Moorland to Herons Creek EIS

Working Paper No. 3
Noise and Vibration Assessment

ArupAcoustics

NSW Roads and Traffic Authority

Moorland to Herons Creek

Noise and Vibration Working Paper

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This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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CONTENTS

1. INTRODUCTION

The Roads and Traffic Authority (RTA) is proposing to upgrade a 22.2 km section of the highway between Moorland and Herons Creek as part of the NSW Government's $1.6 billion contribution to the Pacific Highway Upgrading Program. This section of highway is located on the NSW Mid North Coast between Taree in the south and Kempsey to the north. The Project is proposed to extend from 2.4 km south of Johns River to the existing dual carriageway at Bobs Creek Road just north of Herons Creek. The project will include highway improvements at the townships of Johns River and Kew.

A more detailed description of the proposal is provided in the full EIS.

The proposal will significantly increase the traffic carrying capacity of the highway, and allow higher speeds. The proposal includes several bypass sections (around Johns River and Kew) where there will be a major realignment of the roadway.

This noise and vibration working paper provides an assessment of the expected noise and vibration impacts from the construction and operation of the proposed highway. It provides a review of the measures required to mitigate the adverse impacts.

A comprehensive introduction to traffic noise and a glossary of terms can be found in Section 1 of the RTA Environmental Noise Management Manual, which is available at www.rta.nsw.gov.au/environment/noise/noise_management_manual.html.

2. GENERAL NOISE AND VIBRATION IMPACTS FROM HIGHWAYS

Noise is a consequence of both the construction and use of a major highway. Assessment criteria vary accordingly and applicable codes and standards are discussed in Section 4. The following paragraphs describe the key issues and effects.

During construction works, airborne noise is generated by construction equipment such as bulldozers, rock-breakers, compactors and generators. Road traffic generates airborne noise, due to both the rolling noise of vehicle wheels on the road surface, and engine / exhaust noise of vehicles (especially heavy vehicles such as articulated truck/trailer units).

Airborne noise spreads geometrically from the source, with sound levels reducing progressively with distance. For a source of significant length, such as a many vehicles travelling along the same stretch of road, the attenuation of sound with distance is less than for a “point” source such as a stationary vehicle or an item of construction plant.

Some noise sources have particular directivity characteristics, ie the noise is radiated more intensely in certain directions. For example, exhausts from earth moving machinery are often noisier in the direction that their exhaust is pointing. The height of the source above ground levels can also be relevant. Elevated sources such as the exhaust of a heavy diesel truck or the hammer of a percussive piling rig may result in a sound propagation path that is less obstructed by topographical features or noise barriers, resulting in higher noise levels at a given distance.

Features that block the sound propagation path, such as ridge lines or man-made objects such as buildings or noise barriers, result in the attenuation of noise relative to an uninterrupted path. Care must be taken as large sound reflecting surfaces, such as buildings, can also result in the reflection of additional sound that can adversely impact on noise sensitive receivers.

Airborne noise is generally assessed in terms of the external noise level at a receiver position. Resulting noise levels within buildings will be lower as a result of the sound attenuation provided by the building envelope. The extent of this noise reduction depends on the building construction; with windows open, internal noise levels are typically approximately 10 dB(A) lower than external levels. With windows closed, external levels may be attenuated by 20 dB(A) or more.

Noise and vibration impacts on the community may be categorised as follows, in order of increasing severity:

- community/resident annoyance,
- disturbance to community/resident activities (eg sleep disturbance) and
- adverse effects on human health (eg increased blood pressure, heart rate or impaired performance due to lack of sleep).

Airborne noise has been known to have other adverse effects, such as sleep disturbance for humans, and effects on wildlife, but less research has concentrated on these impacts, and the evidence demonstrating the extent of the impacts is not clear.

3. EXISTING NOISE ENVIRONMENT

3.1 Methodology

During July 2002 ambient noise measurements were conducted at locations along the existing highway and proposed route of the highway upgrade. Unattended noise loggers were used to continuously measure noise at two locations for 12 days between 22 July and 1 August 2002. Attended measurements were also conducted at these and a further thirteen locations along the proposed route on 22, 23, 24, 25 July and 1, 2 and 3 August 2002.

A description of the monitoring locations is given in Section 3.3 below.

The two noise loggers and the sound level meter were mounted on tripods 1.5 m above ground level and set to *fast* time response. The L_{Aeq}, L_{Amax}, L_{A10} and L_{A90} noise indices were measured in free-field conditions (ie away from noise reflecting structures) with a sample period of 15 minutes.

Weather conditions were noted throughout the measurement period from 22 July to 3 August 2002 and noise measurements were discarded where weather conditions were not suitable for noise monitoring.

All measurements were performed in accordance with Australian Standard 1055[1].

3.2 Equipment

The following equipment was used to obtain the baseline noise information:

Equipment manufacturer & type	Description of equipment	Serial No.
Brüel & Kjær 2236	Type 1 sound level meter	1778333
Brüel & Kjær 4188	Condenser microphone	1779907
Brüel & Kjær 4231	Sound level calibrator	1790603
RTA Technology	Sound logging meter	082
RTA Technology	Sound logging meter	083

Table 2: Summary of noise measurement equipment.

1 AS 1055-1997 *Acoustics - Description and measurement of environmental noise*, Standards Australia.

The equipment was checked for calibration before and after each set of measurements.

3.3 Description of Measurement Locations

Ambient noise measurements were undertaken at 14 locations adjacent to the existing and proposed highway alignment. The measurement locations are shown on Figure 1 below, and are described in detail in Sections 3.3.1 to 3.3.14. (Ambient noise measurement locations are also shown in Appendix B).

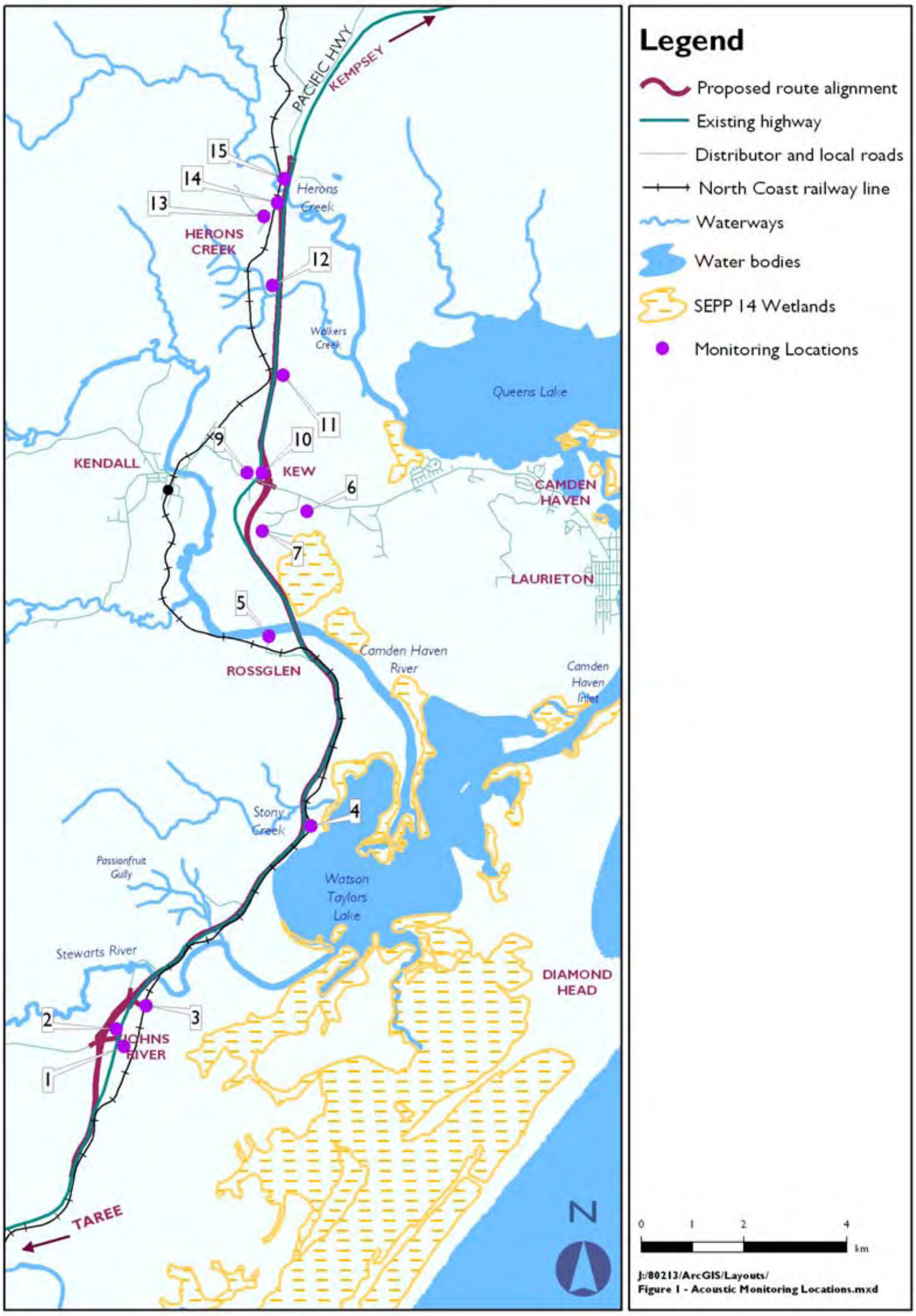


Figure 1: Ambient noise measurement locations.

3.3.1 Site 1 - School, Station Street, Johns River

This location is situated in the main residential area of Johns River and is the southern most monitoring location. It is set back from the Pacific Highway behind two residential properties. There is no line of sight to the Pacific Highway, although this is the dominant noise source affecting this site. Throughout a 24-hour period it was observed that the traffic mix on the Pacific Highway changed from predominantly cars during the day to predominantly heavy goods vehicles during the night.

3.3.2 Site 2 - 253, Pacific Highway, Johns River

This site was an unattended noise monitoring site. It fronts on to the Pacific Highway and is opposite the local store. Traffic is generally fast moving through Johns River and is the dominant noise source at this location.

3.3.3 Site 3 - 28 Wharf Road, Johns River

Wharf road is off the northern outskirts of Johns River. This location is a few hundred metres from the Pacific Highway and only about 50 metres from the North Coast Railway Line. The Pacific Highway is shielded from view when looking directly ahead, but is visible to the left and right. A small number of trains pass this location during both the day and night, when they are the dominant noise source. Although generally traffic, and in particular HGV's are dominant noise sources.

3.3.4 Site 4 - Watson Taylor Road, Stony Creek

This site is set back approximately 150 metres from the Pacific Highway and approximately 30 metres behind the North Coast Railway Line. There is a direct line of sight to the Pacific Highway up Watson Taylor Road. The Pacific Highway is generally the dominant noise source except when trains occasionally pass.

3.3.5 Site 5 - Rossglen Road, Rossglen

This site is located beside the Camden Haven River at the end of Rossglen Road. The North Coast Railway is approximately 200 metres north of the monitoring position. There is a direct line of sight to the Pacific Highway Bridge over the Camden Haven River. Traffic on the bridge is the dominant noise source at this location.

3.3.6 Site 6 - Camden Haven High School, Kew

This site is located outside the school entrance in Valley View Road and is in the region of 1 km east of the Pacific Highway. The Pacific Highway is completely shielded from the monitoring location although it can be heard as a rumble. Ocean Drive running adjacent to the northern boundary of the School is less busy than the Pacific Highway, but due to its closer proximity is the dominant noise source.

3.3.7 Site 7 - Glen Haven Drive, Kew

This site is located at the cul-de-sac at the end of Glen Haven Drive. There is no line of sight to the Pacific Highway due to trees and local ground topography. The Pacific Highway is only a few hundred metres west of the site and is the dominant noise source.

3.3.8 Site 8 - Camden Haven Golf Club, Kew

This site is located at the east side of the Camden Haven Golf Club car park. There is line of sight to the Pacific Highway as it slowly rises north of Kew, while the section in the centre and south of Kew is shielded by various buildings. There is some traffic on Kendall Road that runs past the south end of the golf club car park, although the heavier traffic flow on the Pacific Highway is the dominant noise source.

3.3.9 Site 9 - 4926 Pacific Highway

This site is located on the east side of the Pacific Highway as it rises on an incline north from the centre of Kew. The site is on an earth bank beside the Pacific Highway and consequently only has a grazing incidence of line of sight to the Road. The Pacific Highway is the dominant noise source.

3.3.10 Site 10 - Hastings Council Sewerage Treatment Plant

This site is located approximately half way between Kew and Herons Creek on the east side of the Pacific Highway. The monitoring location was approximately 150 metres down the road that leads to the treatment plant. There is a grazing incidence line of sight to the Pacific Highway, which is the dominant source of noise.

3.3.11 Site 11 - 5301 Pacific Highway

This is the second unattended monitoring site. It is located 1 - 2 km south of Herons Creek on the west side of the Pacific Highway. The noise logger was set up approximately 100 metres from the Pacific Highway. There is line of sight to the road, which is the dominant noise source.

3.3.12 Site 12 - Blackbutt Road, Herons Creek

This site is located approximately 75 metres down Blackbutt Road that runs west off Herons Creek Road in Herons Creek. The timber works close by on Herons Creek Road is a source of noise during the day although noise from vehicles on the Pacific Highway is still audible. At night the Pacific Highway is the dominant noise source. There is no line of sight to the Pacific Highway. The North Coast Railway is set back by approximately 20 - 30 metres from the east side of Herons Creek Road and is visible from the monitoring position. However, the infrequent trains do not significantly affect the local noise climate.

3.3.13 Site 13 - Banks Road, Herons Creek

This site is located half way down Banks Road in Herons Creek. The North Coast Railway runs parallel and to the west of Banks Road, and the Pacific Highway runs approximately 100 metres to the east, parallel with the railway. The infrequent trains are dominant when they pass, but at other times the Pacific Highway is the dominant source of noise.

3.3.14 Site 14 - Herons Creek Public School, Herons Creek

This site is located near the northern boundary of Herons Creek and borders the west side of the Pacific Highway. The Pacific Highway splits into two separate north and southbound lanes just north of the school. The classrooms and monitoring position are approximately 70 metres from the school where there is a line of sight broken up by trees. The North Coast Railway runs in a cutting behind the schools rear boundary, and is out of sight. The Pacific Highway is the dominant source of noise.

3.4 Ambient Noise Measurement Results

The 15-minute attended ambient noise measurement results are presented in Table 3 below. Unattended noise level measurement results are shown in Appendix A.

Traffic volumes were recorded at existing traffic monitoring stations throughout the measurement period by the RTA. Data from RTA Stations No. 09.043.N and 09.043.S were used for verification of the acoustic model.

Site No	Monitoring Locations.	L_{A90}	L_{A10}	L_{Aeq}	Time
1	School, Station Street, Johns River	49	56	53	17:30
1	School, Station Street, Johns River	46	54	51	13:55
1	School, Station Street, Johns River	42	55	51	22:40
1	School, Station Street, Johns River	28	56	51	02:45
2	Rear of 253 plot, Pacific Highway, Johns River	46	60	56	23:00
2	Rear of 253 plot, Pacific Highway, Johns River	32	55	53	03:05
3	Quondong, 28 Wharf Rd, Johns River	43	53	51	13:25
3	Quondong, 28 Wharf Rd, Johns River	48	61	63	17:50
3	Quondong, 28 Wharf Rd, Johns River	52	58	54	23:20
3	Quondong, 28 Wharf Rd, Johns River	49	59	56	03:25
4A	Stoney Creek carpark	54	62	59	17:30
4A	Stoney Creek carpark	40	60	55	03:50
4	Watson Taylor Rd, off Pacific Highway	52	59	56	13:00
4	Watson Taylor Rd, off Pacific Highway	43	59	60	22:15
5	End of Ross Glen Rd, Ross Glen	35	43	42	14:30
5	End of Ross Glen Rd, Ross Glen	43	51	47	17:00
5	End of Ross Glen Rd, Ross Glen	34	43	42	21:50
5	End of Ross Glen Rd, Ross Glen	38	51	47	04:10
6	Entrance to Camden Haven High School	40	49	47	16:25
6	Entrance to Camden Haven High School	36	44	42	21:30
6	Entrance to Camden Haven High School	37	46	44	04:30
7	End of Glen Haven Drive, Camden Haven	39	45	43	15:00
7	End of Glen Haven Drive, Camden Haven	37	45	46	16:00
7	End of Glen Haven Drive, Camden Haven	33	45	42	21:05
7	End of Glen Haven Drive, Camden Haven	38	44	42	04:55
9	Camden Haven Golf Club	44	53	50	15:15
9	Camden Haven Golf Club	48	56	53	15:20
9	Camden Haven Golf Club	42	54	50	20:45
9	Camden Haven Golf Club	44	54	51	05:15
10	4926 Pacific Highway, Kew	49	60	58	14:50
10	4926 Pacific Highway, Kew	48	62	58	20:20
10	4926 Pacific Highway, Kew	45	60	56	05:35
11	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	43	50	47	14:10
11	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	40	55	52	23:55
11	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	40	57	53	02:15
12	5301 Pacific Highway, Herons Creek	44	56	53	1355:
12	5301 Pacific Highway, Herons Creek	41	57	53	00:20
13	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	39	47	49	13:30

Site No	Monitoring Locations.	L_{A90}	L_{A10}	L_{Aeq}	Time
13	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	35	44	41	00:45
13	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	36	48	54	06:00
14	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	41	57	53	12:50
14	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	39	61	56	19:55
14	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	45	57	53	06:15
15	Herons Creek Public School, Pacific Highway	45	57	54	12:30
15	Herons Creek Public School, Pacific Highway	44	61	57	19:30
15	Herons Creek Public School, Pacific Highway	37	60	55	01:40

Table 3: Ambient noise measurement results.

4. NOISE CRITERIA

4.1 Operational Noise Criteria

The basic noise criteria for the assessment are the EPA *Environmental Criteria for Road Traffic Noise* (ECRTN). The noise criteria are measured at the façade of the building at a height of 1.5 m and are;

Type of Development	Criteria		
	Day (7am - 10pm) dB(A)	**Night (10pm - 7am) dB(A)**	**Where criteria are already exceeded.**
1. New freeway or arterial road	55 $dBL_{Aeq,15hr}$	50 $dBL_{Aeq,9hr}$	New road designed so as not to increase existing levels by more than 0.5 dB
3. Redevelopment of existing freeway/arterial road	60 $dBL_{Aeq,15hr}$	55 $dBL_{Aeq,9hr}$	Redevelopment should be designed so as not to increase existing noise levels by more than 2 dB
Sensitive Land Use			
Active recreation areas	60 $dBL_{Aeq,15hr}$	-	
Passive recreation and school playgrounds	55 $dBL_{Aeq,15hr}$	-	
Existing school classrooms	50 $dBL_{Aeq,1hr}$ (internal)		

Table 4: Basic noise level criteria (after Tables 1 & 2 EPA ECRTN).

In addition, Practice Note IV of the *RTA Environmental Noise Management Manual* (ENMM) provides guidance on “selecting and designing ‘feasible and reasonable’ treatment options for road traffic noise". This practice note suggests that noise mitigation should be provided if noise levels are *acute*, ie greater than or equal to 65 $dBL_{Aeq,15hr}$ (daytime) and 60 $dBL_{Aeq,9hr}$ (night-time).

These criteria have been applied along the proposed route as following;

Station	Area	Criteria
0 – 1100 m	South of Johns River	Redevelopment of existing freeway/arterial road
1100 – 3800 m	Johns River Bypass	New freeway or arterial road
3800 – 14400 m	Watson Taylor Lake	Redevelopment of existing freeway/arterial road
14400 – 16500 m	Kew Bypass	New freeway or arterial road
16500 – 22200 m	Herons Creek	Redevelopment of existing freeway/arterial road

Table 5: Application of noise level criteria to the route.

It should be noted that the road traffic noise criteria are provided as guidelines and are "non-mandatory". They provide target noise levels that it is desired to meet where it is reasonable and feasible to do so. The policy document states that in some instances this may be achievable only through "long-term strategies such as improved planning; design and construction of adjoining land use developments; reduced vehicle emission levels through new vehicle standards and regulation of in-service vehicles; greater use of public transport; and alternative methods of freight haulage".

4.2 Sleep Disturbance Criteria

The relationship between event maximum noise levels from road traffic and sleep disturbance is not currently well defined. The ECTRN discuss sleep disturbance in relation to the number of noise events causing awakenings during the night-time period. As the relationship between noise and sleep disturbance is not fully understood, the ECTRN acknowledges sleep disturbance from road traffic and states that the continuation of research into its assessment is important.

It identifies that;

- Maximum internal nosie levels below 50-55 dB(A) are unlikely to cause awakening reactions, and
- One or two noise events per night, with maximum internal noise levels of 65-70 dB(A) are not likely to affect health and wellbeing significantly.

The RTA Environmental Noise Management Manual (ENMM) was published following the inception of this project, and provides a protocol for assessing maximum noise levels in Practice Note III (PN-III).

PN-III suggests that;

- at locations where road traffic is continuous rather than intermittent, the $L_{eq,9hr}$ (night-time) target noise levels should sufficiently account for sleep disturbance impacts.
- however, where the emergence of maximum levels (L_{max}) over the ambient (L_{eq}) is greater than 15 dB(A), the $L_{eq,9hr}$ criteria may not sufficiently account for sleep disturbance impacts.

Therefore, an assessment of the impact of sleep disturbance on residents is made in terms of likely maximum noise levels from road traffic, the extent to which these maximum noise levels exceed the ambient level, and the expected number of noise events from road traffic during the night.

4.3 Construction Noise and Vibration Criteria

Construction noise and vibration is temporary in nature. Many of the construction activities associated with a highway infrastructure project usually only occur in a particular location for a matter of days or weeks as work progresses along the length of the line. In addition to site-wide works, some construction activities (such as batching plants) will take place at designated work-sites. Here, some of the construction activities will be of longer duration.

4.3.1 Criteria for Airborne Construction Noise

Chapter 171 of the EPA's Environmental Noise Control Manual (ENCM)[2] sets out noise criteria for construction projects. The L_{A10} noise parameter is used as the descriptor to assess construction site noise (ie the noise level that is exceeded for 10% of the time, indicative of the average maximum level). The relevant criterion depends on the pre-existing L_{A90} noise level (being the noise level that is exceeded for 90% of the time, representative of the "background" noise level) and the duration of the construction activity.

The relevant criteria are as follows;

- for construction periods of four weeks or less, the L_{A10} noise level from construction activity should not exceed the existing L_{A90} background noise level by more than 20 dB.
- for construction periods of between four and 26 weeks, the L_{A10} noise level from construction activity should not exceed the existing L_{A90} background noise level by more than 10 dB.
- for construction periods greater than 26 weeks, the L_{A10} noise level from construction activity should not exceed the existing L_{A90} background noise level by more than 5 dB.
- for construction noise that is tonal or impulsive in nature, a 5 dB penalty is applied.

A summary of these criteria is given in the table below;

Construction Period	Criteria
4 weeks or less	$L_{A10} \leq L_{A90} + 20$ dB
4 weeks to 26 weeks	$L_{A10} \leq L_{A90} + 10$ dB
greater than 26 weeks	$L_{A10} \leq L_{A90} + 5$ dB
tonal or impulsive noise	+5 dB penalty

Table 6: Summary of construction noise criteria.

While the total construction period for the entire project is likely to be greater than 26 weeks, many construction activities will progress along the route during the construction period. Where appropriate, these construction activities may be.

2 EPA NSW Environmental Noise Control Manual, Chapter 171.

For large construction projects such as this it is considered appropriate to treat noisy stages of work (such as the earthworks associated with a bridge replacement, for example) as discrete construction periods and assess them against the short and medium term guidelines, provided the cumulative affect of longer-term works is carefully managed.

Where construction noise is audible at residential premises, the EPA guideline recommends that construction should be limited to the following times;

- Monday to Friday, 7:00am to 6:00pm, with a maximum of nine hours per day.
- Saturday 7:00am to 1:00pm if inaudible on premises, otherwise 8:00am to 1:00pm
- No construction work to occur on Sundays or public holidays.

Due to the nature of highway projects, some construction work may be required to take place outside of those preferred hours. These activities will require very careful noise management, including close liaison with the local community, and the implementation of best practical measures to limit disturbance to the surrounding community.

Experience also shows that certain noisy processes, such as sheet piling, are likely to exceed the EPA guidelines at nearby locations even if carried out during the preferred hours. Practical alternatives are not always available and, in these cases, it will be necessary to ensure that the quietest suitable equipment is selected, that temporary noise screening is implemented where practical, and that the timing of the works is subject to prior discussion with the community.

In addition to the major construction activities and processes, some construction plant may be required to operate continuously (24 hours a day). These items of equipment should be treated as "semi-permanent" and the lowest criterion is appropriate (ie L_{A10} noise level should not exceed the existing L_{A90} background noise level by more than 5 dB). This is broadly similar to the criterion that would be imposed under the EPA Industrial Noise Policy (INP)[3] for permanent industrial noise sources.

Noise generated by haulage trucks and other construction related traffic is dealt with in two ways. Firstly, while trucks are operating on the construction site (eg during deliveries or spoil removal, including reversing beepers), noise must be assessed in the context of the contribution to the overall site activity noise. Secondly, when trucks leave the site to join the surrounding roads, the noise impact of the construction traffic must be assessed in terms of the change in overall traffic noise level. The criteria laid down in the EPA's Environmental Criteria for Road Traffic Noise will then be adopted. In this context the criterion is;

> *For land use developments with potential to create additional traffic on existing roads, the traffic arising from the development should not lead to an increase in existing noise of more than 2 dB.*

4.3.2 Criteria for Groundborne Construction Vibration

Criteria for construction vibration must address both;

- the potential for disturbance and annoyance to building occupants, and
- the potential for damage to buildings and other structures.

With regard to disturbance and annoyance, Australian standard AS 2670[4] defines limits for both continuous and transient vibration events. These limits are given in the form of

[3] EPA NSW Industrial Noise Policy: January 2000

[4] AS 2670: Part 2: 1990 *Evaluation of human exposure to whole body vibration , Continuous and shock induced vibration in buildings (1 to 80 Hz)*, Standards Australia.

multiplying factors to be applied to base curves representing the threshold of human perception. The table below shows the applicable multiplying factors.

Multiplying factors to be applied to base curves seeFig 2b AS2670			
Type of Building Occupancy	Time	Continuous or intermittent vibration	Transient vibration
Critical working areas eg. precision laboratories	Day Night	1	1
Residential	Day	2 to 4	30 to 90
	Night	1.4	1.4 to 20
Office	Day Night	4	60 to 128
Workshop	Day Night	8	90 to 128

Table 7: Continuous / intermittent and transient vibration levels below which the probability of adverse comment is low.

For example, the base curve (representing the threshold of human perception) for vertical vibration is a velocity of 0.1 mm/s (rms) and is shown in Figure 2b of AS 2670. Applying a multiplying factor of 4 would result in an applicable vibration limit of 0.4 mm/s (rms).

With regard to the potential for ground vibration to cause damage to structures, it should be noted that vibration levels may reach much higher values than those applicable to human perception and comfort before the onset of any significant risk. There are no directly applicable Australian Standards or guidelines, but a number of overseas standards are helpful. It is recommended that the guidelines and limits in the British Standard BS 7385[5] are adopted as damage criteria for this project, together with a more conservative limit of 5 mm/s in the first instance.

The standard states in Annex A that *'the age and existing condition of a building are factors to consider in assessing the tolerance to vibration. If a building is in a very unstable state, then it will tend to be more vulnerable to the possibility of damage arising from vibration of any other groundborne disturbance'.* It is recommended that buildings of importance are considered on a case-by-case basis with detailed engineering analysis being carried out if appropriate.

4.3.3 Blasting and Vibration Exposure

Ground vibration and airblast (also called blast overpressure) are two environmental impacts from blasting. The airblast is generally more noticeable than the ground vibration. High levels of vibration transmitted through the ground and the airblast could annoy residents, or in the extreme, cause damage to buildings or structures.

Recommended limits for the vibration level and blast overpressure from blasting and are found in guidelines from the Australian and New Zealand Environment Conservation Council (ANZECC)[6]. These limit blast overpressure to 115 dB(lin, peak) at any residence, and ground vibration to 5 mm/s peak particle velocity (PPV). The guidelines also restrict blasting to

5 BS 7385: Part 2: 1993 *Evaluation and measurement for vibration in buildings, Guide to damage levels from groundborne vibration,* British Standards Institution.

6 *Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration*, Australian and New Zealand Environment Council, September 1990.

between 9 am and 5 pm on weekdays and Saturday, and recommend only one detonation per day. Blasting at night should be avoided unless it is absolutely necessary. (These criteria are slightly more stringent than those documented in AS2187.2-1993[7]).

The criteria for control of blasting noise and vibration impact at potentially affected residences are summarised in Table 8, below.

Time of Blasting	Blast Over-pressure Level, dB	Ground Vibration, Peak Particle Velocity, mm/s
Monday to Saturday, 9am – 3pm	115	5
Monday to Saturday, 6am – 9pm Monday to Saturday, 3pm – 8pm	105	2
Sunday, Public Holiday, 6am – 8pm Any day, 8pm – 6am	95	1

Table 8: Criteria for the control of blasting impact on residences.

Building damage is unlikely to be caused below these vibration levels, while building damage and human discomfort will be minimal below the overpressure limits. ‘Conventional’ blasting at ‘normal’ distances is unlikely to create ground vibration levels of sufficient magnitude to cause building damage. Cracks in buildings are far more likely to be caused by local ground and foundation movements caused by the settlement and swell of the ground due to prolonged wet or dry weather.

The EPA acknowledges that there could be some exceedance of the overpressure limit of 115 dB and ground vibration limit of 5 mm/s on infrequent occasions. This should be limited to not more than 5% of total blasts. During this time the overpressure level should not exceed 120 dB at any time and the ground vibration limit should not exceed 10 mm/s at any time.

5. NOISE MODELLING AND PREDICTIONS

Noise levels have been predicted using the CoRTN[8] road traffic noise prediction methodology, as implemented in SoundPLAN v6 environmental noise prediction software[9]. As the CoRTN methodology predicts 18hr or 1hr L_{A10} noise levels (10 percentile, or average maximum), corrections have been derived to convert the basic L_{A10} results to the 15hr and 9hr L_{Aeq} noise levels used by the EPA.

The corrections are based on actual traffic flows and noise levels measured adjacent to the existing Pacific Highway corridor between Moorland and Herons Creek in June-August 2002.

A SoundPLAN model of the existing road with measured traffic flows was compared to measured noise levels at 14 reference locations to calculate an overall site specific calibration factor for the noise model.

Traffic volumes were recorded at existing traffic monitoring stations throughout the measurement period by the RTA. Data from RTA Stations No. 09.043.N and 09.043.S were used in the model verification.

7 AS 2187.2-1993 *Explosives - Storage, transport and use - Use of explosives*, Standards Australia, 1993.
8 *Calculation of Road Traffic Noise*, Department of Transport, Welsh Office, 1998.
9 Braunstein + Berndt GmbH

5.1 Model Calibration

A SoundPLAN model of the existing road with measured traffic flows was compared to measured noise levels at 14 control locations to calculate an overall calibration factor for the noise model.

The measured and predicted noise levels used to calibrate the model are shown in Table 9 below.

Site No.	Monitoring Locations	Date	Time	Measured $L_{A10,\ 15min}$	Total Hourly Vehicles	% HGV	Posted Speed, km/h	Calculated $L_{A10,1hr}$
1	School, Station Street, Johns River	22/07/2002	17:30	56	801	13.2	60	57.2
1	School, Station Street, Johns River	25/07/2002	13:55	54	645	11.1	60	55.9
5	End of Ross Glen Rd, Ross Glen	23/07/2002	17:00	51	661	13.2	100	51.2
5	End of Ross Glen Rd, Ross Glen	24/07/2002	21:50	43	198	33.0	100	48.0
7	End of Glen Haven Drive, Camden Haven	24/07/2002	21:05	45	198	33.0	100	45.0
7	End of Glen Haven Drive, Camden Haven	23/07/2002	16:00	45	773	11.0	100	48.6
7	End of Glen Haven Drive, Camden Haven	25/07/2002	15:00	45	784	10.1	100	48.5
8	Camden Haven Golf Club	25/07/2002	15:15	53	784	10.1	60	53.9
8	Camden Haven Golf Club	23/07/2002	15:20	56	809	10.1	60	54.0
8	Camden Haven Golf Club	24/07/2002	20:45	54	223	30.8	60	50.9
9	4926 Pacific Highway, Kew	24/07/2002	20:20	62	223	30.8	60	57.5
9	4926 Pacific Highway, Kew	23/07/2002	14:50	60	715	9.9	60	59.9
10	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	23/07/2002	14:10	50	715	9.9	100	56.0
11	5301 Pacific Highway, Herons Creek	23/07/2002	13:55	56	597	11.1	100	58.6
12	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	23/07/2002	13:30	47	597	11.1	100	51.5
13	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	23/07/2002	12:50	57	671	9.8	100	59.3
13	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	24/07/2002	19:55	61	298	21.3	100	57.2
14	Herons Creek Public School, Pacific Highway	23/07/2002	12:30	57	671	9.8	100	54.3

Site No.	Monitoring Locations	Date	Time	Measured $L_{A10,\ 15min}$	Total Hourly Vehicles	% HGV	Posted Speed, km/h	Calculated $L_{A10,1hr}$
14	Herons Creek Public School, Pacific Highway	24/07/2002	19:30	61	298	21.3	100	52.2
4B	Watson Taylor Rd, off Pacific Highway	25/07/2002	13:00	59	645	11.1	100	57.5
1	School, Station Street, Johns River	24/07/2002	22:40	55	216	35.7	60	53.9
1	School, Station Street, Johns River	24/07/2002	2:45	56	92	66.1	60	52.2
2	Rear of 253 plot, Pacific Highway, Johns River	24/07/2002	3:05	55	56	58.0	60	52.9
2	Rear of 253 plot, Pacific Highway, Johns River	24/07/2002	23:00	60	167	51.6	60	57.3
5	End of Ross Glen Rd, Ross Glen	24/07/2002	4:10	51	88	49.7	100	45.6
7	End of Glen Haven Drive, Camden Haven	25/07/2002	4:55	44	79	49.7	100	42.2
8	Camden Haven Golf Club	24/07/2002	5:15	54	123	34.7	60	48.7
9	4926 Pacific Highway, Kew	24/07/2002	5:35	60	123	34.7	60	55.3
10	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	24/07/2002	2:15	57	92	66.1	100	51.6
10	150m down approach road to sewerage farm off the Pacific Highway, nr Kew	24/07/2002	23:55	55	167	51.6	100	53.4
11	5301 Pacific Highway, Herons Creek	24/07/2002	0:20	57	133	65.5	100	56.4
12	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	24/07/2002	6:00	48	300	19.4	100	49.6
12	75m down Blackbutt Rd, off Herons Creek Rd, Herons Creek	25/07/2002	0:45	44	123	65.5	100	49.0
13	Behind 10 Banks Rd (Track off Herons Creek Road, nr Pacific Highway)	24/07/2002	6:15	57	300	19.4	100	57.0
14	Herons Creek Public School, Pacific Highway	24/07/2002	1:40	60	139	65.7	100	52.1
4B	Watson Taylor Rd, off Pacific Highway	24/07/2002	22:15	59	216	35.7	100	55.3

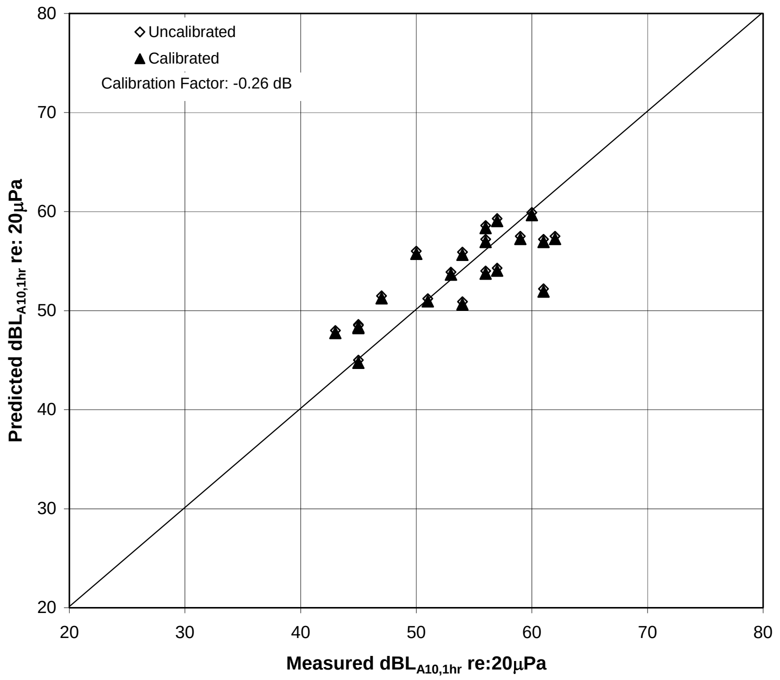
Table 9: Summary of verification measurements and predictions.

A comparison between the daytime measured and predicted noise levels are shown in Figure 2 below. A comparison of night-time noise levels is shown in Figure 3.

Overall daytime and night-time calibration factors were calculated by minimising the least-squared difference between the measured and predicted levels at each of the locations. This analysis resulted in the following calibration factors

- –0.26 dB, daytime
- +2.47 dB, night-time.

On average the measured levels were 0.26 dB below the predicted levels during the day time, and measured levels were nearly 2.5 dB higher than predicted during the night. It is expected that this is a consequence of the large number of night-time truck movements. These



calibration factors were taken into account in the subsequent noise modelling.

Figure 2: Day-time noise level verification.

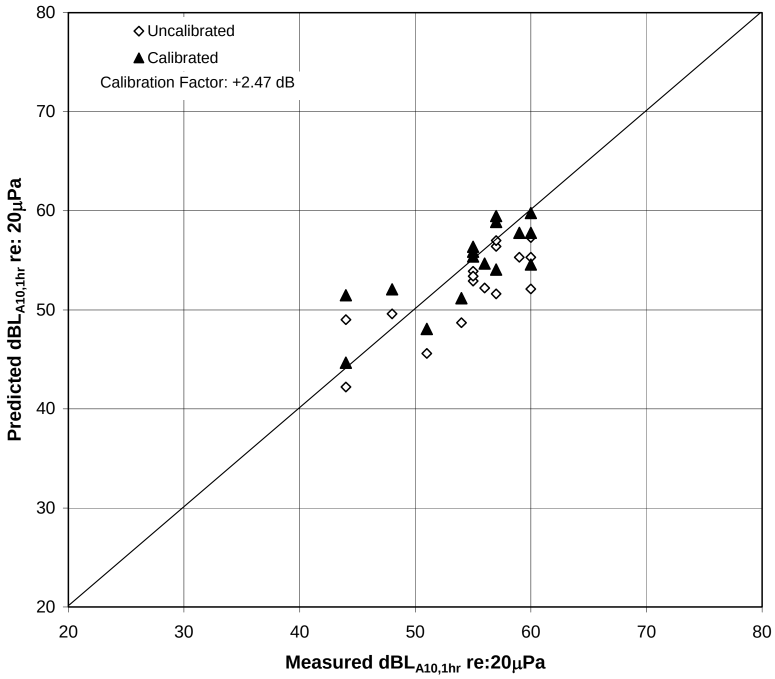


Figure 3: Night-time noise level verification levels.

5.1.1 L_{10} to L_{eq} Correction

As the CoRTN methodology predicts 18hr or 1hr L_{A10} noise levels, corrections have been also derived to convert the basic L_{A10} results to 15hr and 9hr L_{Aeq} noise levels used by the EPA. Based on actual site noise measurements of L_{A10} and L_{Aeq}, a correction of -2.7 dB (daytime) and -3.1 dB (night-time) have been applied. This is close to the nominal correction of -3.0 dB.

5.2 Traffic Flow and Composition Summary

The noise validations and predictions have been based on traffic flow and composition data provided by the RTA. The projected hourly traffic flow data for the year of project opening (2011) and 10 years after opening (2021) is provided in Table 10.

Hour Beginning	Project Opening (2011)	Year 10 (2021)	Proportion of Daily Traffic Flow	% Heavy Vehicles
	Total Vehicles	Total Vehicles		
0	175	228	1.0%	65%
1	163	213	1.0%	66%
2	141	185	0.8%	66%
3	115	150	0.8%	58%
4	124	161	0.8%	50%
5	232	302	1.2%	35%
6	464	605	2.6%	19%
7	729	951	4.0%	14%
8	1040	1358	6.1%	11%

Hour Beginning	Project Opening (2011)	Year 10 (2021)	Proportion of Daily Traffic Flow	% Heavy Vehicles
	Total Vehicles	Total Vehicles		
9	1119	1461	6.6%	10%
10	1205	1573	8.1%	9%
11	1182	1543	8.1%	9%
12	1038	1355	7.3%	10%
13	1092	1426	7.5%	11%
14	1078	1408	8.0%	10%
15	1136	1483	8.4%	10%
16	1045	1364	7.7%	11%
17	875	1143	6.6%	13%
18	595	776	3.9%	19%
19	385	503	2.7%	21%
20	317	413	2.3%	31%
21	260	340	1.8%	33%
22	232	303	1.5%	36%
23	186	243	1.2%	52%
AADV	14929	19487	100%	16%

Table 10: Projected hourly traffic flow data.

5.3 Model Assumptions

The noise prediction model takes account of the overall traffic volume and number of heavy goods vehicles, the vehicle speed, road gradient and type of road surface. The propagation model takes account of losses due to geometrical spreading from the noise source, absorption from the ground and shielding from the ground topography and physical noise barriers, where they are provided.

In accordance with EPA criteria, noise levels have been predicted at 1.0 m from the receiver façade, and a +2.5 dB façade correction has been applied to the noise predictions to take account of reflections of sound from the façade.

The noise model assumes a road noise source emission height of 0.5 m above the road elevation.

The maximum design traffic speed of the proposed road has been assumed to be 110 km/h.

Initially, a ‘worst-case’ pavement surface has been assumed, corresponding to a tined and dragged concrete road surface. A correction of +3.0 dB was applied for this surface, compared to standard dense graded asphalt surfaces. This was to ensure that the noise mitigation requirements were conservative in their location and extent. Where low-noise pavement surfaces (eg open graded asphaltic concrete) are recommended for noise mitigation purposes, a correction of -2.0 dB has been assumed.

6. ROAD TRAFFIC NOISE ASSESSMENT

Noise levels have been predicted at over 400 individual residences and other receiver locations along the proposed route.

The noise level predictions were made both for daytime (7am - 10pm) and night-time (10pm - 7am) for three cases;

- 'Future-Existing', ie predicted Yr2011 (proposed opening date) traffic flows on the *existing* road alignment,
- '2011', ie predicted Yr2011 traffic flows on the proposed dual carriageway alignment, and
- '2021', ie predicted Yr2021 traffic flows (10 years after opening) on the proposed dual carriageway alignment.

Noise mitigation is required if either;

- the predicted '2021' noise level *exceeds* the relevant criterion *and* the noise level increase is greater than 2 dB (Redevelopment) or 0.5 dB (New),

OR

- the noise level is *Acute* (ie > 65 $dBL_{Aeq,15hr}$ daytime, > 60 $dBL_{Aeq,9hr}$ night-time) (even if the increase is <2 dB).

6.1 Road Traffic Noise Catchment Area and Identification of Noise Sensitive Receivers

Road traffic noise catchment areas are shown in red on the Figures in Appendix B. The catchments are labelled Catchment A01 - A40 on the western side of the road alignment, and Catchment B01-B39 on the eastern side of the road alignment. Individual noise sensitive receivers and their noise catchment area are identified in Appendix C.

The noise catchment areas are based on areas likely to have similar noise exposures based on the local topography, road design, setback and receiver type. Catchment areas typically extend to 300 m from the road alignment only, in accordance with the PN-IV procedure. However, RTA advice has been to include noise sensitive receivers that are further than 300 m from the road alignment where they exceed the ECRTN target noise levels.

6.2 Analysis of 'Feasible and Reasonable' Noise Mitigation

Practice Note IV (PN-IV) of the RTA ENMM provides a detailed procedure for *'selecting and designing "feasible and reasonable" treatment options for road traffic noise'* that is aimed at providing a consistent approach to the evaluation, selection and design of appropriate noise control options. In particular, PN-IV Part (a) provides a detailed cost/benefit analysis of noise barrier options, including the level of noise reduction achieved, the number of residences protected and the typical installed cost of noise barriers.

This section of the report provides the analysis of noise mitigation options for the preferred route, in strict accordance with PN-IV. Initially, noise levels have been predicted based on a "Worst-Case" pavement type, on the basis that this would result in the most conservative noise mitigation requirements (see Section 5.3 above). The analysis has been repeated for a low-noise road surface.

6.2.1 Analysis Road Treatment Options and Barrier Heights for Worst-Case Pavement

A summary of the number of affected residences (ie those where noise mitigation is recommended) and the number of residences in each noise exposure range (based on the point receiver results) is given in Table 11 below.

Catchment	Affected Recs.	Day					Night					Catchment	Affected Recs.	Day					Night				
		50-55	55-60	60-65	65-70	70+	50-55	55-60	60-65	65-70	70+			50-55	55-60	60-65	65-70	70+	50-55	55-60	60-65	65-70	70+
A01	1	0	0	1	0	1	0	1	0	0	1	B01											
A02	3	0	0	1	2	1	0	1	0	3	0	B02	0	0	1	3	0	0	0	4	0	0	0
A03	3	0	0	2	1	1	0	1	1	1	1	B03	1	0	1	0	0	1	0	1	0	0	1
A04												B04											
A05	3	0	1	2	0	0	0	1	2	0	0	B05	1	0	1	1	0	0	0	1	1	0	0
A06	6*	0	2	4	0	0	0	4	2	0	0	B06	11*	12	12	4	0	1	17	7	4	0	1
A07												B07	13*	11	18	8	1	0	18	15	5	0	0
A08	3	0	1	1	1	0	0	1	1	1	0	B08	5*	0	1	4	0	0	0	1	4	0	0
A09	0	0	1	0	0	0	0	1	0	0	0	B09	9*	0	2	5	2	0	0	2	6	1	0
A10	1	0	0	0	1	0	0	0	0	1	0	B10	0	0	3	0	0	0	0	3	0	0	0
A11												B11	1	0	0	0	1	0	0	0	1	0	0
A12	4*	0	1	2	2	1	0	2	2	1	1	B12											
A13	1	0	0	0	1	0	0	0	0	1	0	B13	1	0	0	0	1	0	0	0	0	1	0
A14	1	0	0	0	1	0	0	0	1	0	0	B14	0	0	0	2	0	0	0	2	0	0	0
A15	4*	0	0	6	0	0	0	2	4	0	0	B15	0	0	0	1	0	0	0	1	0	0	0
A16												B16											
A17	2	0	0	1	1	0	0	0	2	0	0	B17	5*	0	0	2	3	0	0	0	5	0	0
A18	1	0	0	0	1	0	0	0	0	1	0	B18											
A19												B19	2	0	0	1	1	0	0	0	2	0	0
A20	2	0	1	2	0	0	0	1	2	0	0	B20											
A21												B21											
A22	1	0	0	0	1	0	0	0	0	1	0	B22	2	0	0	1	1	0	0	0	1	1	0
A23												B23											
A24	0	0	1	0	0	0	0	1	0	0	0	B24	1	0	0	1	0	0	0	0	1	0	0
A25	3	1	2	3	1	0	2	2	3	0	0	B25											
A26												B26	3	0	1	1	1	0	0	1	1	1	0
A27	3	1	1	0	1	1	1	1	1	0	1	B27											
A28	18*	26	30	3	3	0	38	15	5	1	0	B28	14*	7	4	1	2	0	9	2	3	0	0
A29	2	0	0	1	0	1	0	0	1	1	0	B29	1	0	1	0	0	0	0	1	0	0	0
A30	1	2	0	0	0	0	2	0	0	0	0	B30	1	1	0	0	0	0	1	0	0	0	0
A31	2	0	1	1	1	0	0	1	2	0	0	B31											
A32												B32											
A33	3	0	0	2	1	0	0	0	3	0	0	B33	3	0	0	3	0	0	0	0	3	0	0
A34	2	0	0	1	1	0	0	0	2	0	0	B34											
A35	2	0	0	1	1	0	0	0	1	1	0	B35	1	0	0	0	0	1	0	0	0	0	1
A36												B36	0	0	2	0	0	0	0	2	0	0	0
A37	5*	0	7	3	2	0	0	9	1	2	0	B37	1	0	0	1	0	0	0	0	1	0	0
A38	1	0	0	0	0	1	0	0	0	0	1	B38											
A39												B39	1	0	0	0	1	0	0	0	0	1	0
A40	1	0	0	0	1	0	0	0	0	1	0	B40											

Table 11: Summary of noise level impacts, 'worst case' road surface (number of affected receivers).

* indicates > 3 affected receivers

In accordance with PN-IV, noise barriers are not considered *feasible and reasonable* where affected residences are grouped in numbers of three or less[10]. This is the situation for the majority of noise catchment areas on this route. (The catchment areas are shown in Appendix B). It is stated in PN-IV that architectural acoustic treatment should be considered for affected residences in these catchments.

10 Step 5, Practice Note IV states *'if the affected residences are grouped in numbers of three or less, go straight to Step 6'*.

There are more than three affected receivers in the following catchment areas (marked with a * in Table 11 above). The provision of noise barriers has been further evaluated for these catchments;

- Catchment A15 (Caringal Drive)
- Catchment A28 (Kew)
- Catchment A37 (Herons Creek)
- Catchment A40 (Herons Creek Public School)
- Catchment B06 (Johns River)
- Catchment B07 (Johns River)
- Catchment B08 (Johns River)
- Catchment B09 (Johns River)

(Note that affected receivers in Catchment A06, A12, B17 and B28 are not *grouped together*[11], and therefore architectural treatment, rather than noise barriers, should be considered for these areas, despite there being more than 3 affected receivers in the catchment.)

Noise barriers have been modelled immediately adjacent to the road edge for each of the catchments areas identified for provision of noise barriers. The noise barriers have been modelled at 0.5 m height increments up to a maximum height of 8.0 m. Noise barriers more than 8 m high are generally considered by the RTA to be visually unacceptable, and require extremely large foundations to provide structural stability under wind loads.

Target barrier options have been calculated in accordance with Practice Note IV (a) *Noise barrier heights*. The target noise levels are unable to be met for *any* of the catchments listed above with a barrier less than or equal to 8 m high. In many cases minimum barrier insertion losses of 5 dB(A) for a 3 m high barrier and 10 dB(A) for a 5 m high barrier[12] are also not achievable.

It is therefore not considered feasible or reasonable to provide noise barriers at *any* location along the proposed road alignment[13] assuming the worst-case road surface.

6.2.2 Analysis Road Treatment Options and Barrier Heights for ‘Low-Noise’ Pavement

Given that the analysis of the ‘worst-case’ road surface in Section 6.2.1 above indicates that barriers are not *feasible or reasonable* at any location, the alignment was re-analysed assuming a ‘low-noise’ pavement[14].

A summary of the number of affected residences and the expected noise exposure range is given in Table 12 below.

11 In accordance with Practice Note IV, Step 6, *‘If residences are closely grouped in numbers of three or less, architectural treatments are preferred over roadside barriers, as it is likely that the cost per residence for barriers will be at least twice that for architectural treatments’*.

12 Practice Note IV(a), Step 1 states that *‘for noise barriers more than 3 m high, the insertion loss must be* more than *5 dB(A) at the most affected residence. For barriers which are 5 m high or higher, the insertion loss must be at least 10 dB(A) at the most affected residence.’*

13 In accordance with Worked Example 3, Practice Note IV(a), Step 1, pp139, RTA ENMM.

14 ‘low-noise’ pavement assumes a correction of -2 dB relative to standard dense graded asphalt, corresponding to an open graded or stone mastic asphalt (see Table 3.1 RTA ENMM).

Catchment	Affected Recs.	Day					Night				
		50-55	55-60	60-65	65-70	70+	50-55	55-60	60-65	65-70	70+
A01	1	0	1	0	1	0	1	0	0	1	0
A02	3	0	1	2	1	0	1	0	3	0	0
A03	2	0	2	1	1	0	1	1	1	1	0
A04											
A05	3	1	2	0	0	0	1	2	0	0	0
A06	**6***	2	4	0	0	0	4	2	0	0	0
A07											
A08	3	1	1	1	0	0	1	1	1	0	0
A09	0	1	0	0	0	0	1	0	0	0	0
A10	1	0	0	1	0	0	0	0	1	0	0
A11											
A12	**4***	1	2	2	0	1	2	2	1	1	0
A13	1	0	0	1	0	0	0	0	1	0	0
A14	0	0	0	1	0	0	0	1	0	0	0
A15	0	0	6	0	0	0	2	4	0	0	0
A16											
A17	1	0	1	1	0	0	0	2	0	0	0
A18	1	0	0	1	0	0	0	0	1	0	0
A19											
A20	0	1	2	0	0	0	1	2	0	0	0
A21											
A22	1	0	0	1	0	0	0	0	1	0	0
A23											
A24	0	1	0	0	0	0	1	0	0	0	0
A25	1	2	3	1	0	0	2	3	0	0	0
A26											
A27	3	1	0	1	0	1	1	1	0	0	1
A28	**13***	30	3	3	0	0	15	5	1	0	0
A29	2	0	1	0	1	0	0	1	1	0	0
A30	0	0	0	0	0	0	0	0	0	0	0
A31	0	1	1	1	0	0	1	2	0	0	0
A32											
A33	0	0	2	1	0	0	0	3	0	0	0
A34	0	0	1	1	0	0	0	2	0	0	0
A35	1	0	1	1	0	0	0	1	1	0	0
A36											
A37	2	7	3	2	0	0	9	1	2	0	0
A38	1	0	0	0	1	0	0	0	0	1	0
A39											
A40	1	0	0	1	0	0	0	0	1	0	0

Catchment	Affected Recs.	Day					Night				
		50-55	55-60	60-65	65-70	70+	50-55	55-60	60-65	65-70	70+
B01											
B02	0	1	3	0	0	0	4	0	0	0	0
B03	1	1	0	0	1	0	1	0	0	1	0
B04											
B05	0	1	1	0	0	0	1	1	0	0	0
B06	**4***	12	4	0	1	0	7	4	0	1	0
B07	**8***	18	8	1	0	0	15	5	0	0	0
B08	1	1	4	0	0	0	1	4	0	0	0
B09	**4***	2	5	2	0	0	2	6	1	0	0
B10	0	3	0	0	0	0	3	0	0	0	0
B11	0	0	0	1	0	0	0	1	0	0	0
B12											
B13	1	0	0	1	0	0	0	0	1	0	0
B14	0	0	2	0	0	0	2	0	0	0	0
B15	0	0	1	0	0	0	1	0	0	0	0
B16											
B17	0	0	2	3	0	0	0	5	0	0	0
B18											
B19	0	0	1	1	0	0	0	2	0	0	0
B20											
B21											
B22	1	0	1	1	0	0	0	1	1	0	0
B23											
B24	0	0	1	0	0	0	0	1	0	0	0
B25											
B26	1	1	1	1	0	0	1	1	1	0	0
B27											
B28	**4***	4	1	2	0	0	2	3	0	0	0
B29	0	1	0	0	0	0	1	0	0	0	0
B30	0	0	0	0	0	0	0	0	0	0	0
B31											
B32											
B33	0	0	3	0	0	0	0	3	0	0	0
B34											
B35	1	0	0	0	1	0	0	0	0	1	0
B36	0	2	0	0	0	0	2	0	0	0	0
B37	0	0	1	0	0	0	0	1	0	0	0
B38											
B39	1	0	0	1	0	0	0	0	1	0	0
B40											

Table 12: Summary of noise level impacts, 'low-noise' road surface (number of affected receivers).

* indicates > 3 affected receivers.

There are more than three affected receivers in the following catchment areas (marked with a * in Table 12 above). The provision of noise barriers has been further evaluated for these sections;

- Catchment A28 (Kew)
- Catchment B06 (Johns River)
- Catchment B07 (Johns River)
- Catchment B09 (Johns River)

Again, residences in Catchments A6, A12 and B28 are not *grouped together*[11], and therefore architectural treatment, rather than noise barriers, should be considered for these areas, despite there being more than 3 affected receivers in the catchment.)

Noise barriers have been modelled immediately adjacent to the road edge for each of the catchments listed above (see Appendix C). The noise barriers have been modelled at 0.5 m height increments up to a maximum height of 8.0 m.

Target barrier options have been calculated in accordance with Practice Note IV (a) *Noise barrier heights* for each of the four Catchments in the following sections.

6.2.2.1 Catchment A28

The predicted effectiveness of noise barriers of varying heights, in conjunction with a low-noise road surface, for Catchment A28 is given in Table 13 below.

Barrier Height	Representative road traffic noise level, dB(A)			
	Segment 1	Segment 2	Segment 3	Segment 4
No Barrier	65	60	55	-
0.5	59	58	52	-
1.0	59	57	52	-
1.5	58	57	52	-
2.0	57	56	51	-
2.5	56	56	51	-
3.0	55	55	50	-
3.5	54	54	50	-
4.0	53	54	50	-
4.5	53	53	49	-
5.0	52	53	49	-
5.5	52	52	49	-
6.0	51	52	48	-
6.5	51	51	48	-
7.0	50	51	48	-
7.5	50	50	48	-
8.0	49	50	48	-

Table 13: Effectiveness of noise barriers of varying heights.

The total and marginal noise benefits for these barrier options are shown in Figure 4 below.

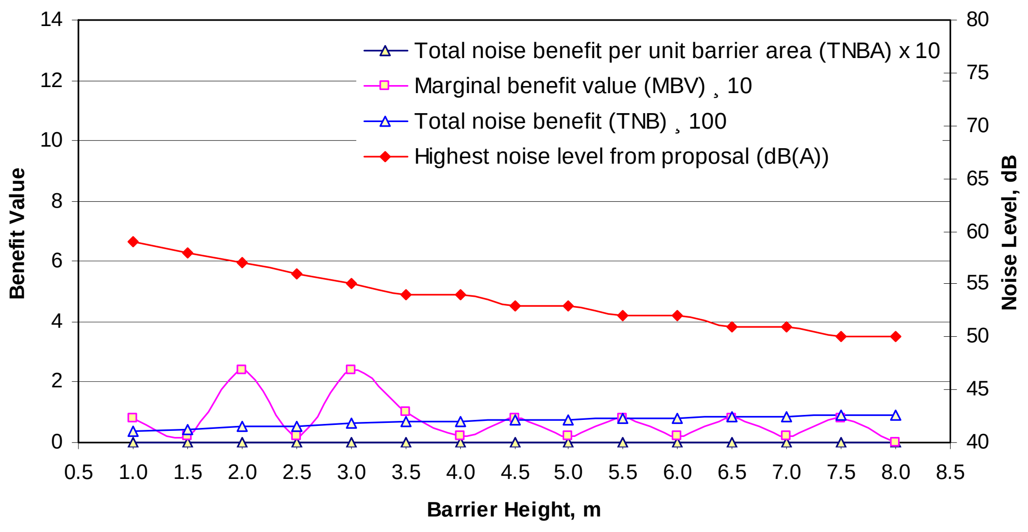


Figure 4: Barrier height effectiveness, Catchment A28, Segments 1, 2 & 3 combined.

The target noise level of $L_{eq(9hr)}$ = 50 dB(A) would be met at the most affected residence if the 7.5 m barrier were adopted. The *Target Barrier*[15] is therefore 7.5 m.

The total noise benefit per unit barrier area (TNBA) and marginal benefit value (MBV) are maximised for an *assessed barrier*[16] of 3.0 m.

A comparison of the cost-effectiveness of the *assessed* and *target* barriers options are given in Table 14 below.

		Assessed barrier	Target barrier
Insertion Loss	Segment 1	10 dB(A)	15 dB(A)
Number of dwellings	Segment 1	1	1
Insertion Loss	Segment 2	5 dB(A)	10 dB(A)
Number of dwellings	Segment 2	4	4
Insertion Loss	Segment 3	5 dB(A)	5 dB(A)
Number of dwellings	Segment 3	1	1
	Cost	$450,000	$1,125,000
	Cost per dB(A) per dwelling	$12,857	$18,750

Table 14: Comparison of noise reduction benefits and costs of the *assessed barrier* and *target barrier* options.

The difference in cost per dB(A) reduction per residence between the two options is 31%. This is significant (>25%)[17], so further analysis of the cost effectiveness of the *target barrier* option compared with the *assessed barrier* options in conjunction with architectural treatment is required (see Table 15 below).

	No. dwellings above TNL for assessed option	Segment Cumulative Noise Level with Assessed Barrier	Segment Exceedence of TNL with Assessed Barrier	Funding Limit Per Residence	Cost of Architectural Treatment
Segment 1	1	55	5	$15,000	$15,000
Segment 2	4	55	5	$15,000	$60,000
Segment 3	1	50	0	$15,000	$15,000
				Total cost of architectural treatment	$90,000
				Extra cost for target 7.5m barrier over assessed barrier	$675,000
				% increase in cost of architectural treatment over extra cost of target barrier	13%

Table 15: Analysis of cost effectiveness of architectural treatment.

Conclusion: The cost per residence for architectural treatment is significantly less than 50% of the cost per residence for the *target barrier* option. Therefore architectural treatment *in conjunction* with the *assessed barrier* (3.0 m) is preferred over the *target barrier*[18].

15 The *target barrier* is the noise barrier having the height required to meet the ECRTN target noise levels.

16 The *assessed barrier* is the noise barrier having the height that provides the greatest marginal noise reduction benefit and the greatest benefit per unit of barrier area.

17 In accordance with Practice Note IV, Step 5, part (i), *'If the difference between the costs per dB(A) reduction per residence is 25% or greater, the cost differences should be considered 'significant' and further evaluation of the options, in accordance with Step 6, will be warranted.*

18 In accordance with Practice Note IV, Step 6, *'If the cost per residence for architectural treatments is less than or equal to 50% of the increase in cost per residence fo the 'target barrier' option, architectural treatments in combination with the 'assessed barrier' option should be preferred'.*

6.2.2.2 Catchment B06

The predicted effectiveness of noise barriers of varying heights, in conjunction with a low-noise road surface, for Catchment B06 is given in Table 16 below.

Barrier Height	Representative road traffic noise level, dB(A)			
	Segment 1	Segment 2	Segment 3	Segment 4
No Barrier	70	60	-	-
0.5	66	57	-	-
1.0	65	57	-	-
1.5	63	57	-	-
2.0	63	57	-	-
2.5	62	57	-	-
3.0	61	57	-	-
3.5	61	57	-	-
4.0	61	57	-	-
4.5	61	57	-	-
5.0	60	57	-	-
5.5	60	57	-	-
6.0	60	57	-	-
6.5	60	57	-	-
7.0	60	57	-	-
7.5	60	57	-	-
8.0	60	57	-	-

Table 16: Effectiveness of noise barriers of varying heights.

The target noise levels are unable to be met for Catchment B06 with a barrier less than or equal to 8 m high. It is therefore not considered feasible or reasonable to provide noise barriers for Catchment B06[19] assuming that a low-noise road surface is provided, and architectural treatment should be provided for affected properties.

6.2.3 Catchment B07

The predicted effectiveness of noise barriers of varying heights, in conjunction with a low-noise road surface, for Catchment B07 is given in Table 17 below.

Barrier Height	Representative road traffic noise level, dB(A)			
	Segment 1	Segment 2	Segment 3	Segment 4
No Barrier	60	55	-	-
0.5	59	54	-	-
1.0	58	54	-	-
1.5	57	53	-	-
2.0	56	52	-	-
2.5	55	52	-	-
3.0	54	51	-	-
3.5	53	50	-	-
4.0	53	50	-	-

19 In accordance with Worked Example 3, Practice Note IV(a), Step 1, pp139, RTA ENMM.

Barrier Height	Representative road traffic noise level, dB(A)			
	Segment 1	Segment 2	Segment 3	Segment 4
4.5	52	49	-	-
5.0	51	49	-	-
5.5	51	48	-	-
6.0	50	48	-	-
6.5	50	48	-	-
7.0	50	48	-	-
7.5	49	47	-	-
8.0	49	47	-	-

Table 17: Effectiveness of noise barriers of varying heights.

The total and marginal noise benefits for these barrier options are shown in Figure 2 below.

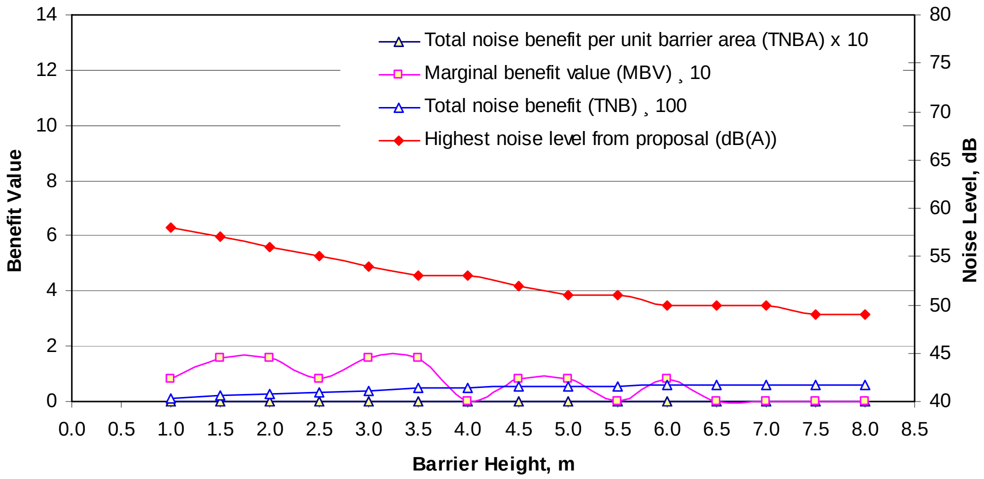


Figure 5: Barrier height effectiveness, Catchment B07, Segments 1 & 2 combined.

The target noise level of $L_{eq(9hr)}$ = 50 dB(A) would be met at the most affected residence if the 6.0 m barrier were adopted. The *Target Barrier*[15] is therefore 6 m.

The total noise benefit per unit barrier area (TNBA) and marginal benefit value (MBV) are maximised for an *assessed barrier*[16] of 3.5 m.

An comparison of the cost-effectiveness of the *assessed* and *target* barriers options are given in Table 18 below.

		Assessed barrier	Target barrier
Insertion Loss	Segment 1	7 dB(A)	10 dB(A)
Number of dwellings	Segment 1	4	4
	Cost	$315,000	$540,000
	Cost per dB(A) per dwelling	$9,545	$12,000

Table 18: Comparison of noise reduction benefits and costs of the *assessed barrier* and *target barrier* options.

Conclusion: The difference in cost per dB(A) reduction per residence between the two options is 20%. This is not significant (ie >25%)[17], so the *target* barrier option (6.0 m) is preferred to the *assessed barrier* in conjunction with architectural treatment.

6.2.4 Catchment B09

The predicted effectiveness of noise barriers of varying heights, in conjunction with a low-noise road surface, for Catchment B09 is given in Table 19 below.

Barrier Height	Representative road traffic noise level, dB(A)			
	Segment 1	Segment 2	Segment 3	Segment 4
No Barrier	65	60		
0.5	60	57		
1.0	60	56		
1.5	59	56		
2.0	58	55		
2.5	57	55		
3.0	57	55		
3.5	57	54		
4.0	56	54		
4.5	56	54		
5.0	56	54		
5.5	56	54		
6.0	56	54		
6.5	56	54		
7.0	56	54		
7.5	56	54		
8.0	56	54		

Table 19: Effectiveness of noise barriers of varying heights.

The target noise levels are unable to be met for Catchment B09 with a barrier less than or equal to 8 m high. It is therefore not considered feasible or reasonable to provide noise barriers for Catchment B09[19] assuming that a low-noise road surface is provided, and architectural treatment should be provided for affected properties.

6.3 Summary of Noise Mitigation Requirements

A detailed cost effectiveness analysis of noise mitigation options has been carried out in accordance with PN-IV of the RTA ENMM. The analysis demonstrates that it is necessary to provide noise mitigation in the form of architectural treatment to buildings and quieter road surfaces in conjunction with both architectural treatment and noise barriers.

Overall, the PN-IV analysis results in the following potential noise mitigation measures;

- Architectural treatment is recommended for approximately 90 residences (see Appendix C for locations).
- Low-noise road surfacing is recommended adjacent to catchments A15, A28, A37, B06, B07, B08, B09, B17 and B28 (at Catchments B17 and B28, architectural treatment may be preferred over the provision of a low-noise road surface).
- Noise barriers are recommended adjacent to catchments A28 and B07.

These mitigation options are discussed further below.

6.4 Noise Mitigation Options

The noise mitigation options have been presented in the community consultation process.

The RTA does not consider it practical to provide short sections of low-noise road surfacing, as it is difficult to adequately maintain. They recommend that architectural treatments to the residences are provided in preference to low-noise road surfacing at these locations. Similarly, it is not considered reasonable to provide a 6.0 m noise barrier near Johns River since it is likely to be visually obtrusive for both the community and road users. It is therefore proposed to provide a 4.5 m noise barrier (consisting of a 1.0 m high noise barrier on a 3.5 m high earth bund) at this location.

Urban design considerations have resulted in a 3.0 m high earth bund on the western side of the highway south of Kew. This will provide additional noise mitigation.

A summary of the mitigation options preferred by the RTA is given in Table 20 below.

Location	Description	Approx Station, (North-Bound/ SouthBound Carriageway)	Approx Length
Johns River	Low Noise Pavement	2400 – 3950 m (NB+SB)	1550 m
Johns River	3.5 m Noise Mound	2570 – 3300 m (SB)	730 m
Johns River	1.0 m Noise Wall	2570 – 2960 m (SB)	400 m
Kew	Low Noise Pavement	15000 – 16600 m (NB+SB)	1600 m
Kew	3.0 m Noise Wall	15370 – 15800 m (NB)	470 m
Kew	3.0 m Visual Mound	15080 – 15520 m (SB)	440 m
Kew	3.0 m Noise Mound	15820 – 16150 m (NB)	330 m
Herons Creek	Low Noise Pavement	20340 –21450 m (NB+SB)	1110 m
Herons Creek School	3.0 m Noise Wall	21660 – 21980 m (NB)	320 m

Table 20: Summary of preferred noise mitigation measures.

In addition to the low-noise road surfacing and noise barriers, architectural treatment will be required at approximately 90 residences (see Appendix C for locations). The form of the architectural treatment is to be agreed with the individual residents, and may include improved glazing and door constructions, installation of acoustic seals, upgrading of building facades and roof constructions, installation of insulation materials and sealing under-floor spaces. The reduction in noise level that will be achieved by these treatments will depend on the structure type and condition of the existing building, but could be an improvement of 10-15 dB(A) indoors.

Noise predictions have been carried out incorporating the noise mitigation shown in Table 19 above. Point receiver results are shown in Appendix C, and noise level contour plots are shown in Appendix D.

The predicted daytime and night-time noise levels for the ‘Future-Existing’, ‘2011’ and ‘2021’ scenarios are shown in the table of point receivers in Appendix C. Note that some residences (particularly those in Kew) have two receiver locations; one adjacent to the existing highway, and one on the rear of the building.

On the noise level contour plots (Appendix D), areas inside the yellow zone are above the “New Freeway” limits (ie 55 $dBL_{Aeq,15hr}$ daytime, 50 $dBL_{Aeq,9hr}$ night-time), while those in the orange zone are above the “Redevelop Freeway” limits (ie 60 $dBL_{Aeq,15hr}$ daytime, 55 $dBL_{Aeq,9hr}$ night-time). (Also, note that the scale used on the night-time contour plots is 5 dB different to the daytime contour scale to reflect the 5 dB more stringent night-time criterion.)

Predicted night-time noise levels are around 2 dB less than daytime noise levels due to lower traffic volumes. However, since the night-time criteria are 5 dB lower than the daytime criteria, it is the night-time noise levels that are critical, and that determine the noise mitigation requirements.

The noise criteria are predicted to be exceeded at many of the residential properties adjacent to the route during both the daytime and night-time. However, existing noise levels at these properties are often already relatively high, and the *increase* in noise level is likely to be small, particularly at properties adjacent to the ‘redevelopment’ sections of the route.

For properties adjacent to ‘New’ sections of the route (eg Stewarts River Road near Johns River, and the Camden Haven residential development near Kew), noise level increases will be higher, while properties adjacent to the existing route in Johns River and Kew are likely to experience significant reductions in noise level.

It is notable that the significant cuttings at the Kew bypass already provide significant reductions to noise.

The noise level at the Camden Haven High School is predicted to be well below the relevant criterion, while at Herons Creek Primary School the noise level already significantly exceeds the 55 $dBL_{Aeq,15hr}$ (external) criterion. The noise level is not expected to change significantly with the proposed highway redevelopment.

6.5 Maximum Noise Levels

Existing maximum noise levels adjacent to the highway are due to individual truck movements, particularly during the night-time period when there is a high proportion of truck movements relative to other vehicles.

Due to the high number of vehicles during the night-time, the emergence of maximum levels (L_{max}) over the ambient $L_{eq,1hr}$ is not likely to be greater than 15 dB(A), except for receivers very close to the road. The $L_{eq,9hr}$ (night-time) target noise levels are therefore likely to reasonably account for sleep disturbance impacts.

There are no major road gradients on the proposed alignment nor are there any controls such as traffic signals. As a consequence, the use of noisy engine braking is likely to be limited.

6.6 Noise Monitoring Programme

The RTA ENMM recommends that post-construction noise monitoring should be included as a part of the operation of the upgraded highway to monitor and review the effectiveness of the noise mitigation in relation to the design noise level targets.

It is recommended that a noise and traffic flow monitoring programme is conducted 12 months after the road opening. This should include:

- measurement of traffic noise levels with normal operational traffic flows
- comparisons of the measured results with predicted noise levels
- verification that road traffic noise levels are in accordance with the project design noise levels.

7. CONSTRUCTION NOISE AND VIBRATION ASSESSMENT

The construction of a dual carriageway road occurs in three stages: earthworks, laying of pavement and final laying of pavement. The duration of the earthworks is likely to exceed 26 weeks at some locations. The laying of pavement could exceed 4 weeks at particular locations. Bridge and embankment construction could include piling activities.

The equipment likely to be used during the construction of the proposed road and the typical sound power levels associated with each type of equipment[20] are listed in Table 21 below.

Construction Phase	Plant	Sound Power Level, dB(A) re 10^{-12}W
Earthworks	Bulldozer	115
	Scraper	115
	Grader	115
	Roller	105
	Water cart	105
Laying of pavement	Trucks	110
	Paving Machine	115
Bridge Construction	Percussive piling machine	130
	Trucks	110
Batching Plants	Batching Plant	106
	Trucks	100
	Bulldozer	115

Table 21: Typical sound power levels of Construction Equipment, dB(A) re 10^{-12} W.

The actual level of construction noise impact will depend on the type of equipment, construction methodology chosen by the construction contractor and final location of the work sites and batching plants. Since each of these is subject to large variation, detailed noise and

[20] AS2436-1981, *Guide to noise control on construction, maintenance and demolition sites, Appendix D*, Australian Standards.

vibration predictions are unlikely to be representative of the final situation, and are not presented in this assessment.

However, practices to reduce construction noise impacts will be required, and may include;

- adherence to the operating time limits and conditions where possible
- agreeing work outside standard operating limits in advance with the community and the DEC
- the location of stationary plant (air-compressors, generators, etc.) as far away as possible from residential areas
- using natural screening by topography wherever possible to reduce noise impacts
- using site sheds and other temporary structures or screens to limit noise exposure where possible
- installing operational noise barriers as early as possible to provide ongoing screening from construction activities, where possible
- the appropriate choice of low-noise construction equipment and/or methods
- modifications to construction equipment or the construction methodology or programme. This may entail programming activities to occur concurrently where a noisy activity will mask a less noisy activity, or, at different times where more than one noisy activity will significantly increase the noise. The programming should also consider the location of the activities due to occur concurrently.
- management and public consultation including, but not limited to; advance notification of planned activities and expected disruption/effects through letter drops, public meetings and effective monitoring of noise levels in and around potentially affected dwellings.

This represents the best practical means of control. Whilst the contractor will be able to achieve moderate reductions in noise and vibration, some impact is expected. A Construction Noise and Vibration Management Plan would be adopted for construction stages incorporating a programme of noise monitoring at sensitive receivers, a community information programme and a complaints hotline.

Similarly, the levels of vibration generated from various construction activities will be site specific, and will be dependant on the ground type, the particular equipment used, and the proximity of the construction activity to the receiver location.

Construction activities associated with general road construction are not expected to generate perceptible levels of vibration at nearby residences due to the considerable propagation distances.

7.1 Piling Noise and Vibration

To reduce the effect on residents of piling noise, nearby residents should be consulted regarding the intended activities associated with the piling process. Sub-contractors carrying out piling activities should be required to undertake pre-construction structural integrity surveys of all properties likely to be affected by piling operations within 300 m of piling.

Mitigation measures to reduce the impact of percussive piling activities include:

- using a resilient pad (dolly) between pile and hammer head
- enclosing the hammer head in a temporary acoustic shroud.

Alternatively, rotary bored or vibro-piling may be used where consistent with the type of pile used and restrictions on soil disturbance.

7.2 Noise and Vibration from Blasting

Blasting may be required, at cutting locations near to Kew, subject to geotechnical investigations.

Many site factors will influence the transmission of vibration through the ground, such as the lithography and topography between the blast site and the receiver locations.

AS2187.2[7] provides a methodology for estimating ground vibration levels, and should be used for sizing of blasts to meet the criteria. In addition, AS2187.2 provides recommendations for reducing the effects of ground vibration and overpressure levels including the following;

- reduce the maximum instantaneous charge (MIC) or charge mass per delay by the use of delays of sufficient length, reduced hole diameter or deck loading
- Ensure that broken rock and excessive humps or toe are removed prior to the firing of the main blastholes
- Optimise blast delay (change burden and spacing) by altering drilling patterns or delay layout or alter hole inclination from the vertical
- Exercise strict control over the location, spacing and orientation of all blast drill holes and use the minimum practicable sub-drilling which gives satisfactory toe conditions.
- Establish times of blasting to suit the situation.

It is recommended that a blasting management plan be developed for the proposed construction process. This plan will include measures to mitigate community disturbance caused by blasting required to construct the route. These measures will include guidelines for shotfirers such as minimising the required Maximum Instantaneous Charge (MIC), minimising face heights, optimising drilling patterns and the times of blasting. The community would be consulted and notified regarding proposed blasting timetables and contacts. All blast vibration and overpressure levels will be measured at representative locations and kept on permanent record, along with any personal responses from the shotfirer and any affected neighbours. Any actions resulting from complaints will also be recorded. A pre-construction survey of potentially affected buildings (including houses) and structures would be carried out prior to commencement of blasting.

8. CONCLUSIONS AND RECOMMENDATIONS

A study has been carried out to assess the impact of noise and vibration on the surrounding community from the proposed alignment for the upgrading of the Pacific Highway from Moorland to Herons Creek.

Traffic noise criteria have been based on the EPA Environmental Criteria for Road Traffic Noise. Construction noise and vibration criteria have been based on EPA guidelines and Australian and New Zealand Standards.

Ambient noise surveys were conducted adjacent to the existing route, and the resulting noise levels were used to calibrate the noise prediction model.

The outcomes from the acoustic model demonstrates that noise mitigation is required for residences along much of the route. This should comprise noise barriers near Johns River, Kew and Herons Creek School, and low-noise road surfacing near Johns River, Kew and Herons Creek. Many residences near to the route will need to be provided with architectural acoustic treatment.

The level of construction noise and vibration will depend on the construction methodology and construction equipment used on the site. However, construction noise and vibration is expected to have some impact on residences near to the upgrade route, and suitable mitigation will be required to reduce the impacts.