

Arup**Acoustics**

Sydney Harbour Casino  
Properties Pty Ltd

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**Project Star, Sydney**

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Acoustic Assessment  
Report

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REV A

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Acoustic Assessment  
Report

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## Contents

	Page
Executive Summary	1
1 Introduction	2
1.1 Background	2
1.2 Scope of Assessment	2
2 Project Description	3
3 Noise Survey	4
3.1 Purpose of the Noise Survey	4
3.2 Methodology	4
3.3 Ambient Noise Environment	7
3.4 Noise Sensitive Receivers	8
4 Noise Criteria	11
4.1 Internal Design Criteria	11
4.2 Industrial Noise Criteria	14
4.3 Entertainment Venue Noise Criteria	18
4.4 Traffic Noise Criteria	19
4.5 Construction Noise Criteria	19
4.6 Construction Vibration Criteria	21
5 Predicted Noise Levels	22
5.1 Construction Noise	22
5.2 On-Site Traffic Noise	23
5.3 Café/Retail Areas	24
5.4 Hotel	25
5.5 Road Traffic Noise	25
5.6 Entertainment Venues	27
6 Assessment of Effects	29
6.1 Construction Noise	29
6.2 Mechanical Plant Noise	30
6.3 Industrial Noise	30
6.4 Road Traffic Noise	31
6.5 Entertainment Venue Noise	31
7 Conclusions	33

## Appendices

### Appendix A

#### Acoustic Terminology

## Appendix B

### Noise Survey Results

## Executive Summary

The proposed Project Star upgrade of the Star City casino and hotel complex has been evaluated against the acoustic assessment requirements set out in the Director-General's requirements, appropriate EPA policy, relevant Australian Standards and legislation.

Design of the proposed development will be conducted in accordance with noise criteria and guidelines set from relevant Australian Standards, criteria from the NSW Liquor Administration Board and the EPA Industrial Noise Policy. In particular, design of the development will incorporate measures to control noise and vibration impacts, including structureborne noise, from the Light Rail line, as well as design measures to preserve the acoustic amenity of the Lyric Theatre.

The construction noise impact from the development is predicted to exceed the applicable noise criteria. Effective management of the construction process to minimise noise will be necessary to mitigate the noise impact of the construction works on surrounding noise-sensitive receivers. A process of community consultation will form an integral part of ameliorating the construction noise impact, coupled with best practice management measures to control noise and vibration impacts on external and internal sensitive receivers.

A construction Noise and Vibration Management Plan should be produced to facilitate the mitigation of construction noise and vibration from the development.

Operational noise levels from the Star City upgrade are generally expected to meet the criteria, subject to appropriate noise mitigation measures including incorporating noise control measures and acoustic design principles into the development, and the effective management of noise from entertainment venues.

Providing that appropriate measures are adopted to manage construction and operational noise from the development, the proposed development is considered to be suitable based on the assessment requirements given by Director-General of the Department of Planning for the Project.

# 1 Introduction

## 1.1 Background

---

Sydney Harbour Casino Properties Pty Ltd are proposing to conduct an expansion and upgrade to the Star City Casino in Pyrmont NSW, to be known as Project Star, including redevelopment of existing areas of the Casino and construction of a new hotel precinct on the former Switching Station site adjacent to the existing Star City complex.

The following acoustic assessment has been prepared by Arup Acoustics to address acoustic issues associated with the proposed development. This assessment has been prepared for Sydney Harbour Casino Properties to form part of a Project Application to NSW Department of Planning (DoP) for approval under Part 3A of *the Environmental Planning and Assessment Act, 1979*.

## 1.2 Scope of Assessment

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Director General's Environmental Assessment Requirements (DGEARs) have been issued to Urbis JHD by DoP for the Project.

There acoustic requirements given under the DGEARs are as follows:

### 7. Noise Impacts

- Demonstrate that the proposal will be designed, constructed, operated and maintained so that there is no unacceptable level of noise impacts (including traffic noise) on amenity in the locality. The consideration of noise impacts shall have specific regard in the following;
  - The proposed development should be protected against noise and vibration from the adjoining light rail;
  - Effective sound insulation should be provided for the protection of the adjacent Lyric Theatre from noise or vibration intrusion from the proposed development.

### 8. Construction Impacts

- Address measures to ameliorate potential impacts arising from construction of the proposed development

This acoustic assessment specifically addresses these requirements.

## 2 Project Description

The Project consists of<sup>1</sup>:

- Construction of a new 309 room hotel and lower level retail, gaming and conference facilities
- Provision of approximately 500 additional basement carpark spaces
- Redevelopment of the retail arcade and pedestrian thoroughfare within the Star City complex
- Redevelopment of the Pirrama Road facade of the casino complex, including new restaurant, retail, gaming and conference spaces, and a new porte-cochere driveway allowing vehicle drop-off facilities from Pirrama Road.

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<sup>1</sup> Urbis (2008) *Star City Casino Upgrade Preliminary Environmental Assessment*

## 3 Noise Survey

### 3.1 Purpose of the Noise Survey

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A noise survey was carried out to assess the current ambient noise levels around the Star City development site and to identify nearby noise sensitive receivers. This survey consisted of both attended and unattended noise monitoring.

The purpose of the noise survey was to identify:

- Existing ambient noise levels, in order to assess the impact of the development on the surroundings and develop noise criteria.
- Potential noise-sensitive receivers in the vicinity.

### 3.2 Methodology

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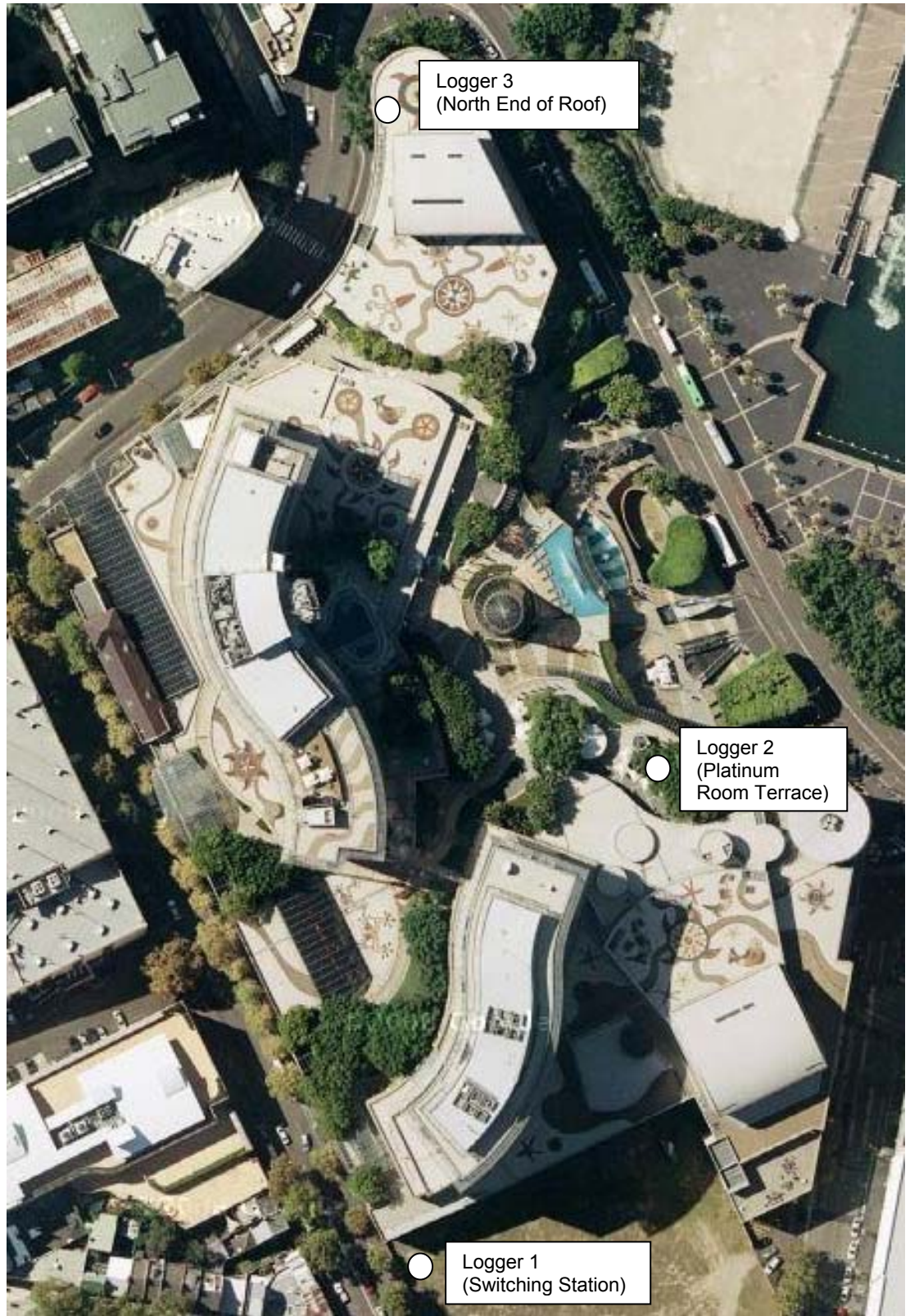
From Thursday 29 May 2008 to Wednesday 11 June 2008, three unattended noise loggers were set up at locations around the Star City complex, as shown in Figure 1.

One noise logger was located on the Switching Station site at the southern end of the Star City complex, and two loggers were set up on the rooftop of the Star City casino. One logger was located on the terrace outside the Platinum Room, on the eastern façade of the casino, and the third logger was located on the roof of the Star Theatre at the northern end of the complex.

The loggers recorded  $L_{A1}$ ,  $L_{A10}$ ,  $L_{A90}$ , and  $L_{Aeq}$  statistical noise level parameters at 15 minute intervals continuously for the two week long measurement period (See Appendix A for a glossary of acoustic terminology). Weather patterns were noted during this period and where noise levels were affected the data was not used. Due to wet weather during the monitoring period, the loggers were kept out for a further week to obtain additional data.

The loggers were checked for calibration before and after the monitoring period, and no significant drift in calibration occurred. However, a technical fault with one logger (at the Switching Station site) meant that no data was obtained for the first monitoring period.

The average hourly noise levels throughout the day have been determined from the total measurement period for all logger locations and split into weekdays and the weekend. These are presented graphically in Appendix B. The raw data from the loggers is available upon request.



**Figure 1:** Noise Logger Locations.

To supplement and verify the unattended measurements some attended noise measurements were also undertaken at the logger locations, and at five additional locations in the surrounding area, as shown in Figure 2. These measurements consisted of attended traffic noise and environmental noise measurements.



**Figure 2:** Attended Noise Measurement Locations.

$L_{A1}$ ,  $L_{A10}$ ,  $L_{A90}$ , and  $L_{Aeq}$  statistical noise level parameters were measured for 15 minute periods. A Brüel and Kjær Type 2250 Sound Level Meter was used to take the measurements. This was checked for calibration before and after the measurements using a Brüel & Kjær Type 4231 Sound Level Calibrator. No deviation occurred. Measurements were taken generally in accordance with the provisions of AS1055<sup>2</sup>.

Measured noise levels are presented in Table 1:

<sup>2</sup> Australian Standard AS1055 (1997) *Acoustics – Description and Measurement of Environmental Noise*

Location	Measured Noise Levels				Comments
	L <sub>A1</sub>	L <sub>A10</sub>	L <sub>Aeq</sub>	L <sub>A90</sub>	
1	77	71	67	56	Traffic noise on Pyrmont Road at 0.5 m from road edge; No specific audible industrial noise above background urban hum
2	75	67	64	58	Ambient noise measurements at Logger 1 location. Industrial noise from Star City and general urban hum; traffic noise from surrounding streets
3	72	67	64	55	Traffic/ambient noise measurements at 115 Pyrmont Street (Receiver 6); Industrial noise only present as urban hum; pedestrian and bus traffic
4	70	64	62	56	Traffic noise measurements on Union Street, outside Receiver 7. Intermittent traffic on Union Street, bird noise, Industrial noise from urban hum and Star City southern façade
5	79	71	68	58	Traffic noise measurements on Pirrama Road, heavy pedestrian, bus and vehicle traffic
6	56	56	55	54	Ambient noise at Logger 2 location on Platinum Room Terrace. Noise from gaming machines, traffic noise, water feature noise
7	61	60	58	56	Ambient noise at Logger 3 location on roof of Star Theatre. Traffic noise from Jones Bay Road
8	59	56	54	52	Ambient noise measurements at Receiver 2 (Saunders Wharf Apartments). Distant traffic noise; marine noise; wind/wave noise; sea birds

**Table 1:** Attended Noise Measurements, dB re 20  $\mu$ Pa.

### 3.3 Ambient Noise Environment

The area surrounding Star City has a prevailing noise environment dominated by traffic noise, with a characteristic 'urban hum' from nearby buildings. Locations on the Pirrama Road frontage of Star City have noise from the water features on the eastern façade of the casino complex, as well as some water noise from Pyrmont Bay.

The area is generally characterised by high background noise levels. These characteristics are consistent with an 'Urban' area as defined in the NSW Industrial Noise Policy (INP)<sup>3</sup>.

### 3.4 Noise Sensitive Receivers

The nearest noise-sensitive receivers to the development are the residential properties surrounding Pyrmont Bay (to the east of the site), and along Union and Pyrmont Streets (to the south and south west of the site).

Due to the large size of the Star City complex, the most sensitive receiver location for each noise source varies depending on the location of the source.

The ambient noise environment at these receivers is characterised by road traffic noise and general urban hum, with some noise from Pyrmont Bay and Sydney Harbour, such as ferry and boat noise and general marine noise e.g. wave noise.

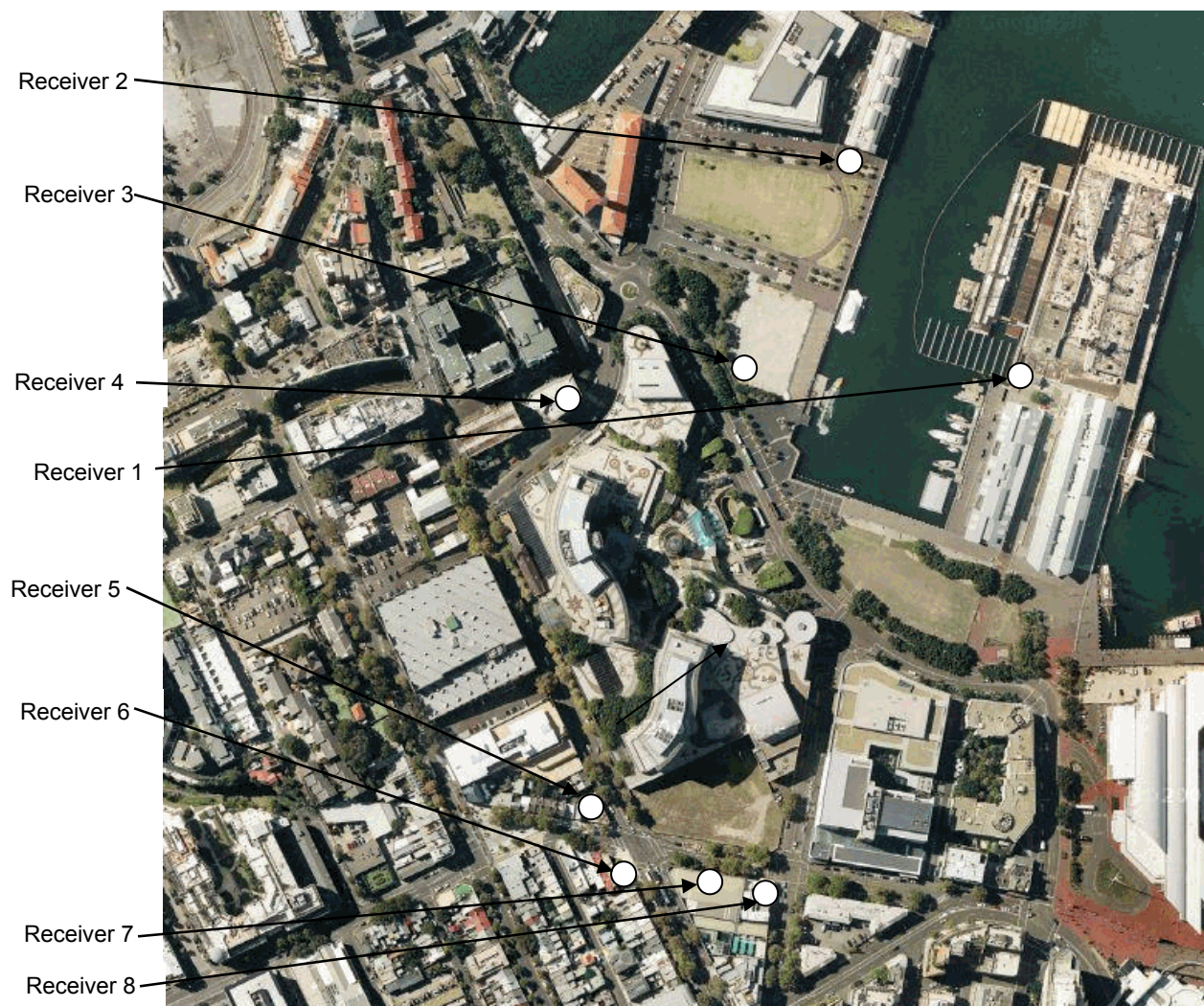
Accordingly, the unattended noise measurements taken at the Star City site are considered to be representative of the noise environment of the surrounding receivers, supplemented by attended measurements at the receiver locations, and have been used in the establishment of noise criteria.

Eight noise sensitive receivers were used to assess the noise impact from construction and operation of the Star City upgrade, including traffic noise. These receivers are detailed in Table 3 and shown in Figure 3.

Receiver Number	Receiver Location	Receiver Category	Approximate Direction from Star City Site
1	Pier 8/9 Apartments	Residential	NE
2	"Saunders Wharf" Apartments	Residential	N
3	Workplace 6 Office Building (Under Construction)	Commercial	NE
4	"Watermark Tower", 2 Jones Bay Road	Residential	N
5	"Talentino Restaurant" 9A Union Street	Commercial	SW
6	115 Pyrmont Street	Residential	SW
7	13A Union Street	Commercial	S
8	33 Union Street	Residential	SE

**Table 2:** Noise Sensitive Receivers.

<sup>3</sup> NSW EPA (2000) *Industrial Noise Policy*



**Figure 3:** Star City Locality, showing Noise Sensitive Receiver Locations.

Residential receivers are sensitive to noise 24 hours a day, seven days a week, whereas commercial receivers are only considered to be sensitive to noise during their hours of operation. Due to the nature of activities at the Star City complex, noise may be generated throughout the day, evening and night time periods as defined in the INP.

Noise from entertainment venues, such as the casino gaming floors, restaurants, conference centre and night venue, may be generated over extended time periods, including after midnight, particularly on weekends or holiday periods.

Noise from the mechanical services system for the Star City development is likely to be present for longer time periods, including the evening and night time periods defined in the INP, and therefore noise from these sources will be assessed for all time periods.

Traffic noise from the development may be generated during both the day and night time periods defined in the ECRTN<sup>4</sup>, in particular during weekend nights, when the casino is likely to experience high patronage. However, traffic survey data<sup>5</sup> shows that the peak traffic flows occur during the evening peak hour, and therefore the peak traffic noise levels are also expected to occur during the evening peak.

Construction noise from the construction of the development will generally be restricted to the day time periods on weekdays and on Saturday mornings.

<sup>4</sup> NSW Environmental Protection Agency (1999) – *Environmental Criteria for Road Traffic Noise*  
<sup>5</sup> R.O.A.R. Data (2008) – *2266 Pyrmont Star City Surveys: Union and Pyrmont Street*

Due to the large size of the Star City complex, the nearest affected noise-sensitive receiver varies between noise sources. An overview of the noise sensitive receivers for operational noise sources is presented in Table 3.

Noise Source	Affected Receivers (from Table 2)	Approximate Distance to Nearest Affected Receiver
Mechanical Plant	All	Varies
Pirrama Road Porte-Cochère	1,2,3	40 m (commercial) 200 m (residential)
Pirrama Road Café/Retail Area	1,2,3	40 m (commercial) 200 m (residential)
Restaurant Areas on Pirrama Road Frontage	1,2,3	40 m (commercial) 200 m (residential)
Restaurants in Pedestrian Arcade (Northern)	4	25 m (residential)
Retail in Pedestrian Arcade (Southern)	5,6,8	40 m (residential)
Hotel Lobby	5,6,7,8	20 m (commercial) 35 m (residential)
Hotel Porte-Cochère	5,6	35 m (commercial) 65 m (residential)
Outdoor Gaming Terrace (Eastern)	1,2,3	35 m (commercial)
Outdoor Gaming Terrace (Southern)	5,6,7,8	200 m (commercial)
Night Venue	1,2,3	125 m (residential)
Conference	1,2,3	45 m (commercial) 240 m (residential)

**Table 3:** Summary of Noise Sensitive Receivers for Operational Noise Sources.

## 4 Noise Criteria

The DGEARs do not give specific details of noise criteria to be used in the assessment. However, the DGEARs require the development to control 'unacceptable ...noise impacts (including traffic noise) on the vicinity'.

To achieve this, design criteria have been determined from several relevant sources, including legislation, EPA policy, relevant Australian Standards and guidelines. Each individual use of the site may have its own specific environmental noise criteria, and therefore several sets of criteria must be considered and developed.

Operational and traffic noise criteria have been determined following the guidance of the Industrial Noise Policy<sup>3</sup> (INP), the Environmental Noise Control Manual (ENCM)<sup>6</sup>, the Environmental Criteria for Road Traffic Noise (ECRTN)<sup>7</sup>, and Australian Standard AS2107:2000<sup>8</sup> as appropriate.

In general, this approach will result in acoustic criteria that are in keeping with industry-standard best practice and legislative requirements.

### 4.1 Internal Design Criteria

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#### 4.1.1 Internal Sound Levels

Recommended satisfactory and maximum internal noise levels and reverberation times for various types of building occupancy are given in AS2107. The AS2107 internal noise levels apply to steady-state background noise within the building occupancy, such as mechanical services noise.

Recommended internal design levels for various spaces for the Star City development are presented in Table 4. In general, Arup Acoustics recommends designing to the maximum AS2107 sound levels to provide a degree of noise masking and speech privacy within spaces, where required.

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<sup>6</sup> NSW Environmental Protection Agency (1994)- *Environmental Noise Control Manual*

<sup>7</sup> NSW Environmental Protection Agency (1999) – *Environmental Criteria for Road Traffic Noise*

<sup>8</sup> Australian Standard AS2107 (2000) – *Acoustics – Recommended design sound levels and reverberation times for building interiors*

Type of Occupancy	Recommended Sound Level	
	Satisfactory	Maximum
Function Rooms	30	35
Meeting Rooms	30	40
Private Offices	35	40
Small retail stores	45	50
Parking Areas / Loading Docks	55	65
Toilets	50	55
Exhibition areas	40	50
Conference areas (with speech reinforcement)	35	45
Hotel Ballroom	35	40
Restaurants and Cafes	45	50
Hotel Rooms – Sleeping Areas	35	40
Hotel Foyers and Recreation Areas	45	50
Gymnasiums	45	55
Bars and Lounges, Games Rooms	45	50

**Table 4:** Internal Design Sound Levels, dB L<sub>Aeq</sub> re 20μPa.

#### 4.1.2 Building Envelope

Arup Acoustics recommends that external noise break-in from noise sources such as road traffic and marine traffic be designed to meet these internal noise level criteria.

Although these sources are not steady state, designing the building envelope with sufficient sound insulation so that noise from these sources meets the overall internal noise levels is considered to be reasonable so that the internal noise amenity of occupants is maintained at all times.

This is in keeping with the character of the Star City development as an iconic, high-quality development and assists in the establishment of an appropriate degree of acoustic amenity for the users of the development. Design of the building elements should also be made with reference to AS3671<sup>9</sup> and AS2021<sup>10</sup>.

#### 4.1.3 Internal Building Design

Design of the development internally should be completed so as to achieve appropriate sound insulation between areas of the building with different sensitivities to noise and to achieve appropriate acoustic privacy between spaces.

Partitions surrounding plant spaces typically will require acoustically-rated constructions to minimise breakout of plant noise.

In particular, partitions between the pedestrian arcades and the Lyric Theatre should be sized to preserve the acoustic amenity of the Lyric Theatre interior, and to avoid intrusive noise break-in to the theatre space, which has the potential to disrupt the operation of the theatre.

<sup>9</sup> Australian Standard AS3671 (1989) – *Acoustics – Road traffic noise intrusion – Building siting and construction*  
<sup>10</sup> Australian Standard AS2021 (2000) – *Acoustics – Aircraft noise intrusion – Building siting and construction*

Areas of the upgrade located adjacent to the Light Rail corridor and station should be reviewed and designed as necessary by an appropriately qualified acoustic consultant to prevent structureborne and airborne noise intrusion from the Light Rail to the rest of the building.

#### 4.1.4 Room Acoustics

Recommended mid-frequency internal reverberation times for various spaces for the Star City development are given in AS2107. Table 5 presents a summary of applicable reverberation time criteria for internal areas of the Star City development.

Type of Occupancy	Recommended Mid-Frequency Reverberation Times, s
Function Rooms	0.6 to 0.8
Meeting Rooms	0.6 to 0.8
Private Offices	0.6 to 0.8
Conference Rooms	Designed according to Curve 1 of AS2107 Appendix A. Specialist advice should be sought
Small retail stores	Minimised as far as possible
Restaurants and Cafes	Minimised as far as possible
Hotel Ballrooms	Designed according to Curve 3 of AS2107 Appendix A. Specialist advice should be sought
Hotel Foyers and Recreation areas	Minimised as far as possible
Bars and Lounges	Minimised as far as possible
Games Rooms	< 1.0

**Table 5:** Internal Design Reverberation Times.

## 4.2 Industrial Noise Criteria

The New South Wales environmental noise policy relating to industrial noise is the *New South Wales Environment Protection Authority Industrial Noise Policy (INP)*<sup>3</sup>, dated January 2000. Noise emission from plant and equipment on the site is required to comply with the noise limits assessed in accordance with the INP.

The objective of the INP is to protect residential areas from noise generated by commercial, industrial or trade premises. Noise limits are set based on land use in the area and existing background noise levels. Compliance is achieved if the adjusted  $L_{eq}$  noise level at any residence affected by noise from the facility is below the noise limit. The adjusted  $L_{eq}$  is determined by applying corrections for such noise characteristics as duration, intermittency, tonality, and impulsiveness.

The assessment of noise emission under INP is based on the calculation of a noise limit at a receiver position, taking into account the land-use in the surrounding area and the background noise level.

The INP separates the day into three different time periods – day, evening and night. These time periods are detailed in Table 6.

Period	Day of Week	Time period
Day	Monday-Saturday	0700-1800hrs
	Sunday, Public Holidays	0800-1800hrs
Evening	Monday-Sunday	1800-2200hrs
Night	Monday-Saturday	2200-0700hrs
	Sunday, Public Holidays	2200-0800hrs

**Table 6:** Industrial Noise Policy Time Periods.

The INP provides guidance on acceptable noise levels from the introduction of new industrial noise sources to an area. The assessment procedure for industrial noise sources has two components:

- Controlling intrusive noise impacts in the short term for residences.
- Maintaining overall noise level amenity for particular land uses such as residences

Both of these components result in noise criteria that should not be exceeded in order to avoid any adverse noise impacts on the affected areas. Both criteria should be taken into account when assessing the noise impact of industrial source(s) associated with the proposed development, and where the intrusiveness and the amenity criterion differ, the lower of the noise criteria is adopted as the project-specific noise criterion.

### 4.2.1 Intrusiveness Criterion

A 15-minute sampling period is typically used when measuring the level of intrusive noise. This is taken to be a reasonable estimate of the period over which annoyance may occur. Therefore the intrusiveness criterion is summarised as follows:

$$L_{Aeq (15 \text{ min})} \leq L_{A90 (15 \text{ min})} \text{ background Level} + 5 \text{ dB}$$

Because of the variable nature of background noise levels, the INP specifies single number background noise levels for use in setting the intrusiveness noise criterion. The Assessment Background Level (ABL) for each time period of a day is the level exceeded by 90 % of the

$L_{A90,15min}$  measurements during that time period. The Rating Background Level (RBL) for a particular time period is the median of the ABL values for that time period for each day of the measurement period.

Industrial noise from the development should be controlled to not exceed the Rating Background Level (RBL) + 5 dB at the boundary of any residential noise sensitive receiver. The intrusiveness criterion does not apply to commercial noise-sensitive receivers.

The unattended noise measurements from all three loggers were used to derive the Rating Background Levels (RBL) for use in setting the intrusiveness criteria. A summary of the intrusive noise criteria for the noise sensitive receivers for the Star City development is given in Table 7:

Logger Location	Receivers	Time Period	RBL	Intrusiveness Criterion
			dB(A)	RBL + 5 dB(A)
Northern End of Roof (Logger 3)	2, 4	Day	56	61
		Evening	54	59
		Night	51	56
Platinum Room Terrace (Logger 2)	1	Day	53	58
		Evening	53	58
		Night	51	56
Switching Station (Logger 1)	6,8	Day	55	60
		Evening	53	58
		Night	50	55

**Table 7:** Intrusive Noise Criteria, Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

#### 4.2.2 Amenity Criterion

Criteria for the protection of amenity are given for various types of receiver and different times of the day. The amenity criterion is set so that the  $L_{Aeq}$  noise level from the industrial noise source does not increase the total industrial noise levels at the receiver above the acceptable noise level (ANL) for that receiver.

The amenity criterion is set based on how close the existing average  $L_{Aeq}$  industrial noise levels are to the ANL, using the adjustment factors given in Table 2.2 of the INP.

In cases where the existing  $L_{Aeq,average}$  noise levels exceed the ANL by more than 2 dB(A), and the existing noise levels are unlikely to decrease in future, then the amenity criterion is set to be 10 dB(A) lower than the existing noise levels at the receiver.

Logger Location	Noise Sensitive Receivers	Time period	Average $L_{eq}$ , dB(A)	Acceptable Noise Level, ANL $L_{eq}$ , dB(A)	Modifying Factor*	Amenity Criterion
		Day	56	60	ANL - 2	<b>58</b>
North End of Roof Logger 3	Residential	Evening	54	50	$L_{Aeq,ave} - 10$	<b>44</b>
		Night	51	45	$L_{Aeq,ave} - 10$	<b>41</b>
	Commercial	In Use	56	65	ANL + 0	<b>65</b>
		Day	57	60	ANL - 3	<b>57</b>
Outside Platinum Room Logger 2	Residential	Evening	57	50	$L_{Aeq,ave} - 10$	<b>47</b>
		Night	54	45	$L_{Aeq,ave} - 10$	<b>44</b>
	Commercial	In Use	57	65	ANL + 0	<b>65</b>
		Day	55	60	ANL - 2	<b>58</b>
Switching Station Logger 1	Residential	Evening	55	50	$L_{Aeq,ave} - 10$	<b>45</b>
		Night	50	45	$L_{Aeq,ave} - 10$	<b>40</b>
	Commercial	In Use	55	65	ANL + 0	<b>65</b>

\* According to Table 2.2 (NSW Industrial Noise Policy, 2000)

**Table 8:** Noise Amenity Criteria, Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

#### 4.2.3 Applicable Criteria

The most stringent of the intrusiveness and the amenity criteria is the limiting criterion and sets the project specific noise level to be met by the proposed development.

Table 9 compares the intrusiveness and the amenity criteria at the closest residential and commercial Noise Sensitive Receivers, and identifies the limiting criterion for each time period.

Noise Sensitive Receiver	Time Period	Intrusiveness Criterion	Amenity Criterion	Limiting Criterion
1	Day	58	57	<b>57</b>
	Evening	58	47	<b>47</b>
	Night	56	44	<b>44</b>
2,4	Day	61	58	<b>58</b>
	Evening	59	44	<b>44</b>
	Night	56	41	<b>41</b>
3	In Use	N/A	65	<b>65</b>
5,7	In Use	N/A	65	<b>65</b>
6,8	Day	60	58	<b>58</b>
	Evening	58	45	<b>45</b>
	Night	55	40	<b>40</b>

**Table 9:** Project Specific Noise Criteria, dB L<sub>Aeq</sub> re 20 $\mu$ Pa.

These criteria form the project-specific noise criteria for industrial noise from the Star City upgrade. A summary of the project-specific criteria for each industrial noise source contained within the Star City development is presented in Table 10, showing the range of criteria that apply at various noise-sensitive receivers.

Source	Time Periods of Operation	Limiting Criterion, dB L <sub>Aeq</sub>
Traffic On-Site (Porte-Cochère)*	Day, Evening, Night	40-44
Retail/Café Areas	Day, Evening	43-47
Mechanical Plant	Day, Evening, Night	40-44

**Table 10:** Overview of Industrial Noise Criteria, Star City Development, dB re 20 $\mu$ Pa.

Traffic noise generated from vehicle movements on site is assessed against the INP criteria. Therefore, traffic movements associated with pick-up and drop-off within the portes-cochère is considered an 'industrial' noise source.

The noise emitted from the portes-cochère is expected to be greatest during high-traffic periods, which are likely to fall into the Day and Evening time periods of the INP. However, noise from traffic movements on site is also expected to be produced throughout the night time period, although at reduced levels. Therefore, assessment of on-site traffic noise has been made considering both the 'peak' noise level and the 'typical' noise level from the portes-cochère.

### 4.3 Entertainment Venue Noise Criteria

The proposed upgrade to the Star City complex will incorporate several entertainment venues, including restaurants, outdoor terrace areas with gaming, an expanded conference space of approximately 1200 capacity, and a night venue. These venues typically produce noise during the evening and night time periods of the INP, and are proposed to be located on the Pirrama Road frontage of the upgraded Star City complex.

Noise criteria for function room event noise have been developed from the guidance of the Industrial Noise Policy and the requirements of the NSW Liquor Administration Board.

The Liquor Administration Board specifies noise criteria for noise emission from licensed premises. It is anticipated that most if not all entertainment venues at Star City will be licensed premises, and therefore noise generated from these venues must be controlled to meet the LAB criteria at the nearest residential receivers.

The Liquor Administration Board (LAB) criteria for noise from licensed premises require that:

- The  $L_{A10}$  noise level emitted from the licensed premises shall not exceed the background noise level in any octave band centre frequency (31.5 Hz – 8 kHz inclusive) by more than 5 dB between 0700hrs (7:00am) and Midnight (12.00am) at the boundary of any affected residence.
- The  $L_{A10}$  noise level emitted from the licensed premises shall not exceed the background noise level in any octave band centre frequency (31.5 Hz – 8 kHz inclusive) between Midnight (12.00am) and 0700hrs (7:00am) at the boundary of any affected residence.
- Notwithstanding compliance with the above, the noise from the licensed premises shall not be audible within any habitable room in any residential premises between the hours of Midnight (12.00am) and 0700hrs (7:00am).

Therefore, the appropriate noise criteria for noise from events at the entertainment venues are as given in Table 11:

Receivers	Time Period	RBL dB(A)	LAB Criterion $L_{A10}$
1	Day	53	58
	Evening	53	58
	Night	51	51
2,4	Day	56	61
	Evening	54	59
	Night	51	51
6,8	Day	55	60
	Evening	53	58
	Night	50	50

**Table 11:** Entertainment Venue Noise Criteria, dB re 20 $\mu$ Pa.

Between 12.00 am and 7:00 am, noise from the licensed premises must not be audible within any habitable room in any residential premises.

#### 4.4 Traffic Noise Criteria

Noise criteria for traffic movements resulting from the Star City upgrade were developed from the INP<sup>3</sup> and the Environmental Criteria for Road Traffic Noise (ECRTN<sup>7</sup>).

In accordance with the INP, road traffic noise from vehicles on the Star City site (i.e. porte-cochère traffic) is characterised as industrial noise, and therefore vehicle movements on site are subject to the noise criteria discussed in Section 4.2 above.

Road traffic noise from vehicles from the Star City site operating on public roads is subject to the ECRTN noise criteria. The ECRTN provides several categories for type of development and appropriate noise planning targets are given for each type of development.

The ECRTN noise criteria are planning goals for new development and as such are not legislative requirements which must be met by new developments, as the ECRTN recognises that achieving these criteria may not be considered 'feasible and reasonable' for all developments.

The Star City upgrade is best characterised as a development of Type 8– *Land use developments with potential to create additional traffic on collector roads*. Table 12 presents an extract from Table 1 of the ECRTN outlining the appropriate noise criteria.

Type of Development	Day Noise Criterion (7 am – 10 pm)	Night Noise Criterion (10 pm – 7 am)
8. Land use developments with potential to create additional traffic on collector road	60 dB $L_{Aeq}(1hr)$	55 dB $L_{Aeq}(1hr)$

**Table 12:** ECRTN Criteria for Star City, dB re 20 $\mu$ Pa

In cases where the criteria are exceeded by existing traffic flows, traffic from the development should not lead to an increase in existing noise levels of more than 2 dB.

#### 4.5 Construction Noise Criteria

Construction Noise Criteria were determined following the advice of the NSW EPA Environmental Noise Control Manual<sup>11</sup>, the EPA Industrial Noise Policy<sup>12</sup> and the City of Sydney Building Sites Noise Code (1988). The defining parameter for construction noise criteria is the duration of construction activities. Construction noise criteria are set based on the background noise levels of the site, which is taken to be the Rating Background Level determined in Section 4.2.

The criteria for demolition/construction noise are as follows:

- Construction period up to 4 weeks and under: the  $L_{A10}$  level measured over a period of not less than 15 minutes when the construction site is in operation must not exceed the background noise level by more than 20 dB:  $L_{A10,15min} \leq BG+20$  dB
- Construction period in excess of 4 weeks but no more than 26 weeks: the  $L_{A10}$  level measured over a period of not less than 15 minutes when the construction site is in operation must not exceed the background noise level by more than 10 dB:  $L_{A10,15min} \leq BG+10$  dB

<sup>11</sup> NSW Environmental Protection Agency - *Environmental Noise Control Manual, Chapter 171*  
<sup>12</sup> NSW Department of Environment and Conservation (2000) – *Industrial Noise Policy*

- Construction period in excess of 26 weeks: the  $L_{A10}$  level measured over a period of not less than 15 minutes when the construction site is in operation.  $L_{A10,15min} \leq BG+5$  dB
- Where background noise levels are 50  $dB_{LA90}$  or higher, the maximum permitted nuisance noise level is 68  $dB_{LAeq,T}$ , regardless of the background noise level.
- The maximum noise level at the site boundary must not exceed 85  $dB_{LA1}$ .

Measurements (other than at the site boundary) are to be taken at the façade boundary of the nearest noise-sensitive residential receiver. The ENCM only provides criteria for residential receivers; for commercial receivers, it is considered reasonable to apply the City of Sydney Code criteria (68 dB  $L_{Aeq,T}$ ) as an external construction noise criterion for these receivers.

The construction programme for the upgrade works will be in excess of 26 weeks duration, and therefore construction noise will be assessed against the most-stringent construction noise criteria for the purposes of this assessment.

All equipment in Group A of Schedule 1 of the Code (i.e. the noisiest equipment, such as rock breakers) must be provided with a Certificate of Acoustic Performance. Noise control treatment should be provided on new plant and machinery as required.

Where necessary, community consultation is also recommended and shall be aimed at providing a communication path directly to the contractor.

A summary of the site-specific construction noise criteria for the Star City site is given in Table 13 below. The most stringent of the  $L_{Aeq}$  or  $L_{A10}$  criteria will apply in each case.

Receivers	Time Period	RBL	Construction Noise Criteria	
		dB(A)	$L_{A10}$	$L_{Aeq}$
1	Day	53	58	68
	Evening	53	58	68
	Night	51	56	68
2, 4	Day	56	61	68
	Evening	54	59	68
	Night	51	56	68
6, 8	Day	55	60	68
	Evening	53	58	68
	Night	50	55	68

**Table 13:** Construction Noise Criteria at Noise Sensitive Receivers, dB re 20  $\mu$ Pa.

#### 4.6 Construction Vibration Criteria

The Sydney Building Sites Code does not include any discussion of vibration criteria and, therefore, cannot be referred to for any appropriate criteria. The vibration criteria are based on the DECC *Assessing Vibration* Guideline<sup>13</sup>, and on relevant Australian and International vibration standards<sup>14</sup>, as summarised in Table 14:

Criterion	Vibration Limit		Comments
	Peak Vibration Particle Velocity (PPV)	Vibration Dose Value	
Human Comfort	0.4 mm/s continuous and impulsive	0.2-0.4 m/s <sup>1.75</sup>	Applies to general occupied spaces, where occupied
Structural Damage	10 mm/s	N/A	Set as an initial limit, to be monitored during construction

**Table 14:** Construction Human Comfort and Structural Damage Vibration Limits at Vibration Sensitive Receivers.

This schedule of vibration limits is intended to ensure human comfort in occupied areas and to prevent structural or cosmetic damage.

These limits also apply to internal vibration-sensitive receivers (i.e. receivers within the Star City complex). Given the proximity of works to the Lyric Theatre, care should be taken to avoid structureborne noise issues within this space during construction.

A construction noise and vibration management plan should be prepared by the construction contractor. This could include restricting the hours of work of some equipment so that it is not used while a performance is underway in the theatre.

It is recommended that a programme of monitoring and consultation be established during construction works to control the vibration impact of the upgrade works on the Lyric Theatre.

If measured vibration levels exceed the human comfort criteria, the hours of work outlined in Section 4.5 will be enforced and a vibration limit to prevent building damage and disruption to equipment and processes of 10 mm/s will then be adopted as the baseline criteria, and appropriate control action shall be taken.

<sup>13</sup> NSW DECC (2006) *Assessing Vibration: A technical guideline*

<sup>14</sup> EPA ENCM, Chapter 174; German standard DIN 4150: Part 3: 1986; Swiss standard SN 640 312:1978; British standard BS7385: Part 2: 1993; Australian Standard AS 2187.2 – 1993

## 5 Predicted Noise Levels

This section contains predicted noise levels at surrounding noise-sensitive receivers from noise sources relating to the Project Star development. An assessment of the compliance of each noise source with the project-specific noise criteria for the development is presented in Section 6, including details of recommended noise-mitigation measures, where necessary.

### 5.1 Construction Noise

At this stage of design for Project Star, details of the amount and types of construction equipment to be used during the demolition and construction works for the new hotel and the upgraded casino have not been finalised. Additionally, the final selection of particular types of plant, including make and model, will be determined by the construction contractor.

Accordingly, there is a component of uncertainty in any construction noise predictions for Project Star, and therefore all predictions are indicative only, and represent likely construction noise levels that may be experienced at surrounding noise-sensitive receivers.

Construction noise levels for Project Star were predicted using quoted equipment noise levels in Table D2 of AS2436<sup>15</sup> and Annex C of BS5228<sup>16</sup>. A selection of typical construction equipment was used for prediction, as detailed in Table 15:

Equipment	Source	Sound Power Level
Tracked Loader (100-200 kW)	AS2436	116
Excavator (100-200 kW)	AS2436	112
Vibratory Roller	BS5228	106
Hydraulic Breaker	AS2436	112
Tower Crane	AS2436	108
Concrete Truck Mixer	BS5228	112
Electric Hoist	AS2436	92
20 t Truck	AS2436	108
Total Sound Power		120

**Table 15:** Construction Equipment Sound Power Levels used for Predictions, dB re 1 pW.

Construction noise levels were predicted at surrounding residential and commercial receivers, taking into account the source-receiver distance; screening of sources and/or receivers; meteorological, ground and atmospheric absorption effects; and reflected noise components, as appropriate. Predicted noise levels from construction are given in Table 16

<sup>15</sup> Australian Standard AS2436 (1981) – *Guide to Noise Control on Construction, Maintenance and Demolition Sites*

<sup>16</sup> British Standard BS5228.1 (1997) – *Noise and Vibration Control on construction and open sites. Part 1: Code of practice for basic information and procedures for noise and vibration control*

Receiver	Type	Construction Noise Level	Criterion (Day)	Meets Criterion?
1	Residential	74	58	No
2	Residential	65	61	No
3	Commercial	87	68	No
4	Residential	84	61	No
5	Commercial	85	68	No
6	Residential	85	60	No
7	Commercial	93	68	No
8	Residential	88	60	No

**Table 16:** Predicted Construction Noise Levels at Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

## 5.2 On-Site Traffic Noise

Noise levels from traffic movements within the portes-cochère were predicted based on measured noise levels from the hotel and casino portes-cochère on the existing Star City complex. Noise levels were measured during peak hour periods, where a steady flow of vehicles were using the porte-cochère, and also during a quieter period mid-afternoon where the porte-cochère received only intermittent traffic.

The measured existing porte-cochère noise levels, at a distance of approximately 3 m from the traffic lane, are summarised in Table 17:

Measurement	Time	Measured Noise Levels				
		L <sub>max</sub>	L <sub>10</sub>	L <sub>eq</sub>	L <sub>90</sub>	L <sub>min</sub>
Background Noise Level – Electronics Hum, noise from water features	2:28 pm	69	67	66	64	64
Intermittent Traffic through Porte-Cochère; Engine noise, door slams, speed bump noise	2:30 pm	78	70	69	66	65
Steady traffic through porte-cochere Tyre squeal; Door slam; Cars over speed bump/bar; Boot slam	4:50 pm	75	71	73	66	65

**Table 17:** Measured Porte-Cochère Traffic Noise Levels, 11 June 08. dB re 20 $\mu$ Pa.

Noise predictions at nearby receivers were made using the CONCAWE<sup>17</sup> noise propagation model. The CONCAWE model was developed for conducting environmental noise predictions for noise from large industrial sites, and is commonly used for modelling

<sup>17</sup> Manning, CJ (1981) – *The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities, Conservation of Clean Air, Water and the Environment (CONCAWE)*.

environmental propagation of sound, including meteorological effects due to wind and/or temperature inversions, ground attenuation and atmospheric attenuation.

Shielding, atmospheric absorption and ground reflection and absorption effects on the noise propagation from source to receiver were considered as part of the predictions. In cases where the source-receiver distance was greater than 100 m, meteorological effects were incorporated in the predictions, with a 'worst-case' methodology being used under 'downwind' propagation conditions. 'Downwind' conditions, where wind is blowing in the same direction as the noise propagation path, result in the greatest increase in noise levels, and therefore represent the most conservative propagation conditions.

Predicted noise levels are given in Table 18 and Table 19 below:

Receiver	Type	Predicted Noise Level (Peak Traffic)	Criterion (Evening)	Meets Criterion?
1	Residential	46	47	Yes
2	Residential	41	44	Yes
3	Commercial	61	65	Yes
5	Commercial	63	65	Yes
6	Residential	47	45	No

**Table 18:** Predicted Porte-Cochère Noise Levels (Peak Traffic) at Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

Receiver	Type	Predicted Noise Level (Low Traffic)	Criterion (Night)	Meets Criterion?
1	Residential	43	44	Yes
2	Residential	35	41	Yes
3	Commercial	55	65	Yes
5	Commercial	57	65	Yes
6	Residential	41	40	No

**Table 19:** Predicted Porte-Cochère Noise Levels (Low Traffic) at Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

### 5.3 Café/Retail Areas

Noise levels from the retail and café areas located on the Pirrama Road frontage and within the pedestrian arcades of the Star City site were predicted based on measured noise levels of café areas and the Harbourside Walk from attended measurements at Star City on 11 June 2008.

Predictions to noise-sensitive receivers were again made using the CONCAWE model, using propagation conditions as described in Section 5.2, and are given in Table 20:

Receiver	Type	Predicted Noise Level	Criterion	Meets Criterion?
1	Residential	37	47	Yes
2	Residential	32	44	Yes
3	Commercial	49	65	Yes
5	Commercial	46	65	Yes
6	Residential	42	45	Yes
8	Residential	33	45	Yes

**Table 20:** Predicted Café/Retail Noise Levels at Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

#### 5.4 Hotel

Noise levels from the hotel lobby (including venues within the lobby such as a bar or lounge) were predicted based on measured noise levels in the existing Star City hotel lobby, which included noise from patrons in the lobby lounge of the existing hotel. Noise levels at the nearest noise-sensitive receivers were again predicted using the CONCAWE methodology.

Predicted noise levels are given in Table 21:

Receiver	Type	Predicted Noise Level	Criterion	Meets Criterion?
5	Commercial	8	65	Yes
6	Residential	13	45	Yes
7	Commercial	22	65	Yes
8	Residential	15	45	Yes

**Table 21:** Predicted Hotel Lobby Noise Levels at Noise Sensitive Receivers, dB re 20 $\mu$ Pa.

#### 5.5 Road Traffic Noise

The road traffic noise impact of the Star City upgrade has been assessed using initial predictions made at residential receivers along Pyrmont Street, Jones Bay Road, Pirrama Road, and Union Street.

Predictions of peak traffic levels were obtained from the Arup Transport Planning traffic assessment for the Star City Upgrade, and are summarised in Table 22. Traffic noise levels were compared for two scenarios; existing noise levels, and noise levels following the completion of the upgrade (“Existing” and “Future”).

Road Segment	Receiver	Scenario	Time Period	Traffic Flow	% Heavy Vehicles
Pyrmont Road	6	Existing	1 hour	642	11.2%
		Future		783	11.2%
Jones Bay Road	4	Existing	1 hour	488	2.7%
		Future		595	2.7%
Pirrama Road	1	Existing	1 hour	705	2.1%
		Future		860	2.1%
Union Street	8	Existing	1 hour	253	4.0 %
		Future		309	4.0 %

**Table 22:** Traffic Volumes used for Prediction, from Arup Transport Planning traffic assessment.

Traffic noise levels at the residential receivers along surrounding roads were predicted using the *Calculation of Road Traffic Noise (CoRTN)*<sup>18</sup> methodology. Although developed in the UK, CoRTN has been widely validated for the prediction of road traffic noise in Australia, and is an appropriate method to obtain indicative traffic noise levels from the development.

CoRTN predicts a one-hour  $L_{A10}$  single number value at a distance of 10 m from the edge of the road. The noise-sensitive residential receivers in the Star City vicinity vary from approximately 5 m to 100 m from the road edge (Receiver 1, Pier 8/9 Apartments) and therefore the predicted noise levels were adjusted to the receiver distance.

For continuous traffic flows,  $L_{A10}$  has been found to be approximately 3 dB(A) higher than  $L_{Aeq}^7$ , and therefore the predicted  $L_{A10}$  values have been corrected to  $L_{Aeq}$  values using this correlation. Traffic speed was taken to be 50 km/h, based on the signposted speeds of the surrounding roads.

To calibrate the CoRTN model for this scenario, noise levels were predicted at the logger location on the roof edge at the northern end of the Star City site, which is exposed to traffic noise from Jones Bay Road. The predicted noise levels were approximately 2 dB(A) below the measured noise levels, which is within the quoted accuracy of the CoRTN model. Additionally, the logger location is also exposed to some traffic noise from Pirrama Road, and it is possible that this is the cause of the difference between the measured and predicted noise levels.

Predicted traffic noise levels are presented in the table below:

Receiver	Existing (Predicted)	Meets Criterion?	Future (Predicted)	Meets Criterion?	Increase	Acceptable?
1	58	Yes	59	Yes	1 dB	Yes
4	68	No	69	No	1 dB	Yes
6	71	No	72	No	1 dB	Yes
8	65	No	66	No	1 dB	Yes

**Table 23:** Traffic Noise Predictions— dB  $L_{Aeq,1hr}$  re 20  $\mu$ Pa.

<sup>18</sup>

United Kingdom Department of Transport (1988) – *Calculation of Road Traffic Noise*

## 5.6 Entertainment Venues

Entertainment venue noise levels were predicted using the CONCAWE methodology, using noise levels obtained from attended measurements at the Star City site, previous Arup Acoustics measurements of noise from entertainment venues such as nightclubs and restaurants, and published data for human voice sound levels<sup>19</sup>.

The restaurants, night venue and conference centre are proposed to have terrace and breakout areas behind the external glazed canopy on the Pirrama Road façade. Screening from this canopy has been taken into account in predicting noise levels at surrounding receivers.

Noise predictions for the night venue and conference centre were made based on amplified music being played in these venues, but with all doors and openings closed. Noise predictions for the restaurants were based on these venues having an external dining terrace behind the Pirrama Road glazed canopy.

The night venue and conference centre were modelled using previous Arup Acoustics measurements of internal reverberant noise levels in a nightclub. Internal areas of restaurants were modelled using previous Arup Acoustics measurements of restaurant noise levels. Noise levels for external restaurant terraces were modelled based on published vocal levels. The outdoor terrace areas on Level 01 were assumed to have poker machines only for the purposes of undertaking noise predictions.

Source noise levels used for entertainment venue predictions are given in Table 24 below:

Source	Type	Octave Band Source Noise Level							
		63 Hz	125Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 KHz
Night Venue	Reverberant Noise Level	85	98	98	96	94	87	79	76
Restaurant Indoor	Reverberant Noise Level	82	80	83	81	80	76	74	66
Poker Machine	Direct Noise Level (1.5 m)	59	61	62	63	62	59	58	56
Restaurant Terrace	Direct Noise Level (1 m)	47	67	75	85	82	76	72	64

**Table 24:** Entertainment Venue Source Noise Levels, dB re 20µPa.

Receiver noise levels were predicted based on the following entertainment venue noise sources for each receiver:

<sup>19</sup>

Receiver	Noise Source					
	Eastern Restaurants	Eastern Gaming Terrace	Night Venue	Conference	Northern Restaurants	Southern Gaming Terrace
1	✓	✓	✓	✓		
2	✓	✓	✓	✓		
4					✓	
6						✓
8						✓

**Table 25:** Entertainment Venue Noise Sources used for Each Receiver

During detailed design of the Star City upgrade, the building envelope design should be reviewed by a suitably qualified acoustic consultant to control noise emission through the function room and appropriate maximum sound levels for entertainment room events will be established.

Appropriate management of events held in these venues will also assist in controlling the noise impact on surrounding receivers. This may consist of measures such as restricting hours of events, limiting the maximum noise output of audiovisual equipment or other measures as required.

Predicted entertainment noise levels are given in Table 26, with an assessment of the predicted noise levels against the LAB entertainment venue noise criteria.

Receiver	Predicted Noise Level	Criterion (0700-0000) (BG+5)	Meets Criterion?	Criterion (0000-0700) (BG+0)	Meets Criterion?	Likely to be Inaudible? (BG-10)
1	41	58	Yes	51	Yes	Yes
2	32	59	Yes	51	Yes	Yes
4	51	59	Yes	51	Yes	No
6	38	58	Yes	50	Yes	Yes
8	40	58	Yes	50	Yes	Yes

**Table 26:** Predicted Entertainment Venue Noise Levels at Noise Sensitive Receivers, dB re 20 $\mu$ Pa

## 6 Assessment of Effects

### 6.1 Construction Noise

The predicted construction noise levels at surrounding receivers exceed the noise criteria at all receivers. Construction and demolition activities are inherently noisy activities, and considering the proximity of the site to surrounding receivers, an exceedance of the criteria from construction activities is not unexpected.

Controlling construction noise impacts can be achieved through several approaches, and the most appropriate means of controlling the construction noise impact of Star City should be considered through a process of consultation with affected stakeholders.

Appropriate administrative or engineering controls should be implemented to assist in reducing the construction noise and vibration impact. AS2346<sup>20</sup> and BS5228 provide further guidelines for controlling the construction noise impact from the development.

The following control measures may be considered:

- Providing acoustic screens and/or enclosures for stationary equipment, such as compressors; or constructing a solid hoarding (of at least 15 kg/m<sup>2</sup> surface density construction) on the site boundary to act as a noise barrier.
- Providing mobile acoustic screens and/or enclosures for construction equipment and activities, or temporary acoustic screens at noise-sensitive receivers, where possible.
- Selecting low noise plant and equipment. Noise levels of plant used on site should not exceed those given in "Schedule 1" of the *City of Sydney Code of Practice for Construction Hours/Noise within the Central Business District*.
- Regular maintenance of plant and equipment.
- Keeping engine covers and access hatches to equipment closed, e.g. compressors, etc.
- Use of alternative construction methods to minimise noise and vibration, e.g. use of concrete crushing jaws instead of rock-breakers, where possible
- Development of a construction works methodology to minimise the effect of direct line of sight (for noise) to affected receivers.
- Position access ways for major plant and trucks at the lowest grade practicable
- Scheduling noisy construction activities during times when noise impact on residents or sensitive receivers is likely to be lowest, e.g. No heavy work before 09:00, and no noisy work during Lyric Theatre performances.
- Introducing respite periods during the day or at weekends where no noisy construction work can take place. These periods are to be determined through consultation and negotiation with affected stakeholders.
- Regular community communication to advise residents of impending noisy activities.

A Noise and Vibration Management Plan should be prepared as part of the Project Star construction and demolition works. This Noise Management Plan should be prepared by an accredited acoustic consultant, and should in particular consider the noise and vibration impacts to internal receivers within the complex during the construction works, especially the Lyric Theatre.

Vibration levels from construction activities are difficult to predict at this stage, as the ground composition and lithology of the site has a significant effect on the propagation of vibration, and the types of equipment to be used on site have not been established. It is

<sup>20</sup>

Australian Standard AS2436 (1981) – *Guide to Noise Control on Construction, Maintenance and Demolition Sites*

recommended that vibration levels be measured at sensitive internal and external receivers at the beginning of each stage of construction/demolition, and work practices modified accordingly to minimise the vibration impact from the works.

Consultation with affected receivers should be followed, and if necessary vibration monitoring could be conducted to assist in controlling the vibration and/or structureborne noise impact of the works.

Control of vibration and structureborne noise from construction and demolition activities could include the following measures:

- Conduct a site dilapidation survey to determine the vibration sensitivity of the nearest receivers, particularly heritage buildings on Union and Pymont Street.
- Use of trenches to block the propagation path of surface vibration
- To mitigate the effects of structureborne noise and vibration, any sections of the existing structure to be demolished should be separated from the remainder of the complex by cutting slots in slabs etc, subject to the confirmation of the temporary stability of the structure to be demolished.
- Vibration levels at the nearest receivers should be measured by a qualified acoustic consultant when works commence. Site-specific vibration limits should be established based on vibration measurements and the findings of the site dilapidation surveys.
- Smaller or hand-driven equipment, such as jackhammers, should be used where possible when working in vibration sensitive areas (such as near the Lyric Theatre or heritage buildings).

Scheduling high-vibration activities during times when vibration impact on sensitive receivers is likely to be lowest, e.g. No heavy work before 09:00, and no demolition/high-vibration works during Lyric Theatre performances. All stages of construction works should incorporate all feasible and reasonable noise and vibration mitigation measures in order to control the noise impact of the development on the surrounding noise sensitive receivers.

The principles of 'Best Management Practice' (BMP) and 'Best Available Technology Economically Achievable' (BATEA) shall be applied at all times.

## 6.2 Mechanical Plant Noise

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The mechanical services of the Star City upgrade have not been designed at this stage. Noise control treatments will be incorporated into the design of the mechanical systems so that the industrial noise criteria are met at all noise sensitive receivers.

During detailed design of these systems, noise control measures, such as acoustic enclosures or louvres and attenuation, will be incorporated where necessary to ensure that the industrial noise criteria for noise from these systems are met.

## 6.3 Industrial Noise

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Noise levels from industrial noise sources in Project Star (including the hotel and Pirrama Road portes-cochère, café/retail areas, and hotel areas) generally comply with the INP criteria, except for Receiver 6 (Pymont Road residential receivers), which are marginally (1 - 2 dB(A)) above the criteria.

### 6.3.1 Porte-Cochère

The noise from the portes-cochère is predicted to be the dominant industrial noise component emitted from the Project Star upgrade of Star City, with other noise sources being generally 10 dB(A) or more lower than the porte-cochère noise levels.

Noise from the new hotel porte-cochère is predicted to cause a small (1-2 dB(A)) exceedance of the industrial noise criteria at Receiver 6. This exceedance is marginal in nature, as an increase of 1-2 dB(A) is only just perceptible for most people.

However, some acoustic treatment is recommended to the porte-cochère to reduce the generated noise levels. This could include providing acoustic absorption to the overhang of the porte-cochère to reduce the reverberant build-up of noise in the porte-cochère.

During the attended measurements, noise from door slams, car ignitions, tyre/brake squeal and from traffic going over speed control devices was observed to form the most prominent component of the noise generated from the porte-cochère.

Although the existing casino/hotel porte-cochère operates successfully without acoustic issues, it is screened from residential receivers by the existing Star City structure, and has direct line of site only to commercial receivers.

In contrast, the new hotel porte-cochère is located closer to residential receivers than the existing casino/hotel porte-cochère, and the new porte-cochère will not be significantly screened by the Star City structure. Therefore, some noise control measures to reduce the noise generation in the new hotel porte-cochère are recommended.

These could consist of engineering and administrative measures, such as:

- Encouraging drivers and hotel staff to minimise noise by not slamming doors or boots
- Incorporating a road surface in the porte-cochère with sufficient roughness to provide additional slip resistance (which reduces the incidence of wheel squeal noise)

Acoustic treatment and/or noise control measures to the new hotel porte-cochère are considered likely to provide sufficient reduction in the noise levels at surrounding receivers that the industrial noise criteria will be met at all receivers.

#### 6.3.2 Café/Retail Areas

Predicted noise levels from the café/retail areas are below the INP noise criteria for all receivers. To minimise the reverberant build-up of noise in these areas and improve the acoustic quality of these spaces, it is recommended that the retail arcades be acoustically treated with absorptive material.

However, no further noise control measures are recommended for these areas.

#### 6.3.3 Hotel

Predicted noise levels from the hotel lobby are below the INP noise criteria for all receivers. Therefore, no noise control measures are recommended for the hotel lobby.

### 6.4 Road Traffic Noise

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The predicted road traffic noise levels on surrounding roads following the completion of the Star City upgrade are generally in excess of the ECRTN targets, except for one receiver (Receiver 1, which is approximately 100 m from Pirrama Road and therefore experiences reduced traffic noise levels). However, the existing measured and predicted traffic noise levels in the vicinity are also generally in excess of the ECRTN criteria, and therefore the impact of the Star City upgrade should be assessed using the provision in the ECRTN that the existing traffic noise levels should not be increased by more than 2 dB(A).

The predicted future noise levels following the completion of the Star City upgrade are less than 2 dB(A) above the existing noise levels for all receivers, and therefore the traffic noise impact of the Star City upgrade falls within the guidelines of the ECRTN.

### 6.5 Entertainment Venue Noise

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Predicted noise levels from entertainment venues generally comply with the LAB criteria before midnight. After midnight, although the predicted noise levels comply with the numeric LAB criterion (BG+0), the noise levels at some receivers are considered likely to be audible in habitable rooms of one receivers— Receiver 4 (Watermark Tower, Jones Bay Road), which means that the third component of the LAB criteria (inaudibility) is not likely to be met at this receiver.

Objective assessment of audibility is difficult, as it is a subjective response to noise and may vary from person to person, and be influenced by tonal or other characteristics in the noise source. However, if the predicted noise levels at a receiver are 10 dB(A) or more below the background noise level, it is considered likely that the noise source will be inaudible at that receiver.

Noise levels from the restaurants in the northern retail/restaurant arcade are predicted to be dominant for this receiver. The predicted noise levels are equal to the Rating Background Level for the night time period.

Predicted noise levels are based on a 'worst-case' assessment, with adverse meteorological propagation conditions ('downwind' conditions, wherever the source-receiver distance exceeds 100 m), and with any operable windows at the receiver assumed to be open.

For Receiver 4, noise levels are approximately the same as background noise levels, and therefore approximately a 10 dB(A) noise reduction would be required before the inaudibility criterion is likely to be met. Given the proximity of source and receiver, the scope to achieve noise reduction through treatments alone is limited. If operation of the restaurants in the northern arcade after midnight is desired, it is recommended that the restaurants be designed to minimise the noise breakout. Measures that could be considered include the following:

- Incorporating acoustic separation (e.g. sound locks or entrance lobbies) on the restaurants
- All restaurants should open onto the arcade, not directly onto Jones Bay Road
- Restaurants and the arcade should incorporate acoustic absorption to minimise the reverberant build-up of sound

Predicted noise levels from the night venue and conference centre comply with the criteria, based on amplified music in these venues, but with doors closed. To minimise the noise impact on surrounding residential receivers, it is recommended that operable windows or doors of the night venue and conference centre be kept closed when amplified music is played in these venues.

Given the presence of noise-sensitive receivers in the Star City locality, all venues should be managed so that noise emission from the venue is controlled. Management measures that may be considered to control entertainment venue noise levels include the following:

- Restricting the hours of operation of venues
- Keeping operable doors or windows closed when noisy activities are underway within the venue (especially night venue and conference centre, and particularly after midnight); this might include closing or restricting access to outdoor areas of the venues.
- Designing venues to control noise emission, including construction of external partitions, internal acoustic treatments, and physical separation between noisy areas and sensitive receivers

If good management practice of the entertainment venues in Project Star is followed, it is expected that the noise impact of these venues can be managed to acceptable levels so as to not cause disturbance to surrounding residential noise-sensitive receivers.

## 7 Conclusions

Construction and operational noise levels from Project Star, Sydney, have been predicted and assessed against applicable noise criteria set from NSW legislation, EPA guidance and industry best practice.

Predicted construction noise levels from the development are generally in excess of the noise criteria at surrounding receivers. Management measures are recommended to minimise the construction noise and vibration impact of the development on internal and external noise- and vibration-sensitive receivers.

Predicted operational noise levels from Project Star, including on-site traffic, external traffic noise, and noise from retail areas, hotel and entertainment venues, generally complies with the criteria, although the criteria are exceeded at some receivers during certain time periods.

It is expected that appropriate design of the development incorporating acoustic treatment, noise control, and good acoustic design principles, as appropriate, coupled with effective management of the noise produced from the development, will sufficiently control the operational noise impact of the proposed casino upgrade and hotel development so that there are no unacceptable noise impacts on the amenity of the surrounding area.



Arup**Acoustics**

Appendix A

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**Acoustic Terminology**

## A1 Glossary of Acoustic Terminology

### ASSESSMENT BACKGROUND LEVEL (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background  $L_{A90}$  noise levels – i.e. the measured background noise is above the ABL 90% of the time.

### 'A'-WEIGHTED SOUND LEVEL dB(A)

The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An 'A'-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. An increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise. A change of 2 to 3 dB is subjectively barely perceptible.

### DECIBEL

The ratio of sound pressures which we can hear is a ratio of  $10^6:1$  (one million : one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound level' (L) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.

Some typical noise levels are given below:

Noise Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside disco
90	Heavy lorries at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office or restaurant
50	Domestic fan heater at 1m
40	Living room
30	Theatre
20	Remote countryside on still night
10	Sound insulated test chamber
0	Threshold of hearing

### EQUIVALENT CONTINUOUS SOUND LEVEL ( $L_{Aeq}$ )

Another index for assessment for overall noise exposure is the equivalent continuous sound level,  $L_{Aeq}$ . This is a notional steady level, which would, over a given period of time, deliver

the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

#### FREQUENCY

The rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to cycles per second. A thousand hertz is often denoted kilohertz (kHz), e.g. 2 kHz = 2000 Hz. Human hearing ranges from approximately 20 Hz to 20 kHz. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

#### IMPACT SOUND PRESSURE LEVEL

The technical parameter used to determine impact sound isolation of floors is the impact sound pressure level,  $L_i$ .

In the laboratory, the weighted normalised impact sound pressure level,  $L_{n,w}$ , is used to represent the impact sound isolation as a single figure.

On site, the weighted normalised apparent impact sound pressure level,  $L'_{n,w}$ , and the weighted standardised apparent impact sound pressure level,  $L'_{n,Tw}$ , are used to represent the impact sound isolation of a floor as a single figure.

These single weighted values are determined by comparing the spectral impact sound pressure levels (as defined in ISO 140-6 & ISO 140-7) with reference values outlined in AS/NZS ISO 717.2.

#### MAXIMUM SOUND LEVEL, $L_{max}$

The maximum sound level is the maximum weighted sound pressure level experienced during the measurement period.

#### PEAK PARTICLE VELOCITY (PPV)

Peak Particle Velocity is the parameter most often used for the quantification of groundborne and structure-borne vibration. It is the maximum positive or negative magnitude of vibration in a defined direction caused by the passage of a wave front during a specified interval. Particle velocity is used in most cases because this parameter has been found to correlate best with the onset of structural damage. It can also be used to provide some guidance on disturbance to people and the sensitivity of equipment and processes to vibration.

#### RATING BACKGROUND LEVEL (RBL)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

#### REVERBERATION TIME ( $RT_{60}$ )

The time, in seconds, taken for a sound within a space to decay by 60 dB after the sound source has stopped is denoted as the reverberation time. The RT is an important indicator of the subjective acoustic within an auditorium. A large RT subjectively corresponds to an acoustically 'live' or 'boomy' space, while a small RT subjectively corresponds to an acoustically 'dead' or 'flat' space.

## SOUND EXPOSURE LEVEL (SEL)

The Sound Exposure Level or Single Event Noise Exposure Level, denoted SEL or  $L_{AE}$ , is a measure of the total amount of acoustic energy contained in an acoustic event. The SEL is the constant sound pressure level that would produce in a period of one second the same amount of acoustic energy contained in the acoustic event.

## SOUND LEVEL DIFFERENCE (D)

The sound insulation required between two spaces may be determined by the sound level difference needed between them. A single figure descriptor, the weighted sound level difference,  $D_w$ , is sometimes used (as defined in AS/NZS ISO 717.1).

The terms used to describe the airborne sound insulation rating of a building element when tested on-site are the weighted normalised level difference ( $D_{n,w}$ ), which corrects the measured sound level difference to a reference absorption area in the receiving room, or the weighted standardized level difference ( $D_{nT,w}$ ), which corrects the measurements to a reference reverberation time in the receiving room.

These single numbers are determined by comparing the spectral sound insulation test results (as defined in ISO 140-4) with reference values, as outlined in AS/NZS ISO 717.1.

## SOUND POWER AND SOUND PRESSURE

The sound power level ( $L_w$ ) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level ( $L_p$ ) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

## SOUND REDUCTION INDEX (R)

The sound reduction index (or transmission loss) of a building element is a measure of the loss of sound through the material, i.e. its sound attenuation properties. It is a property of the component, unlike the sound level difference, which is affected by the common area between the rooms and the acoustics of the receiving room. The weighted sound reduction index,  $R_w$ , is a single figure description of sound reduction index and is defined in BS EN ISO 717-1: 1997.  $R_w$  values are calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site (which are invariably lower than the laboratory figures) are referred to as apparent sound reduction index ( $R'_w$ ) ratings.

## STATISTICAL NOISE LEVELS

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index, which allows for this variation. 'A'-weighted statistical noise levels are denoted  $L_{A10}$ ,  $dBL_{A90}$  etc. The reference time period (T) is normally included, e.g.  $dBL_{A10, 5min}$  or  $dBL_{A90, 8hr}$ .

$$L_{A90(T)}$$

Refers to the sound pressure level measured in dB(A), exceeded for 90% of the time interval (T) –i.e. measured noise levels were greater than this value for 90% of the time interval. This is also often referred to the background noise level.

$$L_{A10(T)}$$

Refers to the sound pressure level measured in dB(A), exceeded for 10% of the time interval (T). This is often referred to as the average maximum noise level and is frequently used to describe traffic noise.

## STRUCTUREBORNE NOISE

The transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, i.e. expansion joints and floating floors.

## VIBRATION

Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structureborne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g.  $1\text{mms}^{-1}$  or as a ratio on a logarithmic scale in decibels:

Vibration velocity level,  $L_V$  (dB) =  $20 \log (V/V_{\text{ref}})$ ,

(where the preferred reference level,  $V_{\text{ref}}$ , for vibration velocity =  $10^{-9}$  m/s).

The decibel approach has advantages for manipulation and comparison of data.

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Appendix B

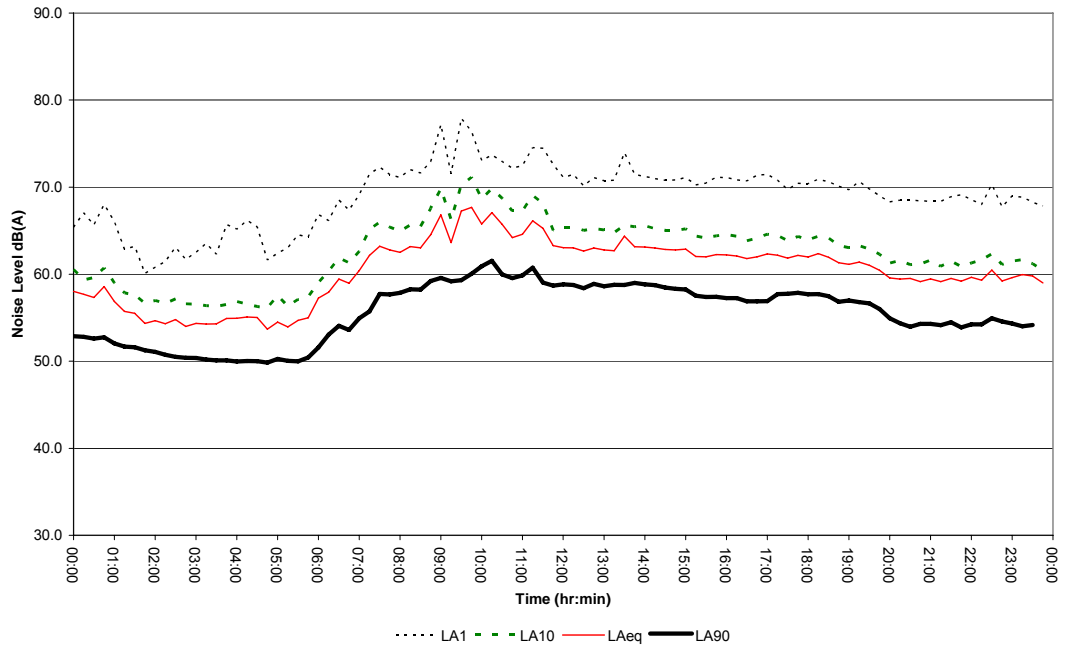
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**Noise Survey Results**

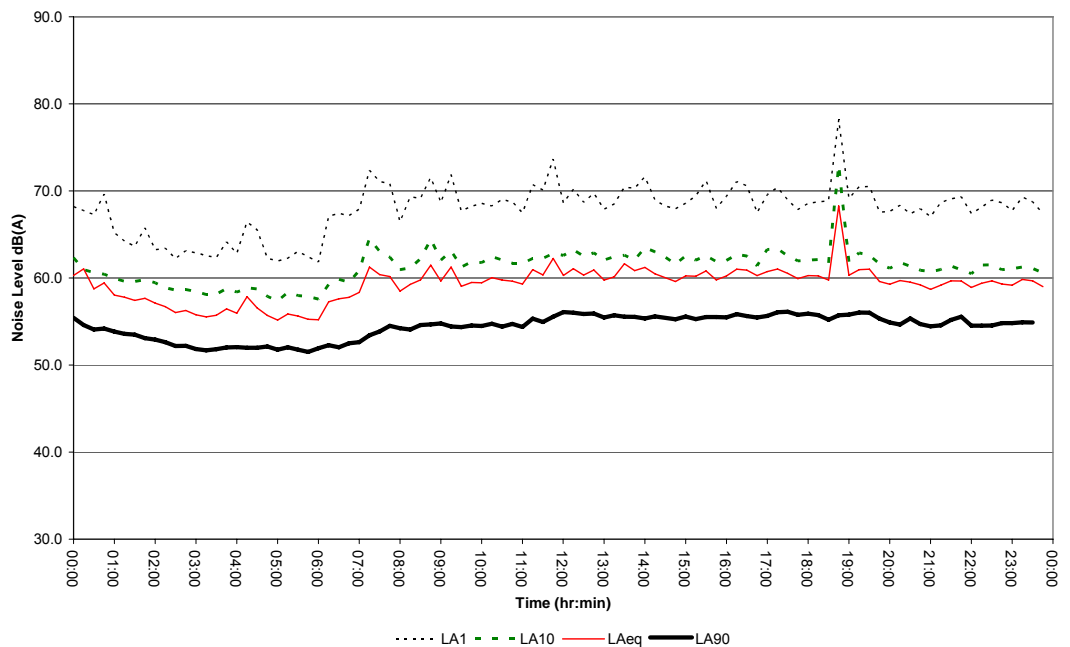
## B1 Unattended Noise Logger Graphs

Noise logger survey results are presented in the figures below.

### B1.1 Logger 1 (North End Of Roof)

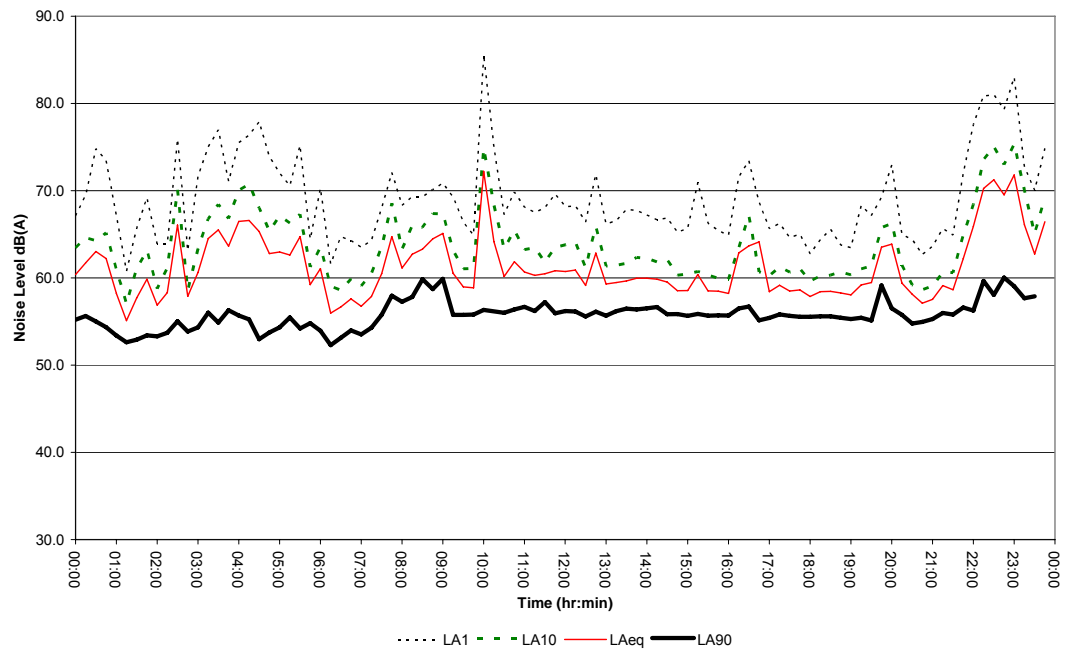


**Figure 4:** Average Weekday Noise Levels, 29 May 2008 to 18 June 2008, Roof above Star Theatre, dB re 20 $\mu$ Pa

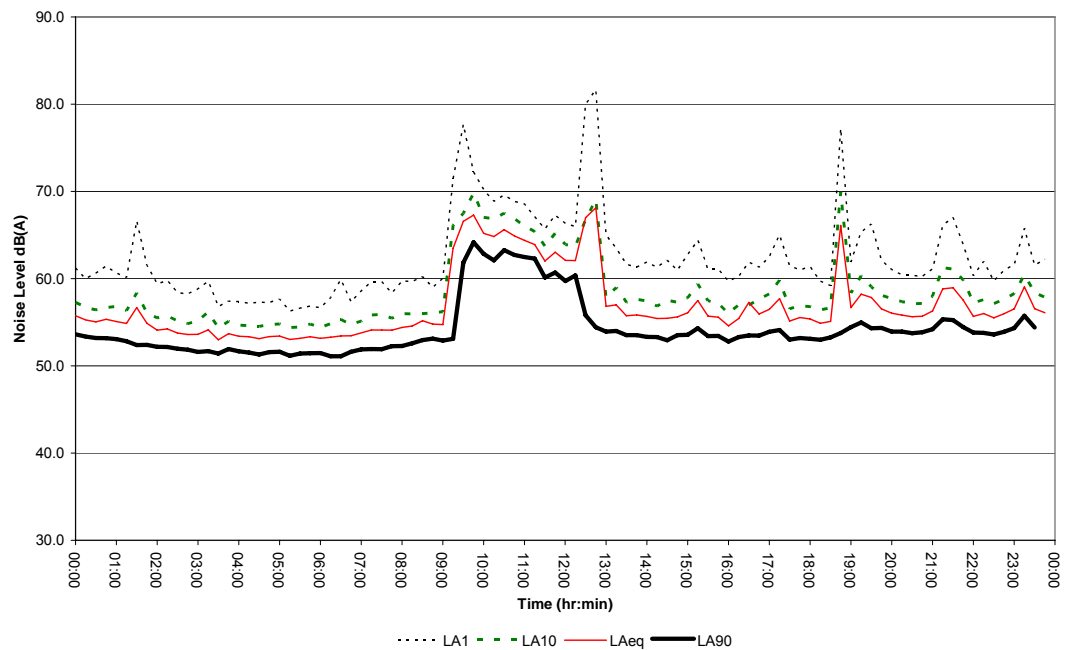


**Figure 5:** Average Weekend Noise Levels, 29 May 2008 to 18 June 2008, Roof above Star Theatre, dB re 20 $\mu$ Pa

B1.2 Logger 2 (Platinum Room Terrace)



**Figure 6:** Average Weekday Noise Levels, 29 May 2008 to 18 June 2008, Platinum Room Terrace, dB re 20µPa

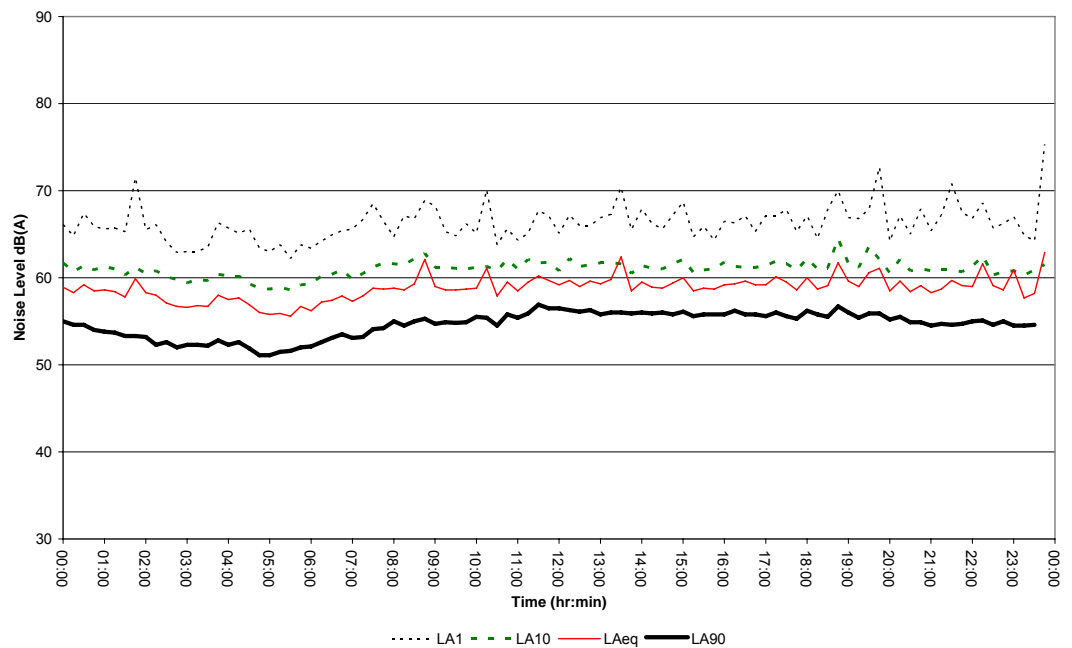


**Figure 7:** Average Weekend Noise Levels, 29 May 2008 to 18 June 2008, Platinum Room Terrace, dB re 20µPa

B1.3 Switching Station Site



**Figure 8:** Average Weekday Noise Levels, 29 May 2008 to 18 June 2008, Switching Station Site, dB re 20 $\mu$ Pa



**Figure 9:** Average Weekend Noise Levels, 29 May 2008 to 18 June 2008, Switching Station Site, dB re 20 $\mu$ Pa