9.3 Operational noise and vibration

An assessment of the noise and vibration impacts associated with the operation of the M2 Upgrade project has been undertaken and is presented below. This assessment is supported by *Technical Paper 2 – Noise and Vibration* (Volume 2).

Director-General's Requirements	Where addressed
Operational noise impacts: • *The environmental assessment must include an assessment of the noise impacts of the project during operation, consistent with the Environmental Criteria for Road Traffic Noise (EPA, 1999). The assessment must include specific consideration of impacts to sensitive receivers (schools, hospitals, aged care facilities), as relevant.*	*Section 9.3, Technical Paper 2*

9.3.1 Operational noise assessment criteria

The M2 corridor runs through several areas of urban residential development. As a result the acoustical design of the M2 Upgrade project, as well as the design and management of potential residual noise impacts at dwellings in the vicinity of the M2 Motorway, introduces challenges with respect to achieving timely, efficient, balanced, equitable, reasonable and cost-effective outcomes for the M2 Upgrade project and the community.

Achieving a balanced acoustical design, especially in terms of feasibility and reasonableness, is guided primarily by the following two references:

- DECCW (formerly EPA), Environmental Criteria for Road Traffic Noise (ECRTN), May 1999.
- RTA, Environmental Noise Management Manual (ENMM), December 2001.

ECRTN classification of the project

In accordance with the DGRs, the assessment of operational noise has been performed in accordance with the requirements of the Department of Environment, Climate Change and Water (DECCW) ECRTN. This document provides guidance for assessing traffic noise impacts through setting design objectives for a range of development types and provides procedures for determining noise mitigation in situations where the exceedances of the objectives occur.

The M2 Upgrade project is classified as a '*Redevelopment of an Existing Freeway/Arterial Road*'. Based on this definition the appropriate criteria are presented in Table 55. As required by the DGRs, Table 55 also presents design noise objectives for the assessing noise impact upon sensitive receivers (for example, schools, hospitals, places of worship).

Table 55 DECCW operational traffic noise criteria

Road type	Daytime criteria (7 am to 10 pm)	Night-time criteria (10 pm to 7 am)	Guidance when the existing ambient noise already exceeds the base criteria
Redevelopment of existing freeway/arterial road	LAeq(15 hour) 60 dB(A)	LAeq(9 hour) 55 dB(A)	In all cases, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB. Where feasible and reasonable, noise levels from existing roads should be reduced to meet the noise criteria. In many 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
Redevelopment of existing collector roads			
Places of Worship	LAeq(1 hour) 40 dB(A) (internal)	LAeq(1 hour) 40 dB(A) (internal)	The most practicable mitigation measures to achieve internal noise goals often involve building (facade) treatments. Other mitigation options include regulation of vehicle exhaust noise, limiting access of heavy vehicles during sensitive times, limitations on exhaust brake use, etc. When such treatments are not able to achieve the nominated target internal noise levels, the redevelopment should be designed so as not to increase existing noise levels by more than 2 dB
Hospital Wards	LAeq(1 hour) 35 dB(A) (internal)	LAeq(1 hour) 35 dB(A) (internal)	
Existing School Classrooms	LAeq(1 hour) 45 dB(A) (internal)	-	
Active Recreation (for example, Golf Courses)	Freeways and Arterial Roads: LAeq(15 hour) 60 dB(A)	-	

The ECRTN recognises that there are generally limited resources to provide noise control on existing roads to meet the target criteria and that the noise minimisation strategies adopted need to take into account what is reasonable and feasible. The ECTRN also notes that in urban settings, background noise levels are elevated and generally increase incrementally over long periods of time. This affects the level of noise mitigation that is practicably achievable.

ENMM classification of the project

The RTA's ENMM was issued in December 2001 and provides guidance in managing and controlling noise (and vibration) from all aspects of road traffic generated noise. Within the ENMM, properties which are subject to noise levels exceeding 60 dB(A) $L_{Aeq(15hour)}$ or 55 dB(A) $L_{Aeq(9hour)}$ are identified as being 'noise affected'. These levels correspond to the ECRTN criteria detailed in Table 55 as applying to the redevelopment of the M2 Motorway.

The ENMM however recognises that the base criteria recommended by the ECRTN are not always practicable, and that it is not always feasible or reasonable to expect that they should be achieved. This is particularly relevant to existing roads in urban environments. Guidance is provided when this situation is apparent.

The ENMM also uses the term 'acute'. This refers to properties which are exposed to the following adverse levels of road traffic generated noise:

- Daytime: 65 dB(A) $L_{Aeq(15hour)}$; or
- Night-time: 60 dB(A) $L_{Aeq(9hour)}$.

In operational road traffic noise assessment, consideration for noise mitigation treatment is given to properties that experience acute levels of noise at the project design stage, even when there is no change in noise level due to the M2 Upgrade project.

The ENMM notes that the most effective way of minimising noise from vehicles and traffic is to control vehicle noise at the source. Examples of such measures may include:

- Reducing traffic volumes by promotion of public transport.
- Implementation of more stringent noise standards for new vehicles.
- The progressive replacement of older, noisier vehicles.
- Measures to ensure noise-control equipment on heavy vehicles and older cars is properly maintained.
- The selection and design of road routes and alignments so as to reduce gradients and achieve smooth traffic flows.
- The use of 'low noise' pavements.
- Restricted access to noisy vehicles.
- Traffic management measures to achieve smooth traffic flows.

Where the above source measures are not practical, or do not provide sufficient noise reduction, additional methods would be required to reduce levels to within acceptable margins. Such methods may include the use of noise walls or architectural treatment of properties.

For the M2 Upgrade project, preference would be given to the use of noise walls to mitigate noise levels. This is because all sensitive receivers behind a particular noise wall benefit from the resulting reduction in noise. Architectural property treatments are utilised to mitigate adverse noise only after all of the other mitigation options noted above have been considered.

M2 Upgrade project road traffic noise objectives

In order to assess both predicted noise levels and the predicted changes in noise levels associated with the M2 Upgrade project, two scenarios were assessed, which are the Future Existing and the Future Design scenarios. These scenarios are described below:

- The 2011 Future Existing scenario represents the 'baseline' scenario and is used to determine the level of road noise predicted at the year 2011, in the absence of the M2 Upgrade project.. This scenario makes use of the M2 Motorway alignment in its existing geometry, with traffic volumes extrapolated to 2011 (the project opening year) by applying an incremental factor to measured existing flows. Thus, this scenario provides an assessment of the noise levels of the M2 Motorway without the proposed upgrade.
- The 2021 Future Design scenario represents the 'assessment' scenario for the M2 Upgrade project and uses the proposed new alignment for the M2 Motorway, together with future traffic volumes predicted to 10 years after the scheduled project opening year. Thus, this scenario provides an assessment of the noise levels of the M2 Motorway after the upgrade has been in place for 10 years.

Both the ECRTN and ENMM acknowledge that achieving the base objectives for existing roads in urban environments is sometimes not realistic. This is especially apparent in situations where the existing levels of background noise are already high and exceed the objectives.

Retrofitting of engineering-type noise controls to existing roads is also noted as having limited effectiveness. For example, additionally increasing the height of already high noise walls provides little additional noise benefit, whilst the associated visual impacts, shadowing, constructability and costs may reduce overall merit. These factors must be taken into account when determining appropriate and realistic noise objectives for any proposal.

The following summarises the noise objectives that have been adopted for the M2 Upgrade project, with consideration of the ECRTN and ENMM. Additional noise mitigation is to be considered where either:

- Scenario 1- The predicted 2021 Future Design noise level exceeds the ECRTN base criteria for redeveloped roads and the predicted noise level increase between the Future Design and Future Existing scenarios due to the M2 Upgrade project is greater than 2 dB(A); or
- Scenario 2 - The predicted 2021 Future Design noise levels are Acute (≥65 dB(A) $L_{Aeq(15hour)}$ or ≥60 dB(A) $L_{Aeq(9hour)}$ regardless of the incremental impact of the M2 Upgrade project.

The widening works associated with the M2 Upgrade project are proposed between chainage 3500 (just west of the proposed new Windsor Road access ramps) and chainage 17800 (just east of the Lane Cove Road intersection). As such, there are two sections of the M2 Motorway where no works associated with the M2 Upgrade project are occurring that would be subject to increased traffic and related traffic noise. These locations are:

- From the junction of the M7 Motorway with the M2 Motorway to just west of Windsor Road (chainage 0 – 3500).
- From east of Lane Cove Road to the Lane Cove Tunnel entrance (chainage 17800 – 20200).

In these locations, where no works associated with the M2 Upgrade project would occur, only the incremental criterion is applicable. This criterion requires that the predicted noise level increase between the Future Existing and Future Design scenarios is limited to 2 dB(A) or less.

Properties that are outside of the extent of the upgrade works and that currently experience acute noise levels would be subject to the original conditions of approval for construction of the M2 Motorway. Any assessment of noise impacts at these properties would occur separately to the M2 Upgrade project.

Sleep disturbance and maximum noise level events

The DECCW's ECRTN and the RTA's ENMM provide guidance as to the likelihood of sleep disturbance resulting from road traffic related maximum noise level events (mainly associated with heavy vehicle movements).

The ECRTN document does not set explicit criteria for road traffic noise as no definitive quantitative correlation has been yet established between heavy vehicles noise levels and sleep disturbance. Notwithstanding the above, the ECRTN and ENMM suggests that:

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

A maximum noise event can be defined as any pass-by noise event for which the difference in the L_{Amax} and $L_{Aeq(1hour)}$ noise levels is greater than 15 dB(A). Furthermore, the ECRTN recommends that the assessment of sleep disturbance should include a consideration of the maximum noise level exceedances occurring during the night-time period and the emergence of these exceedances above the ambient noise level.

Noise criteria – operational phase: mechanical services

Operational noise from mechanical services plant is assessed against different criteria to those applying to operational noise from road traffic. For the M2 Upgrade project, items of mechanical plant are situated in the Norfolk Tunnel in the form of ventilation fans. The criteria used are taken from DECCW *Industrial Noise Policy* (EPA) (2000).

The procedures contained in the DECCW's NSW *Industrial Noise Policy* require a determination of the Rating Background Level (RBL) and ambient L_{Aeq} noise levels during daytime, evening and night-time periods.

The assessment procedure for industrial (for example, mechanical) noise sources has two components:

- Controlling the intrusive noise impacts in the short-term for residents.
- Maintaining noise level amenity for residences and other land uses.

Intrusive criterion

The intrusive criterion for stationary noise sources limits the $L_{Aeq(15\ minute)}$ noise emissions levels to the RBL plus 5 dB(A).

Amenity criterion

The amenity noise goal depends upon the level of ambient 'industrial' L_{Aeq} noise already existing within an area and how this level compares to the acceptable noise levels, as relevant to the M2 Upgrade project, specified in Table 56.

Table 56 NSW Industrial Noise Policy amenity criteria

Type of receiver	Indicative noise amenity area	Time of day	Recommended L_{Aeq} noise level	
			Acceptable	Recommended maximum
Residence	Suburban	Day (7 am-6 pm)	55 dB(A)	60 dB(A)
		Evening (6 pm-10 pm)	45 dB(A)	50 dB(A)
		Night (10 pm-7 am)	40 dB(A)	45 dB(A)
Active Recreation Area	All	When in Use	55 dB(A)	60 dB(A)
Commercial Premises	All	When in Use	65 dB(A)	70 dB(A)

Source: EPA (DECCW), 2000

9.3.2 Existing noise environment

In order to characterise the existing noise environment adjacent to the M2 corridor and to establish the noise levels upon which to base the operational noise emission objectives, ambient environmental noise monitoring was performed at a number of representative locations along the length of Motorway corridor.

The monitoring was completed over two separate surveys. The first of these surveys was completed in March and April 2008 at 24 receptor locations along the M2 Motorway route; the second survey was performed in December 2008 at a further 13 locations (refer to Appendix B of Technical Paper 2 for noise monitoring locations).

The results of the ambient noise surveys are presented in Table 57. To represent overall day to day variations in road traffic noise emissions for freeways, use is made of the $L_{Aeq(15hour)}$ and $L_{Aeq(9hour)}$ noise indices. These indices represent the energy-averaged noise levels that prevail during the daytime (7.00 am to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods. These indices, which are used for the operational assessment, are provided in Table 57.

Table 57 Summary of unattended noise logging – road traffic noise indices

Receiver ID	Address		Road traffic noise indices dB(A)		
			LA10(18hour) 1	LAeq(15hour) 2	LAeq(9hour) 3
S1-1	13 Sierra Place	Baulkham Hills	52.5	51.5	47
S1-2	89 Baulkham Hills Road	Baulkham Hills	58.5	56.5	52.5
S1-3	24 Lambert Crescent	Baulkham Hills	60.5	59	55
S1-4	15 Leatherwood Court	Baulkham Hills	57	55.5	55.5
S1-5	108 Junction Road	Baulkham Hills	62	59	53.5
S1-6	17 Livingstone Avenue	Baulkham Hills	58	56	52
S1-7	10 Murrills Crescent	Baulkham Hills	55.5	54	50
S1-8	13 Leatherwood Court	Baulkham Hills	59.5	57.5	53.5
S1-9	4 Craig Avenue	Baulkham Hills	68	65.5	61
S1-10	10 Petrina Close	Baulkham Hills	66.5	65.5	60
S2-1	12 Mill Drive	North Rocks	48.5	51	45
S2-2	10 Virginia Place	West Pennant Hills	58	56	54
S2-3	11 Wilshire Avenue	Carlingford	61.5	59.5	56
S2-4	70 Westmore Drive	West Pennant Hills	60	58	54
S2-5	3 Mundon Place	West Pennant Hills	54	53	48
S2-6	25 Coral Tree Drive	Carlingford	55.5	53	50.5
S2-7	5 Orchard Road	Beecroft	58.5	56.5	50.5
S2-8	24A Castle Howard Road	Cheltenham	59.5	57.5	52.5
S2-9	13 Williams Road	North Rocks	63.5	61.5	58
S2-10	8 Rajola Place	North Rocks	63.5	61.5	58

Receiver ID	Address		Road traffic noise indices dB(A)		
			LA10(18hour) 1	LAeq(15hour) 2	LAeq(9hour) 3
S2-11	33 Carmen Avenue	Carlingford	65	63.5	59
S2-12	30 Austral Avenue	Beecroft	64	62	57
S3-1	30 Dunmore Road	Epping	64	61.5	57.5
S3-2	4 Somerset Street	Epping	59.5	57.5	52.5
S3-3	56 Somerset Street	Epping	56	53.5	48
S3-4	19 Woodvale Avenue	North Epping	61	59	54
S3-5	6.8 Nile Close	Marsfield	53	51.5	46.5
S3-6	40 Ashburton Avenue	South Turramurra	56.5	55	50
S3-7	45/147 Talavera Road	Marsfield	61.5	60	52.5
S3-8	3.3 Tasman Place	North Ryde	57	56	50.5
S3-9	21 Epping Road	North Ryde	60	58.5	53
S3-10	13 Stewart Close	Cheltenham	60	58	53
S3-11	140 Crimea Road	Marsfield	59	58	52.5
S3-12	150 Crimea Road	Marsfield	54.5	53.5	48
S3-13	2/4 Nile Close	Marsfield	55.5	55	48.5
S3-14	1A Busaco Road	Marsfield	56	54.5	49.5
S3-15	1 Fontenoy Road	Macquarie Park	61.5	60	55

Note 1: The $L_{A10(18hour)}$ level is the arithmetic average of the 18 hourly $L_{A10(1hour)}$ levels over consecutive hours between 6.00 am and 12.00 midnight during a normal working day.

Note 2: $L_{Aeq(15hour)}$ represents the Leq noise level for the period 7.00 am to 10.00 pm.

Note 3: $L_{Aeq(9hour)}$ represents the Leq noise level for the period 10.00 pm to 7.00 am.

Table 57 indicates the noise levels depict through traffic with heavy and continuous traffic flows during peak periods, which is characteristic of a busy motorway.

9.3.3 Operational noise impact assessment

The M2 Upgrade project would require alterations to the existing alignment of the road in many areas along the length of the M2 Motorway. These alterations include the modification of various existing cuttings, embankments and batter slopes in areas where widening works are proposed.

Traffic noise from the M2 Motorway is currently mitigated through noise walls of various heights along almost the entire motorway length. These range from approximately 1.8 metres up to around 7 metres in height. The widening process would therefore affect a large number of the existing noise walls along the route of the M2 Motorway. Some of the affected noise walls are situated adjacent to the road carriageway and others are on top of embankments. All such affected noise walls would be required to be taken down and relocated as part of the M2 Upgrade project, although in most cases new walls would be built.

In certain areas, including some where residential receivers are in close proximity to the M2 Motorway, the proposed widening would bring the new outer running lane (and hence the overall noise emission source) closer to affected receivers.

Governing criterion

The ECRTN stipulates 15-hour (daytime) and 9-hour (night-time) L_{Aeq} noise criteria of 60 dB(A) and 55 dB(A) respectively.

To determine the more stringent of the two criteria, a comparative exercise was performed using all baseline monitoring data to assess the difference between the daytime energy averaged noise level ($L_{Aeq(15hour)}$) and the night-time energy averaged noise level ($L_{Aeq(9hour)}$). This exercise showed that:

Average daytime $L_{Aeq(15hour)}$ noise level = Average night-time $L_{Aeq(9hour)}$ noise level + 4.8 dB(A).

The night-time criterion has therefore been taken as being the governing criterion.

Changes in road traffic noise levels associated with the M2 Upgrade project have therefore been calculated by considering the traffic conditions for the following scenarios:

- 2011 Future Existing – Night-Time $L_{Aeq(9hour)}$ – refer results shown in Appendix D of the Technical Paper 2.
- 2021 Future Design – Night-Time LAeq(9hour) - refer results shown in Appendix E of the Technical Paper 2.

2011 and 2021 future traffic figures

All traffic data, in 18 hour format, used within the modelling of the future years was supplied to Heggies by Hills M2 and is based on the traffic figures in the transport and traffic impact assessment undertaken as part of the M2 Upgrade project environmental assessment. This included both M2 Motorway carriageway volumes along with data for the major surrounding arterial/secondary roads, and is presented in Table 34, Table 35 and Table 36.

The traffic data used as the basis for the operational noise impact modelling is presented in Tables 34, 35 and 36 of Technical Paper 2 and reproduced below in Table 58 (traffic on M2 Motorway), Table 59 (traffic on M2 Motorway on- and off-ramps) and Table 60 (traffic on intersecting roads).

Table 58 Future traffic figures (M2 Motorway carriageway)

Location	Direction	LA10(18hour) Traffic Volumes		
		2011 Future Existing	2021 Future Design	%HGV
Old Windsor - Windsor Road	Eastbound	29750	37480	17%
Windsor - Pennant Hills Road		38780	48360	14%
Pennant Hills - Beecroft Road		34140	44290	8%
Beecroft - Christie Road		38250	49190	8%
Christie - Lane Cove Road		34260	45300	8%
Lane Cove - Delhi Road		25250	35130	7%
Delhi - Lane Cove Road	Westbound	26550	34390	7%
Lane Cove - Herring Road		35360	46060	9%
Herring - Beecroft Road		39940	49840	9%
Beecroft - Pennant Hills Road		36940	46690	9%
Pennant Hills - Windsor Road		42390	50430	13%
Windsor - Old Windsor Road		32140	41170	16%

Table 59 Future traffic figures (M2 Motorway access ramps)

Location	Direction	LA10(18hour) Traffic Volumes		
		2011 Future Existing	2021 Future Design	%HGV
Western end of M2	Eastbound	19390	23220	21%
Western end of M2	Westbound	20700	23320	20%
M2 Abbott Road Exit and Entrance	Eastbound	10360	14260	8%
M2 Abbott Road Exit and Entrance	Westbound	12680	18070	8%
Windsor Road - Off-Ramp	Eastbound	n/a	3910	8%
Windsor Road - On-Ramp	Westbound	n/a	3910	8%
Windsor Road - On-Ramp	Eastbound	9030	14790	5%
Windsor Road - Off-Ramp	Westbound	10250	13170	4%
Pennant Hills Road - Off Ramp	Eastbound	13280	15590	23%
Pennant Hills Road - On Ramp	Westbound	14140	15040	22%
Pennant Hills Road - On Ramp	Eastbound	8640	11520	5%
Pennant Hills Road - Off Ramp	Westbound	8690	11300	6%
Beecroft Road - On Ramp	Eastbound	4110	4900	4%
Beecroft Road - Off Ramp	Westbound	3000	3150	5%
Christie Road Off Ramp	Eastbound	3990	6520	4%
Herring Road On Ramp	Westbound	4580	7390	6%
Herring Road On Ramp	Eastbound	n/a	2630	4%
Herring Road Off Ramp	Westbound	n/a	3610	3%
Lane Cove Road - Off Ramp	Eastbound	9010	10170	12%
Lane Cove Road - On Ramp	Westbound	1980	4250	10%
Lane Cove Road - Loop On Ramp	Westbound	6830	7420	15%

Table 60 Future traffic figures (intersecting roads)

Location	LA10(18hour) Traffic Volumes		
	2011 Future Existing	2021 Future Design	%HGV
Windsor Road	52578	59793	5%
Pennant Hills Road	72433	73864	18%
Beecroft Road	50253	51524	5%
Herring Road	20739	29391	5%
Talavera Road (East of Herring Road)	12860	21902	5%
Talavera Road (West of Herring Road)	9936	15874	5%
Talavera Road (West of Christie Road)	7156	9598	5%
Lane Cove Road	85422	93534	11%

A third 'base' scenario (2008) has also been modelled to allow for validation of the noise model against the ambient noise surveys carried out in 2008. The 2008 base $L_{A10,18hour}$ noise level predictions were compared with the results from the ambient noise monitoring surveys presented in Table 57. The comparison indicates that predicted noise levels provide a consistent, and slightly conservative, estimate of measured levels, with an average difference of +1.0 dB(A) for predicted versus measured levels. The

results are within acceptable tolerances for road traffic noise predictions. Thus, it is anticipated that on average the modelling undertaken would slightly over-predict noise levels and potential impacts associated with the upgrade.

In the above scenarios, potentially significant road traffic noise sources have been taken into account, which is M2 Motorway traffic plus major arterial/secondary roads. For each of the above scenarios the facade maps predict noise levels at every facade of each floor of all buildings along the length of the M2 Motorway. All facade noise levels are evaluated at a distance of one metre from the centre of the facade in question, at a height of 1.5 metres for ground floor storeys and 4.3 metres (1.5 metres plus 2.8 metres for a typical floor to floor height) for first floor storeys. Noise levels have only been evaluated at ground and first floor storeys according to the general convention for assessments of the impacts from road traffic noise.

Re-sheeting of the M2 Motorway road surface with open graded asphaltic concrete (OGA) is proposed as part of the M2 Upgrade project. This pavement type is expected to provide a large noise benefit over the existing expansion cracked and substantially degraded surface. Under normal circumstances (and consistent with the guidance provided in the ENMM) a correction factor of -2.5 dB(A) would typically be applied to OGA low-noise pavement types. However, as there is potential for degradation of the M2 Motorway road surface over time, and to ensure a conservative assessment is achieved, the standard -2.5 dB(A) OGA correction factor has been entirely omitted from calculations in both the Future Existing and Future Design cases. This conservative approach is considered appropriate for the purposes of assessment of potential impacts associated with the upgrade.

Road traffic noise associated with intersecting roads

The M2 Motorway is intersected at various points by a number of existing arterial/secondary roads. Residential receivers which are located close to these intersections are therefore exposed to road traffic noise from both the M2 Motorway and the roads in question. These include Old Windsor Road, Windsor Road, Pennant Hills Road, Beecroft Road, Lane Cove Road and Delhi Road. Where this occurs, and an exceedance of the relevant criteria is predicted, a detailed inspection of the particular receiver in question has been performed to determine which facade(s) and hence which road source was the cause of the exceedance.

Furthermore, inherent within the noise model is the ability to determine the relative contributions to a particular noise level at a single facade from the various sources in the vicinity. Where an exceedance of the noise criteria is apparent near to multiple sources (at M2 Motorway junctions with secondary roads) this process is used to determine the dominant contribution to that particular noise level. The facade maps in Appendix D and Appendix E of the Technical Paper 2 represent the traffic noise levels from M2 Motorway operations combined with all major secondary roads within the M2 corridor. Residential and other sensitive receivers which are deemed to be exceeding the relevant operational criteria as a result of the noise generated by the secondary roads are highlighted on the facade maps in Appendix E of the Technical Paper 2.

Accordingly, only those residential receivers which exceed the nominated criteria as a direct result of noise generated by the M2 carriageway, M2 Motorway on- and off-ramps and all associated upgrade works are included within the subsequent assessment of noise mitigation.

As part of the M2 Upgrade project it is also proposed to widen a number of the roads which intersect or feed on to the M2 Motorway. These include Windsor Road (north of Woodlands Street to the M2 Motorway), Christie Road (M2 Motorway exit ramp to Talavera Road) and Talavera Road (access to the School of Management to Alma Road). Of these, only Windsor Road has residential development fronting on to the road.

Noise assessment

Noise emissions from the M2 Motorway are currently mitigated through noise walls along almost the entire length of the motorway of various heights (1.8 metres up to around 7 metres in height). The noise walls are generally located either at the side of the carriageway or at the crest of cuttings, depending on which location provides the optimal noise benefit for the sensitive receivers situated behind. The existing noise walls do not extend over the complete length of the M2 Motorway.

The opening of the M7 Motorway increased traffic volumes, particularly heavy vehicles, in the section of road between the M7 Motorway and Pennant Hills Road. An assessment of sensitive receivers adjacent to the M2 Motorway, both in sections with existing noise walls and in those sections currently without, has been undertaken with regard to the operational noise criteria for the M2 Upgrade project. The predicted noise levels have been evaluated against the noise management objectives described above.

The 2011 Future Existing facade plots in Appendix D of the Technical Paper 2 show that several residential precincts along the route of the M2 Motorway are subject to noise levels exceeding ECRTN base criteria. This is confirmed by the unattended ambient noise survey detailed in Table 57. The predicted noise levels for these properties have been evaluated against the noise management objectives described above.

2021 Future Design scenario assessment

The operational noise criteria for the M2 Upgrade project have been previously defined in Section 9.3.1 of this report. However, they are provided again below for reference.

- Scenario 1- The predicted 2021 Future Design noise level exceeds the ECRTN base criteria for redeveloped roads and the predicted incremental noise level increase between the Future Design and Future Existing scenarios due to the M2 Upgrade project is greater than 2 dB(A); or
- Scenario 2 - The predicted 2021 Future Design noise levels are Acute (≥65 dB(A) $L_{Aeq(15hour)}$ or ≥60 dB(A) $L_{Aeq(9hour)}$ regardless of the incremental impact of the M2 Upgrade project.

Where exceedances of noise criteria for future scenarios occur within the M2 corridor, additional noise mitigation measures would be considered. Preference is to be first given to the use of noise walls as a mitigation measure as all sensitive receivers behind a particular noise wall benefit from the resulting reduction in noise.

After the design and optimisation process of any such noise walls is complete, architectural property treatment would then be considered to mitigate the remaining properties within the M2 corridor where residual exceedances of the criteria are apparent. Evaluation of the incremental impact of the M2 Upgrade project (2021 – 2011 difference plot are provided in Appendix F of the Technical Paper 2) concludes a 2 dB(A) increase in noise is not apparent in any location along the length of the M2 corridor (excluding two properties immediately adjacent to the realignment of Windsor Road). As such, additional noise mitigation measures have only been considered where the predicted 2021 Future Design noise levels are found to be acute (Scenario 2 above). It is noted that noise levels at the two properties at Windsor Road are also predicted to be acute.

Proposed changes to noise walls and subsequent property treatments to address residual noise impacts are outlined in Section 9.3.5 below.

Norfolk Tunnel widening

As part of the M2 Upgrade Project, it is proposed to widen both directions of the existing Norfolk Tunnel to provide an additional lane in the eastbound direction and an upgraded lane in the westbound direction. In the vicinity of the Norfolk Tunnel, two ground floor and seven first floor properties are

predicted to be acute as a result of the upgrade, and are therefore eligible for consideration for property treatment. These properties are listed with other eligible properties in Table 68. Note that these properties are not subject to an increase of more than 2 dB(A) as a result of the project.

Properties outside of M2 Upgrade project area

The widening works associated with the M2 Upgrade project start from approximately chainage 3500 and finish at around chainage 17800. In areas where no works are proposed, noise mitigation would only be considered where the noise level change as a result of the M2 Upgrade project is more than 2 dB(A) and the receivers experience noise levels above the criteria. Appendix F of Technical Paper 2 shows that all properties in areas outside of the M2 corridor are predicted to be subject to a noise level increase which is less than 2 dB(A) and therefore do not trigger the need for further mitigation to be considered as part of this proposal.

Properties which are outside the extent of the works associated with the M2 Upgrade project that currently experience acute noise levels would be subject to the original conditions of approval for construction of the M2 Motorway. Any assessment of noise impacts at these properties would occur separately to the proposed M2 Upgrade project.

Areas of new housing developments

There are a number of newly built, planned or currently under construction residential developments along the route of the M2 Motorway that were unable to be represented by the 2011 scenario in the noise modelling exercise that has been performed to date. For these new areas, 'Future Design' noise levels have been predicted for the 2021 night time $L_{Aeq(9hour)}$ scenario only, as the ECRTN criterion for this assessment period is the more stringent of the criteria. The 2021 scenario includes the upgrades to the noise walls as discussed above. The increase in L_{Aeq} noise levels as a result of the upgrade are made on the basis of the Future Existing (Year 2011) versus Future Design (Year 2021) scenarios comparison for other areas of the M2 corridor. A +2.5 dB correction factor has been included in all the contour data calculations to allow for the conversion of free field noise level to facade levels, as required by the ECRTN. The assessment of the new areas of residential development is summarised in Table 61. Reference is to be made to the noise contours in Appendix I of Technical Paper 2, where the red contours can be seen to represent the 'Acute' noise level boundary.

Table 61 New residential developments in proximity to M2 Motorway

No.	Location	Storey	Future noise levels above ECRTN Criteria and Incremental Impact > 2dB(A)	Future noise levels Acute ? (≥60 dB(A) $L_{Aeq(9hour)}$)	Additional mitigation required?
1	5 Petrina Crescent, Baulkham Hills	Ground	No	Yes	Yes
		First	No	Yes	Yes
2	Baden Powell Place, Carlingford[1]	Ground	No	No	No
		First	-	-	-
3	Devon Street, North Epping	Ground	No	No	No
		First	No	No	No
4	Waterloo Road, Marsfield[2]	Ground	No	No	No
		First	Yes	Yes	Yes

Note 1: These plots are currently vacant, therefore only ground floors require assessment.

Note 2: This is a multi-unit building.

Table 61 indicates that a further two properties require architectural treatment.

Sensitive land uses

The assessment of areas of sensitive land use (schools, churches, areas of active recreation and hospitals) is discussed in the following paragraphs. When considering sensitive land uses, the same operational criteria scenarios that have been adopted for residential receivers are applicable. Additional noise mitigation is therefore required to be assessed when either:

- Scenario 1- The predicted 2021 Future Design noise level exceeds the ECRTN base criteria for redeveloped roads and the predicted incremental noise level increase between the Future Design and Future Existing scenarios due to the M2 Upgrade project is greater than 2 dB(A); or
- Scenario 2 - The predicted 2021 Future Design noise levels are Acute (≥65 dB(A) $L_{Aeq(15hour)}$ or ≥60 dB(A) $L_{Aeq(9hour)}$ regardless of the incremental impact of the M2 Upgrade project.

It is noted that the ECRTN base criteria for these land uses is different to that applicable to residential properties. The appropriate assessment criteria for these uses are detailed in Table 55.

As has previously been discussed, in areas where no works are proposed, noise mitigation is only required to be considered where the noise level change as a result of the M2 Upgrade project is more than 2 dB(A).

The following assessment includes the predicted future noise levels at each of these land uses. Reference is to be made to the various grid noise maps regarding sensitive lands uses that are presented in the following appendices in the Technical Paper 2:

- Existing Schools – Appendix J.
- Churches – Appendix K.
- Active Recreation – Appendix L.
- Hospitals – Appendix M.

Existing schools

The ECRTN noise goal for existing schools is a daytime $L_{Aeq(1hour)}$ noise level of 45 dB(A). It is noted that this noise criterion is based on $L_{Aeq(1hour)}$ internal noise levels. Any 'internal noise level' refers to the noise level at the centre of the habitable room that is most exposed to the noise source and applies with windows sufficiently open to provide adequate ventilation (notionally an open area equal to 5 percent of the floor area of the room).

When considering the correlation of internal noise criteria with externally predicted levels, Table 62, as taken from the RTA's ENMM (extract from Table 4.2 of ENMM), are considered.

Table 62 ENMM indicative noise reduction criteria

Building type	Windows	Internal noise reduction
All	Open	10 dB(A)
Light frame	Single glazed (closed)	20 dB(A)
Masonry	Single glazed (closed)	25 dB(A)
	Double glazed (closed)	35 dB(A)

Note: adapted from FHWA, 1995.

Therefore, as per the ENMM guidance, when assuming the typical (conservative) reduction of 10 dB(A) for a partially open window, to allow for natural ventilation on the noise exposed facade, the internal ECRTN noise criterion would correspond to an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 55 dB(A).

This criterion may be considered slightly conservative, since the morning and afternoon peaks of traffic would typically occur outside normal teaching hours.

Assessment of all 1-hour noise levels contained within the Technical Paper 2 has been performed using the appropriate noise corrections as derived from the unattended noise logging noise data described in Section 9.3.2, averaged during the corresponding period of the day (day or night).

Table 63 Assessment of existing schools

School	ECRTN Criteria, dB(A) Daytime	Future Noise Levels above ECRTN Criteria and Incremental Impact >2dB(A)	Future Noise Levels Acute (>65dB(A) $L_{Aeq(15hour)}$)	Additional Mitigation Required?
Model Farms High School	LAeq(1hr) 45dB(A) (internal)	No	-	No
Winston Hills Public School		No	-	No
Our Lady of Lourdes Primary School		No	No	No
Muirfield High School		No	No	No
Royal Institute for Deaf and Blind School Children		No	No	No
Epping Heights Public School		No	No	No
Macquarie University		No	No	No

Note 1: Located outside of the M2 corridor, therefore only incremental impact required to be assessed.

With reference to Table 63, the noise contours in Appendix J of Technical Paper 2, and the 2021 Future Design façade plots in Appendix E of the Technical Paper 2 provides conclusions as described in the following subsections.

Model Farm High School and Winston Hills Public School

At Model Farm High School and Winston Hills Public School, which are both outside of the M2 corridor, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels and as such, there is no requirement for additional mitigation to be investigated.

Acute 2021 Future Design noise levels are not required to be assessed at these schools.

Our Lady of Lourdes Primary School

At this school, where no modification to the existing noise walls are proposed, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels, neither are the 2021 Future Design noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

The Royal Institute for Deaf and Blind Children

At the Royal Institute for Deaf and Blind Children (RIDBC), widening of the M2 Motorway is proposed and there is a requirement to relocate a number of the nearby noise walls. The heights of the proposed new noise walls are noted as being in-line with the heights of the existing noise walls (7.2 metres for the noise walls immediately north of the school).

The 2021 Future Design noise levels at this school are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels, nor are the 2021 Future Design noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

Notwithstanding the above, an assessment of the change in noise impacts at the RIDBC with the relocated noise walls in this location being increased in height to 7.8 metres has been performed. This assessment concluded that as only a marginal noise decrease was apparent with the higher height of noise walls, the additional small noise benefit that would be apparent from increasing the height of the noise walls was found to be insufficient to justify the extra cost.

Epping Heights Public School

At this school, where no modification to the existing noise walls are proposed, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels, neither are the 2021 Future Design noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

Macquarie University

At this institution, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels, neither are the 2021 Future Design noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated. It is noted that situated between the M2 corridor and the relevant Macquarie University campus buildings is a relatively busy section of Talavera Road, to the west of Christie Road.

Places of worship

The ECRTN noise goal for places of worship is an internal $L_{Aeq(1hour)}$ noise level of 40 dB(A). This applies to both the day and night-time periods.

Again, to adequately assess internal noise levels from those predicted externally, a conservative noise reduction of 10 dB(A) has been applied to allow for windows along the noise exposed façade being partially open (as defined within the ENMM). This corresponds to an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 50 dB(A).

It is noted that, on average, the assessed 1-hour peak daytime noise levels are approximately 3 dB(A) higher than the night-time peak level and as such, the daytime is considered to be the governing criteria. This is as would be expected for road traffic generated noise, where the highest daytime peak hours (corresponding to either the morning or evening rush hours) experience far greater traffic volumes, and subsequently higher noise levels, than the night-time peak hours.

One place of worship has been identified as being affected by the M2 Upgrade project. This is detailed in Table 64 below. The relevant noise contours are presented in Appendix K of Technical Paper 2.

Table 64 Assessment of places of worship

Place of Worship	ECRTN Criteria, dB(A)		Future Noise Levels above ECRTN Criteria and Incremental Impact >2dB(A)	Future Noise Levels Acute (>65dB(A) $L_{Aeq(15hour)}$)	Additional Mitigation Required?
	Daytime	Night-time			
Our Lady of Lourdes Church	LAeq(1hour) 40dB(A) (internal)	LAeq(1hour) 40dB(A) (internal)	No	No	No

Note 1: The ECRTN defines the Daytime as 7:00am to 10:00pm and the Night-time ad 10:00pm to 7:00am.

At Our Lady of Lourdes Church, where no modification to the existing noise walls are proposed, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels, neither are the 2021 Future Design noise levels predicted to be acute. As such, there is no requirement for additional mitigation to be investigated Inspection of the surrounding area to the church grounds also concludes that a 4.2 metre high noise wall is already in place along the site boundary on the sides that face towards the M2 Motorway.

Areas of active recreation

A number of areas where active recreation occurs have been identified. These are listed in Table 65, and illustrated on the noise contours contained Appendix L of Technical Paper 2.

Table 65 Assessment of areas of active recreation

Area of Active Recreation	ECRTN Criteria, dB(A)	Future Noise Levels above ECRTN Criteria and Incremental Impact >2dB(A)	Future Noise Levels Acute (>65dB(A) $L_{Aeq(15hour)}$)	Additional Mitigation Required?
	Daytime			
Gooden Reserve	Freeway/Arterial Roads: $L_{Aeq(15hr)}$ 60dB(A)	No	No	No
Max Ruddock Reserve		No	No	No
Muirfield Golf Course		No	No	No
Pennant Hills Golf Course		No	No	No
Cheltenham Oval		No	No	No
Epping Oval Athletics Track		No	No	No
Jim Campbell Field		No	No	No
Roger Sheeran Oval		No	No	No
Christie Park		No	No	No

Note 1: The ECRTN defines the Daytime as 07.00 am to 10.00 pm and the Night-time as 10.00 pm to 07.00 am

Note 2: Located outside of the M2 corridor, therefore only incremental impact required to be assessed.

The assessment of areas of active recreation shows that at all locations, the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels. The 2021 Future Design noise levels at the locations which are within the M2 corridor are also not predicted to be acute. As such, there is no requirement for additional mitigation to be investigated.

It is also noted that in these areas no alteration of the existing noise walls is proposed as part of the M2 Upgrade project.

Hospital wards

The ECRTN noise goal for hospital wards is an internal $L_{Aeq(1hour)}$ noise level of 35 dB(A). This applies to both the day and night-time periods. One hospital has been identified as being affected by the M2 Upgrade project – the Macquarie University Hospital. It is anticipated that Macquarie University Hospital would open in the first half of 2010.

As the hospital buildings at the Macquarie University Hospital would be newly constructed it has been assumed that mechanical ventilation would be provided to all ward rooms and hence there would be no requirement to open windows. A conservative external to internal noise reduction of 20 dB(A) has therefore been applied which results in an external $L_{Aeq(1hour)}$ noise level at the building facade of approximately 55 dB(A).

It is noted that the Macquarie University Hospital is located near to proposed upgrade of the Christie Road interchange. The upgrade works include:

- A new eastbound on-ramp to the M2 Motorway at Christie Road.
- Widening of the Christie Road Bridge and Talavera Road (between Christie Road and Herring Road).

The assessment of Macquarie University Hospital is detailed in Table 66, and illustrated on the noise contours contained Appendix M of Technical Paper 2.

It is noted that re-surfacing of the Christie Road and Talavera Road intersection would be completed as part of the upgrade works. To be consistent with the main operational assessment, no correction factor has been applied to the re-surfaced Future Design model.

Table 66 Assessment of hospitals

Hospital Ward	ECRTN Criteria, dB(A)		Future Noise Levels above ECRTN Criteria and Incremental Impact >2dB(A)	Future Noise Levels Acute (>65dB(A) $L_{Aeq(15hour)}$)	Additional Mitigation Required?
	Daytime	Night-time			
Macquarie University Hospital	$L_{Aeq(1hr)}$ 35dB(A) (internal)	$L_{Aeq(1hr)}$ 35dB(A) (internal)	No	No	No

Note 1: The ECRTN defines the Daytime as 7:00 am to 10:00 pm and the Night-time ad 10:00 pm to 7:00 am.

The above assessment of the potential noise impacts at the Macquarie University Hospital indicates that the 2021 Future Design noise levels are not predicted to rise by more than 2 dB(A) over the 2011 Future Existing levels. As the 2021 Future Design noise levels are also not predicted to be acute, there is no requirement for additional mitigation to be investigated.

Upgrade to alignment at Windsor Road intersection

As part of the M2 Upgrade project it is proposed to add two additional on/off access ramp at the Windsor Road Intersection with the M2 Motorway. The current junction layout would therefore be required to be altered to allow efficient access to and from the M2 Motorway.

The properties that are located on Windsor Road in the vicinity of the proposed eastbound off-access ramp are of sufficient distance to not be affected to the realignment of this side of the intersection, however, the proposed layout for the westbound on-access ramp (to the immediate south of the junction) has the potential to impact on the residential receivers in this vicinity as they are situated much closer.

There are a number of properties on Windsor Road which are likely to be affected by the alignment change. Currently the buildings are set back by approximately 10 metres to 15 metres from Windsor Road. The proposed re-alignment would bring the road to within approximately 5 metres to 10 metres of some of the properties.

It is noted that three of the affected properties are multi-unit buildings (258 Windsor Road). These three multi-unit residencies are noted as being recently constructed and were not able to be included within the noise model. Assessment of noise impact due to the re-alignment of the Windsor Road junction has therefore been performed using noise contours at their footprint location.

The various contours are illustrated in Appendix N of the Technical Paper 2. Noise contours have been predicted at both ground floor and first floor heights (1.5 metres and 4.3 metres above the local ground respectively). Future Design noise levels have been predicted for the 2021 night time $L_{Aeq(9hour)}$ scenario only, as the criterion for this assessment period is the more stringent of the criteria. The 2021 scenario includes the upgrades to the noise walls as discussed in Section 6.3.9. A +2.5 dB correction factor has been included in all the contour data calculations to allow for the conversion of free field noise level into facade levels, as required by the ECRTN. Reference to the grid noise within Appendix O of the Technical Paper 2 shows that Future Design noise levels for six properties in the immediate vicinity of the re-alignment at Windsor Road are predicted to be acute (greater than 60 dB(A) $L_{Aeq(9hour)}$). As these properties are directly accessed from Windsor Road and the construction of a noise wall is subsequently not feasible, these properties are therefore to be considered for architectural treatment mitigation (and have been included in Table 68).

It is noted that 266 Windsor Road, which is affected by the re-alignment of the intersection, is a heritage listed building.

Secondary roads – potential noise impacts

As the M2 Upgrade project has the potential to create additional traffic flows on the secondary roads which intersect with the M2 Motorway, an assessment of the likely impacts resulting from this has been completed. The roads which form part of this assessment include:

- Windsor Road.
- Pennant Hills Road.
- Beecroft Road.
- Lane Cove Road.

It is noted that impacts from the alterations to Christie Road, Herring Road and Talavera Road form part of the main assessment.

A comparison of the 2011 Future Existing and the 2021 Future Design traffic volumes has been undertaken to determine the potential noise increase. This assessment found that the highest increase

was apparent on Windsor Road (as a result of the new west facing access ramps) where a 14 percent increase for the 2021 traffic flows is anticipated. This equates to a marginal noise level increase of around 0.6 dB(A).

Sleep disturbance assessment

When assessing short term maximum noise levels from the M2 Upgrade project, the current sleep disturbance guidelines used in NSW have been considered (refer to Section 9.3.1).

The ENMM defines a maximum noise event as any pass-by for which the L_{Amax} noise level exceeds the $L_{Aeq(1hour)}$ noise level by at least 15 dB(A) and is in excess of 65 dB(A).

As there is potential for heavy vehicles to use compression braking to slow upon exiting the M2 Motorway at the location of the proposed new eastbound Windsor Road off-ramp, a maximum noise level assessment has been performed in this location.

Background noise monitoring to determine the existing amount of maximum noise events was completed at 3 Horwood Avenue, Baulkham Hills, on the evening of 9 February 2010. Table 67 summarises the results of this noise monitoring.

Table 67 Maximum noise level assessment

Date	Time period	Measured noise level $L_{Aeq(1\ hour)}$ dB(A)	Number of maximum noise events per hour
09/02/2010	22:00 – 22:59	56.7	6
	23:00 – 23:59	56.1	12
10/02/2010	00:00 – 00:59	53.2	10
	01:00 – 01:59	53.9	9
	02:00 – 02:59	53.9	16
	03:00 – 03:59	55.6	3
	04:00 – 04:59	58.4	8
	05:00 – 05:59	60.1	4
	06:00 – 06:59	58.9	4
Total number of maximum noise events 72			

Results of the analysis of the maximum noise levels show that a maximum noise event (as defined within the ENMM) occurred a total of seventy two times at 3 Horwood Avenue over the night of monitoring. The measured L_{Amax} maximum noise level events varied between 68 dB(A) and 81 dB(A)

Maximum noise level assessment – discussion

The assessment of maximum noise levels which are subject to the receivers in the vicinity of the proposed eastbound Windsor Road off- ramp concludes the following:

- The traffic data for the M2 Upgrade project shows an increase in traffic (2011 Future Existing and 2021 Future Design) on the M2 Motorway carriageway in this location which equates to a noise level increase of around 1 dB(A). The mix of light and heavy vehicles is noted as remaining the same.
- However, the construction of the proposed new Windsor Road off-access ramp is expected to result in a reduction in L_{Aeq} noise levels at the sensitive receivers situated in the vicinity as a result of the proposed access ramp being required to be built up and hence effectively acting as a noise barrier to the road traffic on the main M2 Motorway carriageway (which is the dominant source of noise).
- Sensitive receiver L_{Aeq} noise level reductions of around 2 dB(A) to 4 dB(A) have therefore been predicted between the 2011 Future Existing and 2021 Future Design scenarios in this location.
- The noise barrier effect of the new Windsor Road (west-facing) ramps would induce a comparable reduction for 2021 Future Design L_{Amax} noise levels associated with road traffic on the main M2 Motorway carriageway. As such, the number of maximum noise events associated with heavy vehicles travelling on the main carriageway in this location is anticipated to either remain the same or potentially reduce slightly as a result of the additional attenuation provided by the construction of the proposed off-ramp.
- The proposed off-ramp would however bring vehicles (using the off-access ramp) closer to the sensitive receivers in this location: Currently, 3 Horwood Avenue is approximately 25 metres from the carriageway, the distance from the proposed off-ramp to this property would be approximately15 metres. Although the heavy vehicles on the proposed off-ramp are predicted to be an order of magnitude less than the number of heavy vehicles on the main M2 Motorway carriageway, their proximity to the nearest receivers to the north suggests there is potential for the number of maximum noise level events associated with heavy vehicles exiting the M2 Motorway via the proposed eastbound off-access ramp to increase slightly compared to current conditions.

Stationary noise impacts from mechanical plant

The only mechanical plant items associated with the M2 Upgrade project are the exhaust fans located in the Norfolk Tunnel. The exhaust fans are attached in pairs to the centre of the crown of the roof of each of the tunnels. No additional exhaust fans are proposed as part of the tunnel upgrade works

Noise levels have been predicted to be below the target noise criteria.

9.3.4 Vibration impact assessment

Vibration generated from vehicles (in particular heavy vehicles) travelling along the M2 Motorway, including the main carriageway, on/off ramps and the Norfolk Tunnel, would not give rise to levels of vibration exceeding the daytime or night-time human comfort criteria recommended in AS 2670 – *Evaluation of human exposure to whole body vibration*. This is subject to regular maintenance of the roadway to repair large potholes or deformities as they occur.

9.3.5 Mitigation measures

General approaches to controlling road traffic noise

A range of noise mitigation options are available to reduce the effect of road traffic noise on the surrounding community. The general methods available are listed below.

- Low noise road surfaces: Such as Open Graded Asphaltic Concrete (OGAC) or Stone Mastic Asphalt (SMA). Such surfaces can produce noise level decreases of up to about 4 dB(A) when compared to standard road surface materials. A full re-sheeting of the existing M2 Motorway road surface with a low noise road surface within the boundaries of the proposed Upgrade works would take place concurrently with the upgrade proposal.
- Road maintenance: Maintaining the running surface condition of a road can be important in lessening the incidence of sleep disturbance, for example, sleep disturbance may result where noise is generated by pot holes that are allowed to remain for extended periods of time without repair.
- Traffic management: Such as limiting vehicle speed, signage, etc. These methods can generate noise level improvements of up to 5 dB(A), depending upon the carriageway of interest, however they are more suited to local roads than motorways. Compression brakes can be an important factor in the noise environment of roads used by heavy vehicles. While there are currently no statutory powers to limit the use of compression brakes, some success has been achieved on certain major arterial routes via the use of signage to promote awareness of their use in residential areas. In cases where inappropriate driving behaviour is identified as a significant source of annoyance (for example, excessive use of compression brakes), vehicle driver education strategies would be considered.
- Traffic Re-Routing: This option is particularly useful when applied to heavy vehicles using local and secondary roads in predominantly residential areas.
- Noise Barriers: Noise walls gain their effectiveness by extending the path length of noise over and around the barrier between the source and the receiver. Barriers are usually most effective where both the source and receiver are at a similar elevation.
  Increasing the height of already high noise walls provides limited attenuation. Noise walls are also ineffective when receivers are located at highly elevated positions, as would be the case for upper levels of a residential apartment building overlooking a noise source.
  The potential for using noise walls also depends upon other factors, including access to property, aesthetic impacts, daylight access, overshadowing, drainage, driver line-of-sight around sections of curved carriageway, maintenance access and safety (particularly for drivers and pedestrians).
- Architectural treatment of buildings: This method involves the upgrading of property glazing for windows and sliding doors, and the upgrading of access doors if they are found to be weak points for noise access into a particular building. Double glazing, for example, can reduce internal noise levels by up to 10 dB(A) or more compared to a standard residential grade window. Property treatments may also include the provision of mechanical ventilation if the closure of windows and other facade openings is used as a means of managing internal noise levels in selected spaces.

A range of options would be selected to deliver a noise strategy that aims to achieve the target noise goals for the M2 Upgrade project. Details of what noise mitigation measures would be feasible and reasonable to apply would be identified at the detailed design stage of a road project. This is because site specific details are important in selecting the final mix of noise mitigation measures and the detailed design phase may require small changes to project specifics (such as the level of the road way and staged opening). The process of obtaining feedback from the community may also identify a preference for a certain type of noise mitigation. During the design phase of the project, the project team would be required to assess all available noise options.

As preference is to be given to noise walls as the primary choice of noise mitigation, a discussion of how the noise walls were designed for the M2 Upgrade project follows.

Alteration of noise barriers

The M2 Motorway has existing noise barriers (some on retaining wall structures) located along the alignment. As part of the upgrade, existing noise barriers located along the alignment would require relocation and/or heightening to accommodate widening works.

The relocation of noise walls is generally necessary to allow the widening process of the M2 Motorway to be completed. Where the horizontal alignment of the noise walls is required to be adjusted, an optimum location has been selected (taking constructability, maintenance, access, the extent of the site boundary and drainage issues into consideration) so as to ensure that the noise wall provides the maximum noise benefit possible to the areas situated behind.

In all sensitive receiver locations where future exceedances of the operational noise criteria have been predicted, new or increased height noise walls have been considered where three or more exceeding properties are situated within a catchment area. Where the number of exceeding receivers is found to be less than three, the specification of noise walls is not considered to be a reasonable or cost-effective approach, and architectural treatment of these receivers would be considered.

Where noise walls are required to be relocated by the upgrade works, consideration has been given to increasing the existing height of the walls if exceedances of the operational noise criteria are apparent in the 2021 Future Design scenario. Where no exceedances of the criteria are apparent, the height of the relocated noise wall has been specified as being the same as the existing wall which it is replacing.

To assist in maintaining the noise environment of affected areas during the construction phase of the M2 Upgrade project, it is planned that, in locations where noise walls are required to be relocated as part of the M2 Upgrade project, the new wall would be constructed prior to the existing one being demolished, subject to engineering and feasibility considerations. In areas where this is to happen, an offset distance of approximately 3.5 metres would need to be maintained between the new noise wall and existing noise wall to allow for construction access behind the existing wall.

Noise walls not affected by proposed widening works

Height changes to noise walls that are not proposed to be relocated as part of the widening works have also been considered. Specifically, locations where three or more properties behind a noise wall are predicted to be subject to acute noise levels in the 2021 Future Design scenario have been assessed. In all cases the cost-effectiveness analysis rejected further increases in noise levels, primarily because very small additional benefits would be provided by the height increases. As such, no height changes are proposed for existing noise walls that are not proposed to be relocated as part of the M2 Upgrade project.

Proposed changes to noise walls as part of the M2 Upgrade project

Based on the above assessment two new noise walls are proposed, one existing noise wall would be relocated and heightened, two existing noise walls would be relocated and partially reduced in height and the remaining 19 noise walls would be relocated and maintained at existing heights. Table 8 in Section 6.3.9 describes the affected noise walls that form part of the M2 Upgrade project as well as the rationale for requiring modification. The location of all affected noise walls is also illustrated in Appendix H of the Technical Paper 2.

Residual architectural property treatments at noise wall locations

At some locations where the noise criteria are exceeded as a result of the M2 Upgrade project, the feasibility and reasonableness considerations discussed above have concluded that the construction, or modification, of noise walls is not feasible, reasonable or cost-effective. At such locations, where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment for existing individual dwellings is required to be assessed.

The details of the property treatments related to the M2 Upgrade project are summarised in Table 68, noting that a 'n/a' means that a property has no first floor, and that grey text represents no exceedance of the criteria at ground floor level (refer to Table 68). The changes in noise levels between the Future Existing and Future Design scenarios are predicted to be less than 2 dB(A) at all properties within the study area (with the exception of two properties at Windsor Road). As such, the need for property treatment is determined on the basis of whether 'acute' noise levels are predicted. It is noted that the two properties where a change in noise level of more than 2 dB(A) is predicted are also predicted to be acute and are therefore included in Table 68 below.

Table 68 Year 2021 exceedances and residual architectural property treatments

No.	Address[1]	Approx Chainage	Predicted Noise Level $L_{Aeq(9hr)}$, (dB(A))			
			Ground Floor		First Floor	
			2011	2021	2011	2021
1	52 Junction Road, Baulkham Hills	3350	58	59	59	60
2	1 Watkins Road, Baulkham Hills	3400	59	60	n/a	n/a
3	4 Craig Avenue, Baulkham Hills	3450	62	63	n/a	n/a
4	10 Craig Avenue, Baulkham Hills	3500	57	57	62	62
5	5 Linton Street, Baulkham Hills	4100	56	57	63	64
6	14 Linton Street, Baulkham Hills	4200	57	58	60	61
7	4 Petrina Crescent, Baulkham Hills	4200	60	60	63	64
8	8 Petrina Crescent, Baulkham Hills	4250	60	61	n/a	n/a
9	10 Petrina Crescent, Baulkham Hills	4300	61	62	n/a	n/a
10	12 Petrina Crescent, Baulkham Hills	4300	60	61	n/a	n/a
11	14 Petrina Crescent, Baulkham Hills	4300	60	61	n/a	n/a
12	7 Petrina Crescent, Baulkham Hills	4350	61	61	n/a	n/a
13	266 Windsor Road, Winston Hills	4000	63	66	n/a	n/a
14	262 Windsor Road, Winston Hills	4000	63	67	n/a	n/a
15	258a Windsor Road, Winston Hills	4000	These three properties are newly built two-storey multi-unit dwellings. See discussion in Section 9.3.3			
16	258b Windsor Road, Winston Hills	4000				
17	258c Windsor Road, Winston Hills	4000				
18	254 Windsor Road, Winston Hills	4000	64	66	66	68
19	17 Russell Street, Northmead	4300	59	60	n/a	n/a
20	19 Russell Street, Northmead	4300	59	60	n/a	n/a
21	1 Russell Street, Northmead	4300	56	56	67	68
22	2 Russell Street, Northmead	4400	59	59	65	66
23	37 Dremeday Street, Northmead	4450	59	60	n/a	n/a

No.	Address[1]	Approx Chainage	Predicted Noise Level $L_{Aeq(9hr)}$, (dB(A))			
			Ground Floor		First Floor	
			2011	2021	2011	2021
24	39 Dremeday Street, Northmead	4450	60	61	n/a	n/a
25	41 Dremeday Street, Northmead	4450	60	61	62	62
26	42-44 Dremeday Street, Northmead[2]	4500	62	63	n/a	n/a
27	46 Dremeday Street, Northmead	4500	65	66	n/a	n/a
28	46 Roland Avenue, Northmead	4500	60	61	61	62
29	48 Roland Avenue, Northmead	4500	60	61	61	62
30	41 Williams Road, North Rocks	4950	59	60	60	61
31	39 Williams Road, North Rocks	4950	59	60	n/a	n/a
32	33 Williams Road, North Rocks	5000	59	60	n/a	n/a
33	31 Williams Road, North Rocks	5000	59	60	n/a	n/a
34	29 Williams Road, North Rocks	5100	59	60	61	62
35	25 Williams Road, North Rocks	5100	61	62	n/a	n/a
36	23 Williams Road, North Rocks	5150	60	61	n/a	n/a
37	21 Williams Road, North Rocks	5200	60	61	63	64
38	11 Williams Road, North Rocks	5250	57	58	59	60
39	8 Rajola Place, North Rocks	5300	58	58	60	61
40	93 Barclay Road, North Rocks	5250	58	59	59	61
41	2 Mill Drive, North Rocks	5300	58	59	59	60
42	122 Barclay Road, North Rocks	5400	57	57	59	61
43	120 Barclay Road, North Rocks	5450	58	59	61	62
44	118 Barclay Road, North Rocks	5450	58	59	61	62
45	26 Hepburn Road, North Rocks	6000	55	57	58	60
46	24 Yale Close, North Rocks	6500	58	59	60	62
47	14 Virginia Place, West Pennant Hills	7000	58	59	59	60
48	15 Wilshire Avenue, Carlingford	7400	54	55	62	63
49	13 Wilshire Avenue, Carlingford	7400	57	57	60	60
50	96 Westmore Drive, West Pennant Hills	7400	58	59	59	60
51	86 Westmore Drive, West Pennant Hills	7400	58	59	59	60
52	82 Westmore Drive, West Pennant Hills	7500	59	60	60	61
53	80 Westmore Drive, West Pennant Hills	7500	60	61	n/a	n/a
54	78 Westmore Drive, West Pennant Hills	7550	59	60	n/a	n/a
55	76 Westmore Drive, West Pennant Hills	7600	58	59	59	60
56	74 Westmore Drive, West Pennant Hills	7600	58	59	59	60
57	2 Morton Avenue, Carlingford	7600	60	60	n/a	n/a
58	53 Carmen Drive, Carlingford	7650	61	62	n/a	n/a
59	52 Carmen Drive, Carlingford	7800	58	59	59	60
60	50 Carmen Drive, Carlingford	7850	58	59	59	60

No.	Address[1]	Approx Chainage	Predicted Noise Level $L_{Aeq(9hr)}$, (dB(A))			
			Ground Floor		First Floor	
			2011	2021	2011	2021
61	33 Carmen Drive, Carlingford	7850	60	61	67	67
62	31 Carmen Drive, Carlingford	7850	61	62	n/a	n/a
63	29 Carmen Drive, Carlingford	7900	60	61	n/a	n/a
64	27 Carmen Drive, Carlingford	7900	58	59	61	62
65	20 Lamorna Avenue, Beecroft	9450	55	56	59	60
66	16 Lamorna Avenue, Beecroft	9450	58	58	60	61
67	16 Austral Avenue, Beecroft	9950	58	59	59	60
68	18 Austral Avenue, Beecroft	9950	58	59	59	60
69	20 Austral Avenue, Beecroft	10000	58	59	59	60
70	22 Austral Avenue, Beecroft	10000	58	59	59	60
71	24 Austral Avenue, Beecroft	10050	58	59	59	60
72	28 Austral Avenue, Beecroft	10050	58	60	59	60
73	30 Austral Avenue, Beecroft	10050	60	61	61	62
74	34-2/3 Austral Avenue, Beecroft	10100	59	60	n/a	n/a
75	36-1/2 Austral Avenue, Beecroft	10100	57	58	59	60
76	36-3 Austral Avenue, Beecroft	10100	59	60	60	61
77	6 Ferndale Road, Beecroft	10500	56	57	61	62
78	24 Barombah Road, Epping	11700	59	60	n/a	n/a
79	26 Dunmore Road, Epping	11800	57	58	60	61
80	13 Stewart Close, Cheltenham	12100	50	52	59	61
81	28 Old Beecroft Road, Cheltenham	12150	52	53	59	61
82	28A Old Beecroft Road, Cheltenham	12150	50	51	60	62
83	3 Constance Close, Epping	12500	57	58	60	61
84	5 Callistemon Close, North Epping	12600	56	58	59	61
85	3A Callistemon Close, North Epping	12650	60	62	62	63
86	27 Somerset Street, Epping	12650	62	63	63	64
87	16 Sussex Street, Epping	12650	57	58	59	60
88	21 Sussex Street, Epping	12650	56	56	59	60
89	83 Devon Street, North Epping	13150	55	56	59	60
	Total Number of Properties	89				

Note 1: Exceedances are regarded as residential receivers that are subject to 'Acute' noise levels (≥65dB(A) $L_{Aeq(15hr)}$ or ≥60dB(A) $L_{Aeq(9hr)}$) OR the incremental impact of the project is greater than 2dB(A) (and the project noise goals are exceeded).

Note 2: This property consists of a number of units and would require further investigation during the detailed design phase to determine exactly how many of the units have exceedances.

Signage to limit use compression braking by heavy vehicles

As the M2 Motorway is subject to large volumes of heavy vehicles which have the potential to cause noticeable sensitive receiver noise impacts, a suitable strategy to help mitigate heavy vehicle noise may include the erection of signage which attempts to target the inappropriate use of engine/compression brakes. Some success has previously been achieved on certain major arterial routes in NSW with the use of such signage to promote awareness of their use in residential areas. The newly proposed Windsor Road west-facing access ramps are locations where this may be considered.

Bridge expansion joints

The M2 Upgrade project would require modifications to several of the existing bridges which form part of the current alignment. As the impulsive noise from expansion joints in bridges can create localised impacts, it is therefore proposed that where expansion joints require replacement or modification as part of the M2 Upgrade project, the selecting of suitable components would consider the potential noise generating characteristics in an attempt to minimise the impact on the sensitive receivers which are, in some location, situated in very close proximity to some of the bridge joints.