 6
b)	A review of the operational noise levels in terms of criteria and noise goals established in the *Environmental Criteria for Road Traffic Noise* (EPA 1999);	Section 4
c)	Methodology, location and frequency of noise monitoring undertaken, including monitoring sites at which project noise levels are ascertained, with specific reference to locations indicative of impacts on sensitive receivers;	Section 6
d)	Details of any complaints and enquiries received in relation to the operational noise generated by the project between the date of commencement of operation and the date the report was prepared;	Annexure E
e)	Any required recalibrations of the noise model taking into consideration factors such as noise monitoring undertaken and actual traffic numbers and proportions;	Section 9

MCoA No.	MCoA Details	Reference this document
f)	An assessment of the performance and effectiveness of applied noise mitigation measures together with the review and if necessary, reassessment of all reasonable and feasible mitigation measures; and	Section 9
g)	Any additional feasible and reasonable measures to those identified in the review of noise mitigation measures requires by Condition 2.15, that would be implemented with the objective of meeting the criteria outlined in the *Environmental Criteria for Road Traffic Noise* (NSW EPA, 1999), when these measures would be implemented and how their effectiveness would be measured and reported to the Director-General and the DECC.	Section 9
3.3	The Proponent shall provide the Director-General and the DECC with a copy of the Operational Noise Report within 60 days of completing the operational noise monitoring referred to under condition 3.2 of this approval, or as otherwise agreed by the Director-General.	This document

3.3 Legislation

Key environmental legislation relating to the management of road traffic noise includes:

- Protection of the Environment Operations Act (1997);
- Protection of the Environment Administration Act (1991);
- Environment Planning and Assessment Act (1979); and
- Local Government Act (1993).

3.4 Guidelines and Background Documents

The key references relevant to general road traffic noise management include:

- Environmental Criteria for Road Traffic Noise (ECRTN), NSW EPA, May 1999;
- Environmental Noise Management Manual, NSW RMS (ex RTA), 2001; and
- Noise Wall Design Guidelines, NSW RMS (ex RTA), May 2003.

Background studies and assessment of potential noise impacts as a result of the operation of the project include:

- Banora Point – Upgrading the Pacific Highway – Environmental Assessment (Volumes 1, 2 and 3), Parsons Brinkerhoff Australia Pty Ltd, February 2008
- Banora Point – Upgrading the Pacific Highway – Environmental Assessment Submissions Report, Parsons Brinkerhoff Australia Pty Ltd, July 2008
- Pacific Highway Upgrade Program, Banora Point – Director-General's Environmental Assessment Report, NSW Department of Planning, February 2009
- Banora Point Upgrade: Operational Noise Management Report – 100% Design Stage, Banora Point Upgrade Alliance, September 2012
- Renzo Tonin & Associates, Banora Point Upgrade - Operational Noise Monitoring Plan, September 2012

4 Project Noise Level Objectives

During the design stage, noise level objectives for this project were established as per the ECRTN and the ENMM, in accordance with the requirements of MCoA 2.15. Further to this, other Environmental Documents for the project (outlined in Section 3.4) were taken into consideration during the development of the operational noise mitigation measures.

The noise level objectives for the project are detailed in the Operational Noise Management Report (ONMR) [ref. TE314-01F11 (rev 11), 19 September 2012]. A summary of these is presented below.

4.1 Residential Noise Receptors

According to the ECRTN and the ENMM, the project has the following two (2) noise criteria categories with respect to Table 1 of the ECRTN:

- **Category 1** – New Freeway or Arterial Road Corridor: areas not previously exposed to road traffic noise.
- **Category 3** – Redevelopment of Existing Freeway / Arterial Road: areas previously exposed to road traffic noise.

The relevant noise criteria for the project are summarised in Table 4.1 below.

Table 4.1 – Noise Criteria for Residential Receivers

Type of Development	Noise Criteria, dB(A)		Where Criteria are Already Exceeded
	Day	Night	
New freeway or arterial road corridor	$L_{Aeq(15hr)}$ 55	$L_{Aeq(9hr)}$ 50	The new road should be designed so as not to increase existing noise levels by more than 0.5dB.
Redevelopment of existing freeway/ arterial road	$L_{Aeq(15hr)}$ 60	$L_{Aeq(9hr)}$ 55	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2dB.

(Source: NSW ECRTN)

In addition to the above, where the predicted design year noise levels at residences exceed 65dB(A) Day and 60dB(A) Night as a result of the project, then the noise exposure is considered to be 'acute' and noise control measures were considered.

To establish the most reasonable and feasible noise mitigation treatment in areas affected by significant traffic noise levels, reference is made to Practice Note IV of the ENMM.

4.2 Non-Residential Land Use Developments

In addition to the above noise criteria, other non-residential noise sensitive receivers were identified in the ONMR and were categorised in accordance with Table 2 of the ECRTN.

The relevant non-residential receiver noise level objectives for this project are summarised in Table 4.2 below.

Table 4.2 – Noise Criteria for Non-Residential Receivers

Sensitive Land Use	Noise Criteria, dB(A)		Where Criteria are Already Exceeded
	Day	Night	
Passive recreation and school playgrounds	Freeway / arterial roads: $L_{Aeq(15hr)}$ 55	-	Where existing levels of traffic noise exceed the criteria, all feasible and reasonable noise control measures should be evaluated and applied. Where this has been done and the internal or external criteria (as appropriate) cannot be achieved, the proposed road or land use development should be designed so as not to increase existing road traffic noise levels by more than 0.5dB(A) for new roads and 2dB(A) for redeveloped roads or land use development with potential to create additional traffic.

(Source: NSW ECRTN)

4.3 Maximum Noise Level Assessment

Maximum noise levels generated by road traffic noise have the potential to cause disturbance to sleep. MCoA 2.15 does not specifically require an assessment of maximum noise levels to be considered during the development of noise mitigation for sensitive receptors. However, the ECRTN requires maximum noise levels during each hour of the night time period (10pm to 7am) to be assessed and reported to give an indication of the likelihood of awakening reactions.

Although the ECRTN requires the assessment of maximum noise levels, it does not include noise criteria for assessing the maximum noise level events. This is primarily because research conducted to date in this field has not been definitive and the relationship between maximum noise levels, sleep disturbance and subsequent health effects is not currently well defined. Guidelines for assessing maximum noise levels are provided in Practice Note III of the ENMM. The guidelines are to be used as a tool to help prioritise and rank mitigation strategies, but should not be used as a decisive criterion in itself.

The ENMM defines a “maximum noise event” as any pass-by for which:

$$L_{max} - L_{eq\,(1hr)} \geq 15 \text{ dB(A), where the } L_{max} \text{ noise level is greater than 65 dB(A)}$$

The above is reiterated in the EA (2008), where it states:

> *‘”There are no specific night-time noise criteria for maximum noise events specified in the NSW ECRTN; however, Practice Note 3 of the RTA’s ENMM provides a protocol for assessing maximum noise levels. This protocol defines a ‘maximum noise event’ for any pass-by that produces a difference between the L_{Amax} and the L_{Aeq} of greater than or equal to 15dB(A); however, this only applies to events resulting in a maximum noise level in excess of 65dB(A).”*

In accordance with the project’s requirements, it is noted that the monitored maximum noise levels have not be used to determine compliance of the operational noise levels or the adequacy of mitigation measures presented in the ONMR, but instead the monitored results can provide a comparison of the maximum noise levels with and without the project.

5 Project Noise Mitigation Measures

There have been a number of methods used on the project to mitigate traffic noise. The following summarises the suite of noise mitigation measures implemented on the project to reduce noise impacts to receivers:

1. Road design features;
   - increased distance between the road and receivers (eg. optimising road alignment, inclusion of landscaped areas and parklands to act as buffers between road and receivers, etc)
   - use of cuttings in road to provide noise shielding
   - shielding from road structures (eg retaining walls, bridge structures etc)
   - minimising the number of bridge/viaduct expansion joints, and where they are required use of low-noise expansion joints
   - reduced road gradient
2. Low-noise pavement;
3. Roadside noise barriers and walls; and
4. At-property noise control treatments.

5.1 Road Design Features

Road design features of the project which assists in reducing traffic noise impacts include:

- Various cuttings and retaining walls, including a land bridge, which shield the road from residences.
- Noise walls which provide shielding of the road from residences.
- Low noise finger plate expansion joint systems were installed at the two expansion joint locations on the viaduct, namely the southern and northern abutments of the viaduct. The underside of the northern abutment’s expansion joint, which is closest to residential properties, was enclosed with a noise reducing baffle after the post-opening noise monitoring was conducted. This baffle is expected to reduce peak noise levels generated by vehicle tyres passing over the expansion joint and emanating from the underside of the viaduct, for the benefit of adjacent residential properties located along Bione Avenue.

5.2 Low-Noise Pavements

The main carriageway of the project and each of the on and off ramps at the southern and northern interchanges were finished with a low noise surface of Stone Mastic Asphalt (SMA), as these sections are the most densely populated sections of the project and traffic are at higher speeds. SMA provides significant and worthwhile noise reduction benefits.

Local roads were finished with Dense Graded Asphalt (DGA), including the old Pacific Highway (ie. Sexton Drive).

5.3 Noise Barriers and Walls

In accordance with MCoA 2.15 noise walls were designed to meet the requirements of the ECRTN during the design phase of the project.

Noise barriers are most feasible where residences are closely grouped, where the barriers do not cause access difficulties to properties, and where they are visually acceptable. To derive the most appropriate height for noise barriers, a detailed feasibility analysis of the noise walls was completed during the design phase in accordance with Practice Note IV of the ENMM. The analysis confirmed the optimum noise mitigation requirements, including the appropriate mix of at-road and at-property treatments. A summary of the feasibility analysis and assessment outputs is presented in the ONMR.

In summary, noise barriers and walls have been constructed in accordance with the requirements of the ECRTN and the ENMM. The ONMR presents the schedule of the noise barriers that were designed for the project and these range from 0.7m high for concrete crash barriers to 3.5m high for noise barriers.

5.4 At-Property Noise Control Treatment

After implementing all feasible and reasonable 'at-road' noise mitigation measures, such as:

- road design features (eg minimising road grades, provision of cuttings, inclusion of landbridge, optimising the viaduct structure etc);
- low-noise pavement; and
- noise walls;

the remaining properties exceeding the project noise goals were offered 'at-property' noise mitigation treatments. At-property noise mitigation treatments were selected in accordance with the ENMM.

To determine the type of noise mitigation treatment suitable for each affected property, consideration was given to the following:

1. the remaining extent (or degree) of noise exceedance over external noise level goals at each affected facade of affected dwellings, after implementing at-road noise mitigation measures,
2. the existing construction of each affected facade and ventilation provisions to affected habitable rooms of affected dwellings, and
3. optimisation of at-property noise treatment at each affected dwelling.

Following the noise modelling process undertaken during the design phase of the project, a total of 75 properties were identified for consideration of at-property treatment in addition to at-road noise mitigation measures described above. The addresses of properties identified for consideration of at-property treatment are presented in the ONMR. Following the ONMR, further assessments and inspections of individual properties were conducted as identified by the BPUA and a total 92 properties were finally offered at-property treatment.

In order to determine the level of at-property treatment required, detailed on-site inspections of each individual property identified for treatment was undertaken, which included noting down the construction of the affected facades and the dimension of affected rooms, windows and/or doors. Details of the level of treatment required were presented in at-property treatment schedules prepared for each impacted property.

6 Noise Monitoring

6.1 Noise Monitoring Methodology

Noise monitoring was conducted in accordance with:

- Australian Standard 2702-1984 “Acoustic Methods of Measurement of Road Traffic Noise”,
- ECRTN Appendix C4 ‘Noise monitoring procedures’, and
- ENMM Appendix E ‘Model consultant brief for post-construction road traffic noise monitoring’.

Furthermore, Renzo Tonin & Associates produced a Banora Point Upgrade - Operational Noise Monitoring Plan (September 2012) which captures the key elements of the above documents and provides a noise monitoring and assessment methodology that is specific to this project. The monitoring plan was prepared in consultation with the Banora Point Upgrade Alliance and RMS.

6.1.1 Long-Term Noise Monitoring

All long-term (unattended) noise monitoring was conducted using Renzo Tonin & Associates’ noise monitors. The noise monitoring equipment complies with Australian Standard AS IEC 61672.1 2004 “Electroacoustics - Sound Level Meters” and are designated as either Type 1 instruments suitable for laboratory and field use and/or Type 2 instruments suitable for field use.

A noise monitor consists of a sound level meter in a weather resistant enclosure. Ambient noise levels are recorded at a rate as low as a few milliseconds per sample. Every 15 minutes, the data is processed statistically and stored in memory.

A noise monitor was installed at each nominated monitoring location and generally positioned 1m from the most affected facade to a habitable area and at a height of 1.5m above the floor level for a minimum of seven (7) valid days in accordance with the ENMM.

In some instances, the most affected facade to a habitable area was either located on the first floor level (eg. garage or storage area on ground floor) or was covered over by a roof (eg. verandahs, balconies, pergolas, awnings etc) which can adversely affect noise readings. In these cases, the noise monitor was located in the ‘free-field’ (ie. a minimum 3.5m away from any façade) and a +2.5dB(A) facade correction was applied to the measured noise levels to convert the free-field measurements to equivalent measurements at 1m from the relevant building facade.

6.1.2 Short-Term Noise Monitoring

For multi-storey dwellings, long-term (unattended) monitoring was conducted at the most accessible floor of the dwelling and additional short-term (attended) noise monitoring was conducted at 1m from the subject façade on the other floor/s and at a height of 1.5m above the corresponding floor level. Short-term monitoring was conducted concurrently with the long-term noise monitoring, using a Type 1 sound level meter during the deployment and / or the collection of the long-term noise monitor.

The measured short-term results were compared to the concurrent results of the corresponding long-term monitor to determine a correlation between the two measurement locations. This procedure is used to establish the equivalent traffic noise levels over the long term monitoring period at the short term measurement location.

To illustrate this procedure assume the following example:

Say a noise level of 55dB(A) was measured during the day at the short-term location (Location A) and over exactly the same short-term period a noise level of 52dB(A) was measured at the long-term location (Location B). That means that noise levels at Location A are generally 3dB(A) louder than at Location B during the day. If this noise level difference between the two locations is repeatable and found to be reasonably consistent throughout different periods in the day, then if at Location B a daytime noise level of 57dB(A) was measured over a 7 day period, this means that at Location A daytime noise levels would be expected to be 60dB(A). A similar process can be followed for night-time noise levels.

6.1.3 L_{Amax} Noise Monitoring

Maximum (L_{Amax}) noise levels from the project were monitored continuously during the night periods (10pm to 7am) using the same Type 1 noise monitors used for traffic noise monitoring, as described above. L_{Amax} noise levels were monitored at the same five (5) locations where L_{Amax} noise levels were previously measured as described in the ONMR. An additional location at a resident on Bione Avenue was chosen to address community concerns and to obtain an understanding of L_{Amax} noise levels near an expansion joint of the viaduct.

6.1.4 Noise Monitors

All acoustic instrumentation used for the operational noise monitoring are designed to comply with the requirements of Australian Standards AS IEC 61672.1 2004 “Electroacoustics - Sound Level Meters”, and carry appropriate and current NATA (or manufacturer) calibration certificates.

6.1.5 Meteorology During Monitoring

Measurements affected by extraneous noise, wind (greater than 5m/s at the microphone) or rain were excluded from the recorded data.

Meteorological data was obtained from two (2) weather stations (Davis Instruments – Vantage Vue, Model no. 6357) installed and located on the southern and northern ends of the project, which allowed for greater accuracy in checking weather conditions closer to the noise monitoring sites. It is noted that during noise monitoring there was a large amount of wet and windy weather and as a result the monitoring period was extended over a suitable length to obtain a minimum of seven (7) valid days in order to obtain valid data for each day of the week at all monitoring locations.

It is noted that noise enhancing or noise diminishing meteorological conditions from winds and temperature inversions do not form part of the requirements of the ECRTN and ENMM. Although distances of noise monitoring locations from the road were relatively short and impacts from such adverse meteorological conditions are minimal, due consideration was given to the potential influences of such meteorological conditions on the noise monitoring data.

6.1.6 Noise Monitoring Outputs

The noise monitoring instruments typically stored L_{A90}, $L_{Aeq,15hr}$, $L_{Aeq,9hr}$ and L_{Amax} noise levels as a minimum on a continuous basis at 15-minute intervals. In addition, the noise instruments used at the L_{Amax} monitoring locations stored L_{Amax} noise levels continuously at 1-second intervals. While measurement results for all these indices were retained, the study primarily focuses on the $L_{Aeq,15hr}$ and $L_{Aeq,9hr}$ results, as these are the noise assessment indices embodied in the ECRTN.

Upon processing the noise monitoring data, any noise levels monitored during adverse weather conditions (wind greater than 5m/s at the microphone and/or rain) were excluded.

Further to the exclusion of noise data affected by adverse weather, noise data was further reviewed to also discard extraneous non-road traffic noise. Extraneous noise was determined based on the following considerations:

- unusually high $L_{Aeq(15min)}$ noise peaks in comparison to adjacent periods and in comparison to noise levels during the same period on other similar days of the week;
- unusually high peaks across all noise metrics within the same periods and equivalent periods on other similar days of the week;
- short periods of anomalous traffic flow in comparison to adjacent periods and the same periods on other similar days of the week;
- fauna noise (eg insects, birds etc) affecting noise levels – for example at several monitoring locations a peak in the $L_{A90(15min)}$ and often in the $L_{Aeq(15min)}$ and $L_{A10(15min)}$ levels was found during the evening hours of 7:30 to 8:30pm as a result of insect noise (eg crickets) at dusk;
- moderate winds potentially increasing flora noise (eg. rustling leaves) and potentially influencing noise propagation; and
- review of audio files to confirm the likely cause of identified extraneous noise events.

Once extraneous noise data was removed, days and nights with the least amount of excluded data were preferred over those with large amounts of data missing, in order to adopt valid daytime and night-time noise levels representing each of the 7 days of the week.

6.2 Noise Monitoring Locations

Where possible, the noise monitoring sites were selected to be the same as those monitored as part of the design phase of the project and as presented in the ONMR so to allow direct comparisons to be made with noise monitoring locations selected prior to the project's construction.

Where it was not possible to conduct noise monitoring at the previously monitored locations, noise monitors were setup at suitable alternative locations within close proximity to the originally selected locations. This was the case for the monitoring location at 41/12 Trigonie Avenue, because approval for access was not obtainable from the property owner in the allowable time frame. Therefore, an alternate location at 42/12 Trigonie Avenue was chosen as the noise environment was considered to be similar to that of the original location.

Furthermore, additional noise monitoring locations to those monitored as part of the design phase of the project were selected to monitor noise levels at properties where concerns have been raised by the community with regard to traffic noise. This provides an opportunity for the BPUA to address specific areas of concern raised by the community. This provides an opportunity for the BPUA to address specific areas of concern raised by the community.

Other site specific conditions also influenced the selection of final noise monitoring locations, including access availability to a site, consideration of localised extraneous noise sources (eg. air conditioners, pool plant, other equipment etc) and building features (eg, covered balconies, verandahs, pergolas, awnings etc), which could adversely affect noise measurements.

6.2.1 Long-Term Noise Monitoring Locations

The locations where long term (unattended) operational noise monitoring was conducted are listed in Table 6.1 below. These monitoring locations are marked on the maps in Annexure B.

Following the preparation of the Banora Point Upgrade - Operational Noise Monitoring Plan (September 2012) and a review of the plan by BPUA and RMS, operational noise monitoring commenced in November 2012.

Table 6.1 – Long-Term Operational Noise Monitoring Locations

Location No.	Monitoring Address	Facade of Dwelling
M1	36 Summit Drive	Northeast
M2	10 Pacific Highway	North
M3	20 Somerset Avenue	North
M4	5 Pacific Highway	East
M5	40 Pioneer Parade	Northeast
M6	18 Pioneer Parade	East
M7	17 Pioneer Parade	East
M8	50 Martinelli Avenue	South
M9	51 Bione Avenue	Southwest
M10	10 Laura Street	South
M11	11 Elsie Street	Northwest
M12	1 Oyster Point Road	North
M13	42 Kimberley Circuit	East
M14	113 Winders Place	Northeast
M15	60/12 Trigonie Drive	Southeast
M16[1]	42/12 Trigonie Drive	South
M17[2]	159/67 Winders Place	Northeast
M18[2]	8 Banora Boulevard	North
M19[2]	14 Laura Street	North
M20[2]	Unit 2, 41A Bione Avenue	Southwest
M21[2]	5/57 Bione Avenue	West

Notes: 1. Alternate location to 41/12 Trigonie Avenue
2. Additional noise monitoring locations to those monitored during the design phase

Long-term noise monitoring was undertaken at the above locations between 5th November and 27th November 2012.

Traffic counts, vehicle classifications and vehicle speed data was monitored concurrently with the noise monitoring, by a third-party contractor who provided data enabling the commencement of the operational noise monitoring analysis on 15th December 2012.

6.2.2 Short-Term Noise Monitoring Locations

Short-term (attended) noise monitoring was generally undertaken at multi-storey properties or where it was not practical for long-term noise monitors to be installed over several weeks at the applicable habitable floor level requiring assessment.

Short-term noise monitoring was undertaken at the locations listed in Table 6.2 below.

Table 6.2 – Short-Term Operational Noise Monitoring Locations

Location No.	Monitoring Address	Facade of Dwelling	Details
M1	36 Summit Drive	Northeast	Ground floor habitable area elevated above ground
M2	10 Pacific Highway	North	Double storey dwelling
M4	5 Pacific Highway	East	Ground floor habitable area elevated above ground
M5	40 Pioneer Parade	East	Ground floor habitable area elevated above ground
M6	18 Pioneer Parade	East	Elevated single storey dwelling
M8	50 Martinelli Avenue	South	Double storey dwelling
M9	51 Bione Avenue	Southwest	Double storey dwelling
M12	1 Oyster Point Road	Northwest	Double storey dwelling
M20	Unit 2, 41A Bione Avenue	Southwest	Triple storey dwelling
M21	5/57 Bione Avenue	West	Double storey dwelling

6.2.3 L_{Amax} Noise Monitoring Locations

Detailed L_{Amax} noise monitoring was undertaken at the locations shown in Table 6.3 below and were conducted at the same time as the long-term unattended noise monitoring.

Table 6.3 – L_{Amax} Noise Monitoring Locations

Location No.	Monitoring Address	Facade of Dwelling
M3	20 Somerset Avenue	North
M4	5 Pacific Highway	East
M6	18 Pioneer Parade	East
M9	51 Bione Avenue	Southwest
M13	42 Kimberley Circuit	East
M14	113 Winders Place	Northeast

7 Traffic Volumes and Classification

In accordance with Practice Note viii of the ENMM, traffic volumes, classification of vehicles and vehicle speeds were monitored concurrently with the operational noise monitoring along the project length by a third-party contractor.

The locations where traffic counting was conducted are listed below and are shown on the maps in Annexure B.

Main Alignment

- Site 3 – North of Barney's Point Bridge
- Site 7 – Under land bridge
- Site 18 – South of Greenway Drive overpass

Pacific Highway Ramps

- Site 1 – Southern Interchange northbound off-ramp
- Site 2 – Southern Interchange southbound on-ramp
- Site 11 – Northbound off-ramp to Minjungbal Drive
- Site 12 – Northbound on-ramp to Minjungbal Drive and Pacific Highway
- Site 14 – Southbound on-ramp from Minjungbal Drive
- Site 15 – Northern Interchange northbound on-ramp
- Site 17 – Northern Interchange southbound off-ramp

Local Roads

- Site 4 – Sextons Hill Drive south of Terranora Road
- Site 5 – Terranora Road
- Site 6 – Sextons Hill Drive north of Terranora Road
- Site 8 – Laura Street
- Site 9 – Sextons Hill Drive south of Darlington Drive
- Site 10 – Darlington Drive
- Site 13 – Minjungbal Drive / Darlington Drive extension
- Site 16 – Minjungbal Drive

Table 7.1 below presents the counted traffic volumes, vehicle classifications and vehicle speeds (based on an 85^{th} percentile) at the traffic monitoring sites listed above.

Table 7.1 – Monitored Traffic Volumes, Vehicle Classifications and Speeds

Traffic Counting Site	Day – 7am to 10pm (15hr)			Night – 10pm to 7am (9hr)		
	Total Vehicles	Heavy Vehicles %	Speed[1]	Total Vehicles	Heavy Vehicles %	Speed[1]
Main Alignment – combined both carriageways						
Site 3	40,912	11%	107	4,206	24%	108
Site 7	41,628	9%	104	4,306	21%	103
Site 18	46,178	15%	109	5,052	26%	109
Pacific Highway Ramps						
Site 1	3,252	6%	85	206	6%	85
Site 2	3,362	5%	72	332	6%	72
Site 11	9,627	5%	90	537	9%	93
Site 12	12,147	6%	58	1,044	5%	63
Site 14	6,637	3%	73	368	9%	76
Site 15	8,206	6%	95	740	8%	100
Site 17	9,805	4%	77	815	5%	82
Local Roads – combined both directions						
Site 4	6,628	5%	57	706	5%	58
Site 5	7,352	6%	46	648	8%	48
Site 6	7,823	5%	60	654	5%	60
Site 8	3,631	3%	49	288	3%	48
Site 9	10,705	5%	68	865	5%	71
Site 10	14,226	4%	57	1,210	4%	59
Site 13	11,815	5%	62	886	5%	65
Site 16	28,532	5%	57	1,720	7%	61

Note: 1. Speed represents the 85th percentile speed monitored during the traffic volume monitoring

The monitored traffic volume data presented above can be compared to the AADT volume data used in the design noise model for the design year of the project (2022 ie 10 years after opening), as presented in the ONMR and reproduced below in Table 7.2.

Table 7.2 – Forecasted Design Year 2022 AADT Volumes and Compositions

Section of Road or Ramp	Direction	Day – 7am to 10pm (15hr)			Night – 10pm to 7am (9hr)		
		Total Vehicles	Heavy Vehicle %	Speed[1]	Total Vehicles	Heavy Vehicle %	Speed[1]
Main Alignment							
Between Barney's point Bridge and Southern Interchange on and off ramps	northbound	35,940	13.4%	100	3,990	28.6%	100
	southbound	27,800	13.0%	100	3,090	27.8%	100
Between Southern Interchange on and off ramps and Minjungbal Drive on and off ramps	northbound	32,080	14.7%	100	3,630	30.9%	100
	southbound	24,300	14.5%	100	2,760	30.4%	100
Between Minjungbal Drive on and off ramps and Northern Interchange on and off ramps	northbound	22,610	16.9%	100	2,640	34.8%	100
	southbound	17,100	17.0%	100	1,990	34.7%	100
Between Northern Interchange on-ramp and Tweed Heads Bypass	northbound	32,830	13.2%	100	3,670	28.6%	100

Section of Road or Ramp	Direction	Day – 7am to 10pm (15hr)			Night – 10pm to 7am (9hr)		
		Total Vehicles	Heavy Vehicle %	Speed[1]	Total Vehicles	Heavy Vehicle %	Speed[1]
Between Tweed Heads Bypass and Minjungbal Drive off-ramp	southbound	31,890	11.4%	100	3,450	24.9%	100
Pacific Highway Ramps							
Southern Interchange off-ramp	northbound	3,860	2.1%	80	360	5.6%	80
Southern Interchange on-ramp	southbound	3,310	2.7%	80	320	6.3%	80
Minjungbal Drive off-ramp	northbound	9,470	9.4%	80	990	20.2%	80
Minjungbal Drive on-ramp	southbound	7,200	8.8%	80	770	19.5%	80
Northern Interchange on-ramp	northbound	10,220	5.0%	60 / 100	1,030	12.6%	60 / 100
Minjungbal Drive off-ramp	southbound	14,790	4.9%	80	1,460	11.6%	80
Local Roads							
Southern Interchange - Old Pacific Highway	northbound	4,620	1.7%	80	430	4.7%	80
	southbound	4,020	2.2%	60	390	5.1%	60
Sexton Hill Drive - south of Terranora Rd	northbound	4,090	2.0%	60	380	5.3%	60
	southbound	3,490	2.6%	60	340	5.9%	60
Terranora Road	northbound	5,160	0.0%	60	480	0.0%	60
	southbound	6,160	0.0%	60	570	0.0%	60
Sexton Hill Drive - between Terranora Rd & Laura St	northbound	6,190	1.3%	60	580	3.4%	60
	southbound	6,590	1.4%	60	630	3.2%	60
Laura Street east of Pacific Highway	eastbound	2,420	0.0%	60	210	0.0%	60
	westbound	2,490	0.0%	60	230	0.0%	60
Sexton Hill Drive - between Laura St & Darlington Drive	northbound	7,610	1.1%	60	710	2.8%	60
	southbound	7,940	1.1%	60	740	2.7%	60
Darlington Drive	northbound	11,230	4.5%	60	1,100	10.9%	60
	southbound	9,580	4.4%	60	940	10.6%	60

Note: 1. Speed represents the posted speed

By comparing the traffic volumes monitored in November 2012 (Table 7.1) to the forecasted design year 2022 Average Annual Daily Traffic (AADT) traffic volumes, it is found that traffic volumes are predominantly lower in November 2012 than the 2022 AADT. This is as expected given the 10 year time gap and the corresponding traffic growth between the two periods. Also the general approach taken during the design stage was to model noise impacts using conservatively high traffic volume forecasts for 2022 as shown.

Notwithstanding the above, it is noted that the difference in total traffic volumes between these two periods translates to only a small difference in noise levels, as it generally takes more than approximately a 25%, 60% or 100% traffic volume increase to increase noise levels by 1dB(A), 2dB(A) or 3dB(A), respectively.

Relevant to this operational noise report, traffic data was collected concurrently with the noise monitoring in November 2012 to compare to the 2022 AADT traffic data that was used in the design model, so the design noise model can be adjusted to give equivalent 2012 modelled noise levels at each monitoring location. This process is described in more detail further in this ONR.

8 Noise Assessment Methodology

8.1 Noise Assessment Protocol

According to Practice Note viii of the ENMM, the operational noise monitoring and assessment protocol is as follows:

> *"Post-construction monitoring is undertaken to determine whether the mitigation measures have been adequate for the predicted design noise levels to be met.*
>
> *The "Design Noise Level for Year 1" is the noise level for the road development at project opening, after all feasible and reasonable mitigation strategies have been applied.*
>
> *Provided traffic flows and mixes following the road's opening are in line with those used for the predictions, it can be expected that if the predicted noise levels for Year 1 are achieved the predicted Year 10 noise levels will also be achieved.*
>
> *It should be recognised that noise prediction modeling has some accuracy limitations and will commonly produce acceptable errors of around 2 dB(A). In addition, when noise levels for a new road are being monitored short-term and uncharacteristic variations in traffic flow need to be taken into account when comparing the measured and predicted noise levels."*

Also according to Practice Note viii of the ENMM, if the monitoring indicates operational noise levels exceeding the design noise levels for Year 1 then the following action shall be taken:

1. *"If the measured noise levels exceed the design noise levels for Year 1 by 2 dB(A) or less, the noise data should be examined, the prediction methodology and suitability of mitigation measures should be reassessed and the reasons for the marginal exceedance(s) be identified and reported.*
2. *If measured noise levels exceed the design noise level for Year 1 by more than 2 dB(A), the adequacy of the noise mitigation needs to be reviewed, and if problems are identified steps need to be taken to rectify the situation. Additional noise treatments may be required to achieve the design noise level, where this is feasible and reasonable."*

8.2 Compliance Assessment Procedure

An assessment of compliance with the operational noise levels predicted in the review of operational noise mitigation measures presented in the ONMR was undertaken, as required by MCoA 3.2. The methodology used for the assessment is as follows:

1. Monitor operational traffic noise levels of the project in Year 1 (November 2012) at the monitoring locations presented in Table 6.1 and Table 6.2 of this ONR.
2. Correlate the long-term monitoring with the short-term monitoring at relevant location/s on each property and apply a correction to establish equivalent traffic noise levels at all critical floor levels and positions of buildings selected for assessment.
3. Concurrently with the noise monitoring, monitor traffic volumes, vehicle classifications and vehicle speeds in Year 1 (November 2012) along the main alignment, ramps and local roads.

4. Compare the monitored traffic data for Year 1 to the traffic data used in the design noise model and determine a noise level adjustment, based on the difference in traffic data at each location.

5. Apply the noise level adjustment to normalise the monitored Year 1 noise levels with the modelled Year 1 noise levels at each location. This allows for a direct and meaningful comparison to be made at Year 1 between the monitored 2012 noise levels and the modelled 2012 noise levels using the design noise model.

6. Compare the 2012 monitored noise levels to the 2012 modelled noise levels at each monitoring location to evaluate the accuracy of the noise model used during the design phase of the project.

7. Where the monitored noise levels are found to exceed the modelled noise levels by 2dB(A) or less [ie monitored levels are within +2dB(A) of modelled levels], then the:

    i. noise data and traffic data requires examination,

    ii. the prediction methodology and mitigation measures require checking, and

    iii. reasons for the marginal exceedance(s) identified and reported.

    Notwithstanding this, it is noted that the project's operational noise levels are deemed to comply with the project's noise design objectives where the monitored noise levels are found to be within +2dB(A) of the modelled noise levels.

8. Where the monitored noise levels are found to be greater than 2dB(A) in comparison to the modelled noise levels [ie monitored levels are greater than +2dB(A) of the modelled levels], then a more detailed analysis is required including:

    i. close inspection of the installed in-corridor noise mitigation measures in case of defects which can be rectified,

    ii. close inspection of the as-built road corridor survey and comparison to the project's design drawings and files, and

    iii. where appropriate, consider impacts from other non-project road traffic noise.

9. Following Step 8 above and in accordance with MCoA 3.2 (e), locations of non-compliance would have the noise model for their surrounding area recalibrated using the monitored traffic data and the monitored noise levels. The noise model would be re-run to identify each property where the monitored noise levels at year of opening are greater than +2dB(A) above the modelled noise levels at year of opening.

10. Following Step 9 above and in accordance with MCoA 3.2 (f), run the recalibrated noise model to establish revised design year (Year 10, 2022) traffic noise levels at the identified subject properties and compare these against the project's noise goals as set out in the ONMR to identify properties exceeding those goals.

11. Following Step 10 above and in accordance with MCoA 3.2 (g), evaluate the adequacy of the noise mitigation measures implemented for the identified subject properties. Where the noise mitigation measures are found to be inadequate, additional feasible and reasonable noise mitigation measures would require investigation with the objective of meeting the project's noise goals.

It is noted, where monitored 2012 (Year 1) noise levels are found to exceed the modelled 2012 (Year 1) noise levels by 2dB(A) or less [ie monitored levels are within +2dB(A) of modelled levels], then this confirms that the modelled 2022 (Year 10) noise levels presented in the ONMR will also be within 2dB(A) of actual noise levels in 2022 (Year 10). This is supported by Practice Note viii of the ENMM, which states:

> *"Provided traffic flows and mixes following the road's opening are in line with those used for the predictions, it can be expected that if the predicted noise levels for Year 1 are achieved the predicted Year 10 noise levels will also be achieved."*

8.3 Additional Noise Mitigation Measures

In accordance with the ENMM and the Banora Point Upgrade - Operational Noise Monitoring Plan, additional mitigation measures will only be considered where monitored 2012 noise levels are found to be greater than 2dB(A) in comparison to modelled 2012 noise levels [ie monitored levels are greater than +2dB(A) of modelled levels], and only after the completion of Steps 8, 9, 10 and 11 of the above procedure. Any necessary additional mitigation measures will be determined and provided where feasible and reasonable in accordance with the ECRTN and the ENMM.

'Feasibility' relates to engineering considerations and what can practically be built. 'Reasonableness' is judged in terms of noise mitigation benefits and costs, and many other aspects such as community views, aesthetic impacts, existing and future noise levels at the affected sites and the benefits arising from the development.

Given that there are physical limitations associated with applying any necessary additional noise mitigation measures to within the road corridor as the project has been constructed and is operational, where found necessary and practical, consideration will be given to the provision of at-property treatment to additional properties, subject to the consent of affected property owners. That is, any additional at-property mitigation measures will be determined in consultation with affected property owners.

8.4 L_{Amax} Noise Assessment

L_{Amax} events from the project are generally from heavy vehicles passing by the monitoring locations and at some locations from vehicles travelling over the expansion joints of the viaduct.

The L_{Amax} noise levels measured at the L_{Amax} monitoring locations presented in Table 6.3 were compared to the L_{Amax} noise levels measured in 2009 during the pre-construction noise monitoring and presented in the ONMR.

9 Noise Monitoring Results and Assessment

9.1 Monitored Operational Traffic Noise

The operational noise levels measured at the nominated monitoring locations are summarised in Table 9.1 below. For multi-storey dwellings, noise levels are presented for the ground floor level and the upper floor level/s, determined through the correlation of long-term noise monitoring results and short-term noise monitoring results.

Furthermore, Table 9.1 also presents the modelled 2012 operational noise levels as described in Section 8.1 for the corresponding monitoring locations. The difference between the modelled 2012 operational noise levels and the monitored 2012 operational noise levels are presented to determine the accuracy of the noise model used in the design phase. As discussed previously, where differences are greater than 2dB(A) [ie. monitored 2012 operational noise levels are greater than +2dB(A) of the modelled 2012 operational noise levels] a more detailed analysis of the adequacy of the mitigation measures implemented will be required.

Results of the long-term operational noise monitoring are presented in Annexure C.

Table 9.1 – Comparison of Monitored 2012 and Modelled 2012 Operational Noise Levels

Location No.	Monitoring Address	Floor Level	Facade	Monitored 2012 Operational Noise Level, dB(A)		Modelled 2012 Operational Noise Level[1], dB(A)		Difference Between Monitored and Modelled Noise Levels[2], dB(A)	
				$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night
M1	36 Summit Drive	Ground	Northeast	67	62	69	64	-2.4	-1.8
M2	10 Pacific Highway	Ground	North	61	53	60	54	0.9	-1.8
		First	North	60	51	61	55	-1.6	-4.2
M3	20 Somerset Avenue	Ground	North	61	54	61	55	-0.5	-0.4
M4	5 Pacific Highway	Ground	East	67	60	64	57	2.6	2.8
M5	40 Pioneer Parade	Ground	Northeast	64	57	63	57	1.8	0.8
M6	18 Pioneer Parade	Ground	East	63	57	65	61	-2.3	-4.0
		First	East	69	64	68	64	1.3	-0.4
M7	17 Pioneer Parade	Ground	East	57	50	55	51	1.9	-0.8
M8	50 Martinelli Avenue	Ground	South	59	54	59	56	-0.3	-1.7
		First	South	57	52	60	56	-3.1	-4.5
M9	51 Bione Avenue	Ground	Southwest	61	58	61	58	-0.4	-0.2
		First	Southwest	62	59	63	60	-1.2	-1.0
M10	10 Laura Street	Ground	South	58	51	58	55	0.2	-4.1
M11	11 Elsie Street	Ground	Northwest	61	57	61	57	0.2	-0.4
M12	1 Oyster Point Road	Ground	North	59	54	57	52	2.0	1.9
		First	North	60	55	59	54	0.4	0.3
		First	West	61	56	59	54	1.8	1.8
M13	42 Kimberley Circuit	Ground	East	59	54	60	55	-0.2	-0.3
M14	113 Winders Place	Ground	Northeast	61	55	59	55	1.5	-0.3
M15	60/12 Trigonie Drive	Ground	Southeast	56	52	58	53	-1.8	-0.5
M16	42/12 Trigonie Drive	Ground	South	52	47	55	50	-2.7	-3.0
M17	159/67 Winders Place	Ground	Northeast	60	55	58	54	2.0	0.7
M18	8 Banora Boulevard	Ground	North	62	57	61	57	1.8	0.1
M19	14 Laura Street	Ground	North	60	55	60	56	-0.1	-1.4
M20	Unit 2, 41A Bione Avenue	First	Southwest	66	62	66	63	-0.3	-1.1

Location No.	Monitoring Address	Floor Level	Facade	Monitored 2012 Operational Noise Level, dB(A)		Modelled 2012 Operational Noise Level[1], dB(A)		Difference Between Monitored and Modelled Noise Levels[2], dB(A)	
				$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night
		Second	Southwest	70	66	70	66	0.3	-0.5
		Second	Northwest	65	61	64	61	1.2	0.1
		Second	Southeast	69	65	69	65	0.4	-0.4
M21	5/57 Bione Avenue	Ground	West	58	53	58	54	-0.8	-1.4
		First	West	59	54	59	56	0.1	-1.4
		First	South	57	52	57	54	-0.2	-1.8

Notes:
1. Based on adjustment applied to year 2022 noise levels modelled using the design noise model. Adjustments were calculated through comparison of 2012 monitored traffic data and 2022 AADT forecasted traffic data used in the design noise model.
2. As per the ECRTN and the ENMM, reported noise levels are presented as rounded whole numbers. Differences in noise levels are presented to 1 decimal point to allow for a more detailed comparison.

9.2 Investigation of Marginal Differences

From Table 9.1 it can be seen that monitored 2012 operational noise levels at all monitoring locations are within +2dB(A) of the modelled 2012 operational noise levels, which are considered marginal differences, with the exception of one property which is discussed later.

In accordance with Step 8 of the Compliance Assessment Procedure presented in Section 8.2 of this ONR, where there are marginal differences at a monitoring location, an examination of the operational noise monitoring results and the adequacy of the mitigation measures are investigated. Table 9.2 below presents the outcomes of the investigation and reasons for the marginal differences for each property monitored to be within +2dB(A) of its corresponding modelled noise level. Locations found to have modelled noise levels higher than monitored noise levels are not covered in Table 9.2, as predicted noise levels at these locations are conservatively higher than actual noise levels.

Table 9.2 – Investigation of Properties with Marginal Noise Level Differences

Location No.	Monitoring Address	Comply with Project's Noise Criteria?		Noise Level is NOT Acute?	Low Noise Pavement?	Noise Barrier?	At-Property Treatment?	Comments
		Target	Allowance					
M2	10 Pacific Highway	×	×	✓	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in day noise levels. Also the main alignment of new Pacific Highway located further than the old Pacific Highway.
M4	5 Pacific Highway	×	✓	×	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the +2.6 to +2.8dB(A) differences in day noise levels. Also the main alignment of the new Pacific Highway is located further than the old Pacific Highway, therefore the project noise contributions are insignificant compared to other traffic noise. Overall traffic noise levels have also significantly reduced due to the project and the receiver has achieved a significant noise benefit as a result.
M5	40 Pioneer Parade	×	✓	✓	✓	✓	×	Main alignment of new Pacific Highway located further than old Pacific Highway with significant noise contributions from Sexton Hill Drive adding to the total noise levels; main alignment located in a cutting with large retaining walls and noise walls offering significant noise shielding and landbridge provides additional shielding. Additional noise mitigation is therefore not reasonable.
M6	18 Pioneer Parade	×	✓	×	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in day noise levels. Also significant noise contributions from Sexton Hill Drive adds to the total noise levels. Furthermore, the main alignment of the new Pacific Highway is located further than the old Pacific Highway providing the receiver with a noise benefit from the project.
M7	17 Pioneer Parade	✓	N/A	✓	✓	✓	×	Noise levels comply with the project's noise criteria and are not acute. Therefore, no further noise mitigation measures required.

Location No.	Monitoring Address	Comply with Project's Noise Criteria?		Noise Level is NOT Acute?	Low Noise Pavement?	Noise Barrier?	At-Property Treatment?	Comments
		Target	Allowance					
M10	10 Laura Street	✓	✓	✓	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in day noise levels. The main alignment is also located in a cutting with large retaining walls providing significant noise shielding benefits.
M11	11 Elsie Street	×	✓	✓	✓	×	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in day noise levels.
M12	1 Oyster Point Road	×	N/A	✓	✓	✓	×	Main alignment located in a cutting with large retaining walls and noise walls providing significant noise shielding benefits; landbridge provides additional shielding and there is noticeable traffic noise contribution from Sexton Hill Drive adding to the total noise levels at this receiver. Also noise level differences range from +0.3 to +1.8dB(A) and noise levels are not acute. Therefore, additional noise mitigation is not considered reasonable.
M14	113 Winders Place	×	✓	✓	✓	✓	×	Noise levels comply with project's noise criteria and are not acute. Therefore, no further noise mitigation measures required.
M17	159/67 Winders Place	✓	✓	✓	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in noise levels.
M18	8 Banora Boulevard	×	✓	✓	✓	✓	✓	Noise levels comply with project's noise criteria and are not acute. Therefore, no further noise mitigation measures required.
M20	Unit 2, 41A Bione Avenue	×	×	×	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in noise levels and main alignment located in a cutting with large retaining walls and noise walls.
M21	5/57 Bione Avenue	×	×	✓	✓	✓	✓	Extent of at-property treatment provided is sufficient to address the marginal difference in day noise levels.

As shown in Table 9.1 a substantial number of properties were monitored to have noise levels below the modelled noise levels. Table 9.2 however deals with those properties found to have monitored noise levels greater than modelled noise levels.

Table 9.2 shows that although the monitored 2012 operational noise levels are within 0 to +2dB(A) of the modelled 2012 operational noise levels at some of the properties, the at-road and/or at-property mitigation measures implemented for these properties are determined to be adequate. In these circumstances, it is not reasonable to install additional noise mitigation measures.

Only one property had a difference greater than +2dB(A) between the monitored 2012 operational noise levels and the modelled 2012 operational noise levels. This property was 5 Pacific Highway, which was determined to have differences of +2.6dB(A) and +2.8dB(A) between the monitored 2012 operational noise levels and the modelled 2012 operational noise levels for the day and night periods, respectively. However, during the site visit to 5 Pacific Highway for the operational noise monitoring, it was observed that the predominant traffic noise was from Sexton Hill Drive (old Pacific Highway) and not the main alignment of the new Pacific Highway (the project). Traffic noise from the new Pacific Highway at this location was slightly audible and would not have contributed significantly to the overall traffic noise levels at the monitoring location.

In addition to the comparison between the monitored 2012 operational noise levels and the modelled 2012 operational noise levels for 5 Pacific Highway, a further comparison was made between the monitored 2012 operational noise levels and the noise levels monitored in 2009. Results of the comparison are presented in Table 9.3 below and are the noise levels monitored by the long-term noise monitor.

Table 9.3 – Comparison of 2009 and 2012 Monitored Noise Levels for 5 Pacific Highway

Address	2009 Monitored Noise Level, dB(A)		2012 Monitored Noise Levels, dB(A)	
	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night	$L_{Aeq\ (15hr)}$ Day	$L_{Aeq\ (9hr)}$ Night
5 Pacific Highway	74	70	66*	59*

*Note: * dominant traffic noise is from non-project traffic noise*

From the above table it can be seen that traffic noise levels from the old Pacific Highway (before the upgrade) monitored in 2009 were 8dB(A) and 11dB(A) higher than the traffic noise levels from the project monitored in 2012 for the day and night periods, respectively. Although the monitored 2012 operational noise levels at 5 Pacific Highway are slightly greater than 2dB(A) more than the modelled 2012 operational noise levels, overall traffic noise levels have significantly reduced due to the project and the receiver has achieved a significant noise benefit as a result, leaving behind only the residual noise from non-project traffic noise.

Furthermore, 5 Pacific Highway has already been treated under the Noise Abatement Program and the treatment provided is more than adequate to address the exceedance found, so it is not feasible and reasonable to provide further noise mitigation measures.

9.3 Noise Assessment Outcomes

The comparison confirms that there is a clear trend of compliance, that is monitored 2012 operational noise levels are within +2dB(A) of the modelled 2012 operational noise levels, which confirms the adequacy of the traffic noise mitigation measures applied to the project.

Given that the monitored 2012 (Year 1) operational traffic noise levels are found to be within +2dB(A) of the modelled 2012 (Year 1) operational noise levels, then the modelled 2022 (Year 10) noise levels presented in the ONMR will also be within 2dB(A) of actual noise levels in 2022 (Year 10) and is in accordance with the requirements of Practice Note viii of the ENMM.

Further to the results presented in Table 9.1, the relationship between the monitored 2012 operational noise levels and the modelled 2012 operational noise levels are also presented in graphical form below to demonstrate the adequacy of the noise model used in the design phase of the project.

From Figure 1, it can be seen that the $L_{Aeq(15hr)}$ modelled 2012 operational noise levels during the day period are typically the same as the monitored 2012 operational noise levels, which indicates that the noise model used during the design phase of the project was consistent in modelling operational noise levels for the day period. This is shown by comparing the line of 'ideal fit' (**black** line where modelled levels equal monitored levels) and the line of 'best fit' (**blue** line which is the regression line for the modelled and monitored data points).

Furthermore, Figure 2 shows $L_{Aeq(9hr)}$ modelled 2012 operational noise levels are typically slightly higher than the monitored 2012 operational noise levels for the night period. This is demonstrated by the line of 'best fit' (**blue** line which is the regression line for the modelled and monitored data points) being slightly above the line of 'ideal fit' (**black** line where modelled levels equal monitored levels). This indicates that the noise model used during the design phase was predicting slightly higher operational noise levels than actual noise levels monitored at the selected monitoring locations, resulting in a conservative noise model for the night period. Given that the night period is the determining period in terms of noise mitigation design for this project, then this assists in designing conservative noise mitigation measures for the project.

Figure 1 - Comparison of Modelled 2012 to Monitored 2012 Operational Noise Levels – Day $L_{Aeq(15hr)}$

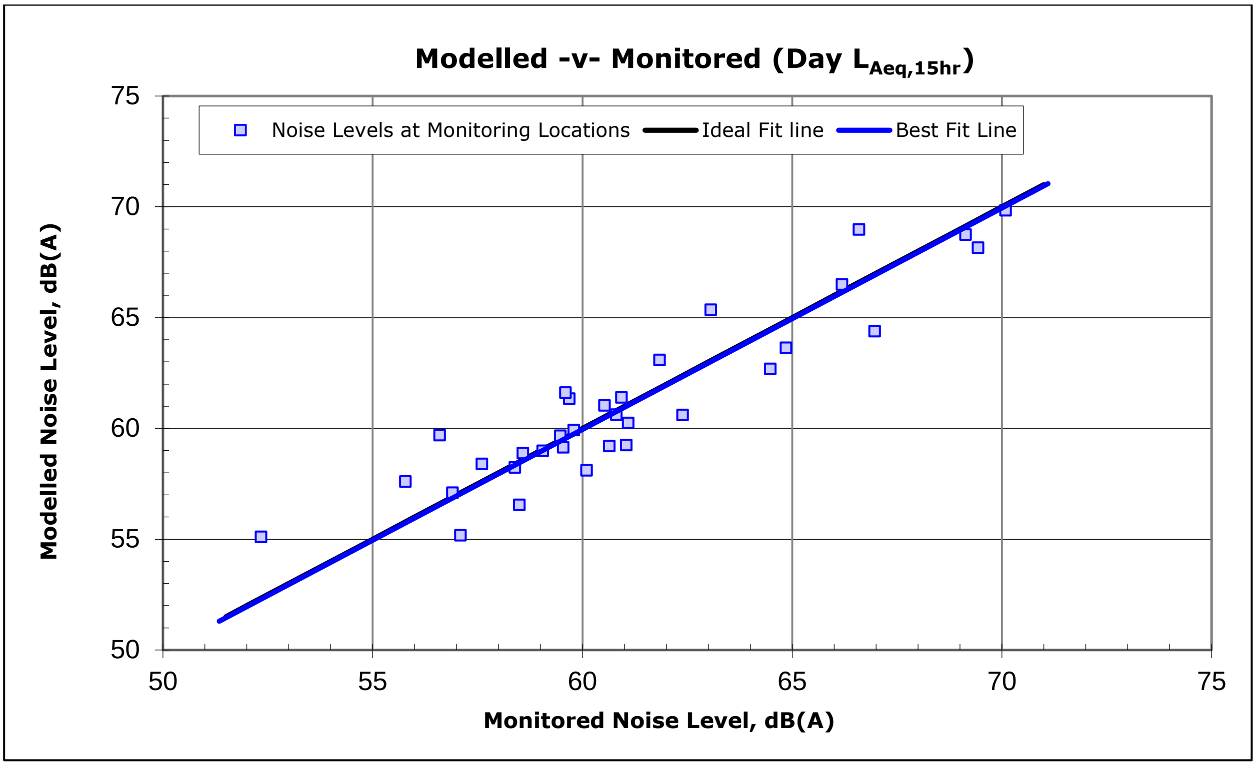
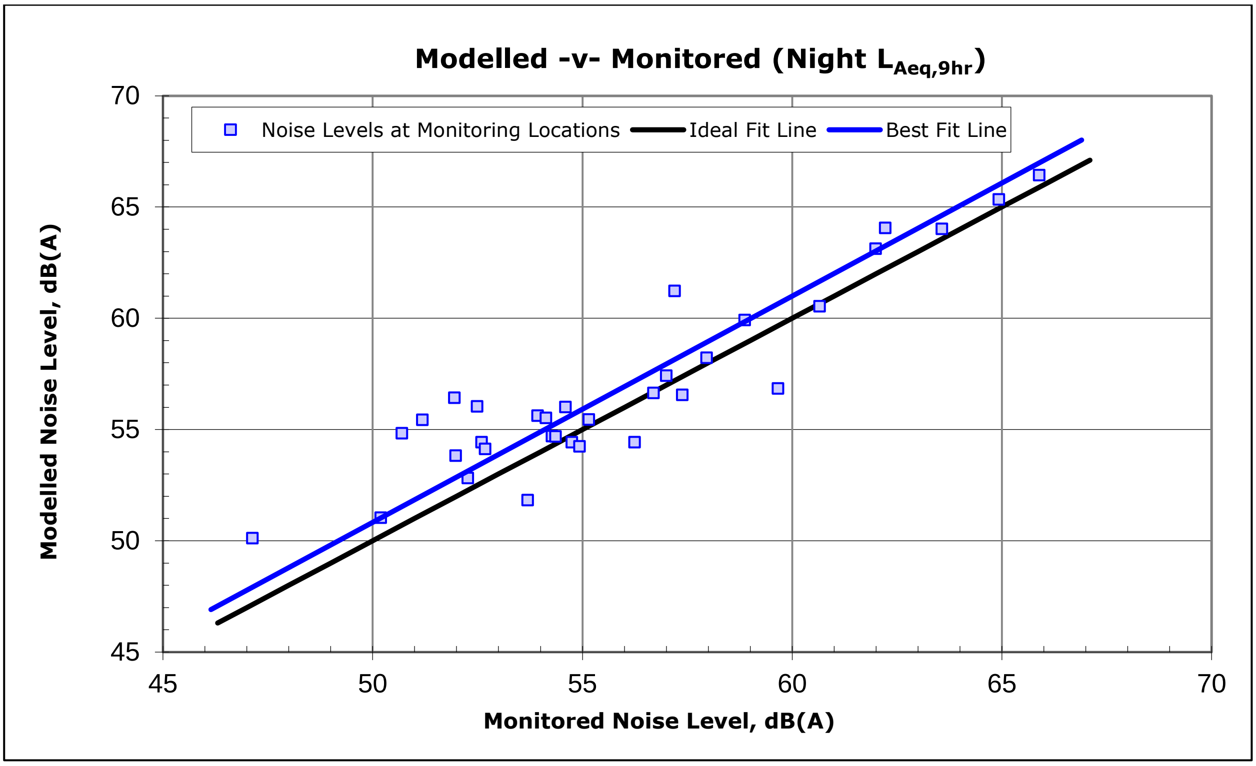


Figure 2 - Comparison of Modelled 2012 to Monitored 2012 Operational Noise Levels – Night $L_{Aeq(9hr)}$



9.4 L_{Amax} Noise Monitoring Outcomes

The L_{Amax} noise level represents the loudness of the maximum noise events and can be used when assessing sleep arousal. As recommended by the ENMM, the L_{Amax} noise levels reported below are those that occur at night (between 10pm and 7am), and where $L_{max} – L_{eq}$ is greater than 15dB(A).

Table 9.4 below summarises the comparison of the maximum noise level events measured at each monitoring location during the noise monitoring in 2009 and the operational noise monitoring in 2012. Detailed results of the maximum noise level monitoring are provided in Annexure D.

It is noted that the results from the 2012 operational noise monitoring are based only on the nights during the monitoring period where the data is not significantly affected by wind or rain (ie. no more than 1 hour) in order to obtain valid and reliable results.

Table 9.4 – Summary of Maximum Noise Level Events along Existing Pacific Highway

Address	Distance to Old Pacific Hwy	Distance to Project	L_{Amax} Range (10pm-7am), dB(A)		No. of Events (10pm-7am)	
			2009 Design Phase	2012 Operational	2009 Design Phase	2012 Operational
20 Somerset Avenue	20m	226m	77 – 92	69 – 72	23 – 40	13 – 27
5 Pacific Highway	18m	135m	77 – 91	73 – 75	19 – 49	62 – 86
18 Pioneer Parade	25m	46m	67 – 88	69 – 75	15 – 28	13 – 43
51 Bione Avenue[1]	180m	37m	N/A	73 – 77	N/A	27 – 64
42 Kimberley Circuit	27m	52m	65 – 78	70 – 74	7 – 19	25 – 49
113 Winders Place	18m	23m	67 – 90	69 – 75	16 – 29	31 – 64

Note: 1. L_{Amax} noise monitoring was not undertaken at this location in 2009

From the above table, the number of L_{Amax} noise level events monitored during the 2012 operational noise monitoring typically increased at four locations compared to the noise monitoring conducted in 2009 during the design phase. Only the monitoring location at 20 Somerset Avenue shows L_{Amax} noise level events to have decreased.

In the case of 51 Bione Avenue, a number of L_{Amax} noise level events could be attributed to vehicles travelling over the northern expansion joint of the viaduct, which is located directly adjacent to the property. However, since the post-opening noise monitoring was conducted, the underside of the northern abutment's expansion joint, which is closest to residential properties, was enclosed with a noise reducing baffle. This baffle is expected to reduce peak noise levels generated by vehicle tyres passing over the expansion joint and emanating from the underside of the viaduct, for the benefit of adjacent residential properties located along Bione Avenue.

Although L_{Amax} noise level events have increased following the operation of the project, L_{Amax} noise levels have reduced since those measured during the 2009 design phase. The reason for the decrease could be due to the main alignment of the new Pacific Highway being located further away compared to the old Pacific Highway (except for 51 Bione Avenue), at-road noise mitigation measures (eg noise barriers) and the reduction in the gradient (slope) of the main alignment, resulting in lower L_{Amax} noise levels from traffic on the main alignment.

10 Conclusion

Renzo Tonin & Associates (NSW) Pty Ltd has completed the operational noise monitoring and assessment of road traffic noise for the Pacific Highway Upgrade in Banora Point, NSW in accordance with the requirements set out in relevant Ministers Conditions of Approval, the NSW ‘Environmental Criteria for Road Traffic Noise’ and the NSW ‘Environmental Noise Management Manual’.

The design noise model was found to be within an acceptable margin of 2dB(A) for noise prediction modelling as per Practice Note viii of the ENMM at all operational noise monitoring locations, with the exception of one monitoring location. However, it was determined that traffic noise levels at this location have significantly reduced as a result of the project which provided a net benefit to the receivers along Sexton Hill Drive.

Therefore, the operational noise monitoring assessment confirms that the design noise model has been adequate in assisting with the design of suitable noise mitigation measures and confirms the adequacy in the performance and effectiveness of the traffic noise mitigation measures implemented on this project.