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AUSTRALIA HABITAT AND TARONGA WILDLIFE RETREAT

Noise and Vibration Assessment

28 September 2016

Taronga Conservation Society Australia

TH918-02F02 (r3) Noise and vibration assessment

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1 Introduction

1.1 Background

Taronga Conservation Society Australia has submitted a State Significant Development Application (SSDA) to the Department of Planning and Environment pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act) for a proposed Australia Habitat and Taronga Wildlife Retreat at Taronga Zoo.

The NSW Environmental Protection Agency (EPA) and Department of Planning and Environment (DoPE) have made a number of responses to the SSDA which are to be addressed before the SSDA will be granted approval.

This report assesses construction noise and vibration and operational noise from the proposal in accordance with the Secretary's Environmental Assessment Requirements (SEARs), and addresses the responses made by the EPA and DoPE.

1.2 Assessment objectives

The assessment objects of this report are to determine the levels of operational noise and construction noise and vibration impact on sensitive receivers located near to the project, and determine the levels of mitigation that will be required to enable compliance with the relevant authorities.

This assessment considers the followings policies and guidelines:

- NSW Industrial Noise Policy (EPA 2000)
- Interim Construction Noise Guideline (DECC 2009)
- Assessing Vibration – A Technical Guideline (DEC 2006)

1.3 Secretary's Environmental Assessment Requirements

Item 7 and Item 9 of SSD 7419 Secretary's Environmental Assessment Requirements (SEARs) outline the following noise and vibration assessment requirements:

> *7. Noise*
>
> *Identify and provide a quantitative assessment of the main noise generating sources and activities during operation. Outline measures to minimise, mitigate and manage the potential noise impacts on surrounding sensitive residential receivers and other occupiers of land.*
>
> *9. Construction Impacts*
>
> *The EIS shall assess, quantify, report on and identify measures to ameliorate potential construction impacts during the demolition, site preparation and construction phases of the development,*

including, traffic, access, noise and vibration (including hours of operation and any respite periods), air quality, dust, erosion and sediment control, water quality and water conservation, waste management and transportation of waste, management and disposal of hazardous materials (including asbestos), management and disposal of concrete waste and rinse water, and other cumulative environmental impacts.

1.4 Responses to submission

The NSW Environmental Protection Agency (EPA) and Department of Planning and Environment (DoPE) have made the following responses to the submission in relation to noise and vibration from the construction and operation of the proposal.

1.4.1 EPA submissions

The EPA remains concerned about the risks of unacceptable noise impact which may arise from inadequate noise impact assessment, management and mitigation measures.

The EPA anticipates that the operation of the proposed facilities may change the nature and intensity of noise impacts on surrounding residences. The NSW Industrial Noise policy, January 2000 (INP) provides guidance material on noise impact assessment.

The EPA considers that the proponent should provide predicted worst case noise impacts on surrounding residences as required by the SEARs.

The EPA notes that ESI Appendix L does not establish the background noise level at noise sensitive receivers (i.e. residences), especially those located to the north and northeast of the project site.

Appendix L does not provide the quantitative operational noise impact assessment required by the SEARs. Instead, Appendix L section 3.1 appears to suggest that -

(a) noise impact on the surrounding residents is unlikely to be a matter of concern, and

(b) the focus of noise impact assessment should be on the amenity of guests accommodated on site.

Appendix L section 3.1 proposes that "... the primary sources of noise will be the restaurant/lounge activities and any mechanical plant and equipment serving the development." However, The EPA understands that -

(a) the development will include a dining/function room on the top level (i.e. level 2) with an associated outdoor terrace. (Appendix L indicates that the bar and restaurant are proposed to be operate from 6:00am to 1:00am 7 days per week but omits the operating times for the function facilities on level 2),

(b) EIS section 6.4.1 indicates that the parking to serve guest accommodation will be provided in the existing Whiting Beach Road multi-storey carpark immediately opposite residences on the northern side of that road.

The EPA is aware that certain outdoor entertainment activities at the Zoo have been the subject of noise complaints. However, Appendix L does not provide an assessment of typical noise impacts (including sleep disturbance impacts) arising from amplified music and predictable behaviour of function centre and terrace, bar and restaurant patrons.

Appendix L section 4 assesses road traffic noise impacts but does not assess noise impacts associated with evening and 'night-time' (10:00pm to 7:00am) use of the existing multi-storey carpark). However, the EPA is unclear where parking for patrons and staff of the function centre, bar and restaurant will be provided and thus is unable to comment on any likely noise impacts associated with that activity.

Section 3.2.2 of Appendix L proposes that noise impacts assessment of mechanical plant (Likely to include roof top ventilation plant and lift motors) be deferred until the detail design stage of the development.

Recommendation

The proponent should (before and consent is issues), identify the background noise level for the locality measured at the most affected noise sensitive receivers (including residences north and northeast of the site) in accordance with guidance material in Chapter 3 of the NSW Industrial Noise Policy.

Recommendation

The proponent should undertake a comprehensive quantitative assessment of noise impacts associated with operation of the new facilities (including evening and night-time car park use) together with design for feasible and reasonable noise impact avoidance and mitigation, including but not limited to:

(a) potential sleep disturbance impacts on surrounding residents; and

(b) whether or not there is a need to apply 'modifying factors' (see INP chapter 4) to noise monitoring data and associated noise impact assessment.

The proponent should commit to averting unacceptable noise impacts on surrounding noise sensitive receivers by -

- *preparing a detailed operations noise impact statement that incorporates feasible and reasonable measures to avoid, minimise and manage noise and incorporating those noise avoidance and minimisation measures at the design stage of the project,*

- *establishing and fostering a good relationship with surrounding residents (including facilitation of the logging noise complaints and of obtaining an active and timely response to those complaints;*
- *undertaking a noise monitoring program to 'ground truth' noise impact predictions at set periods following commencement of operation of the new facilities;*
- *restricting loading dock and waste collection activities to 'day-time' as defined in the NSW Industrial Noise Policy, January 2000;*
- *undertaking a noise monitoring program at various periods after commencement of operation of each project element to verify that measured noise levels do no exceed levels predicted in the required noise impact statement and acceptable noise levels identified in the NSW Industrial Noise Policy, January 2000.*

1.4.2 DoPE submissions

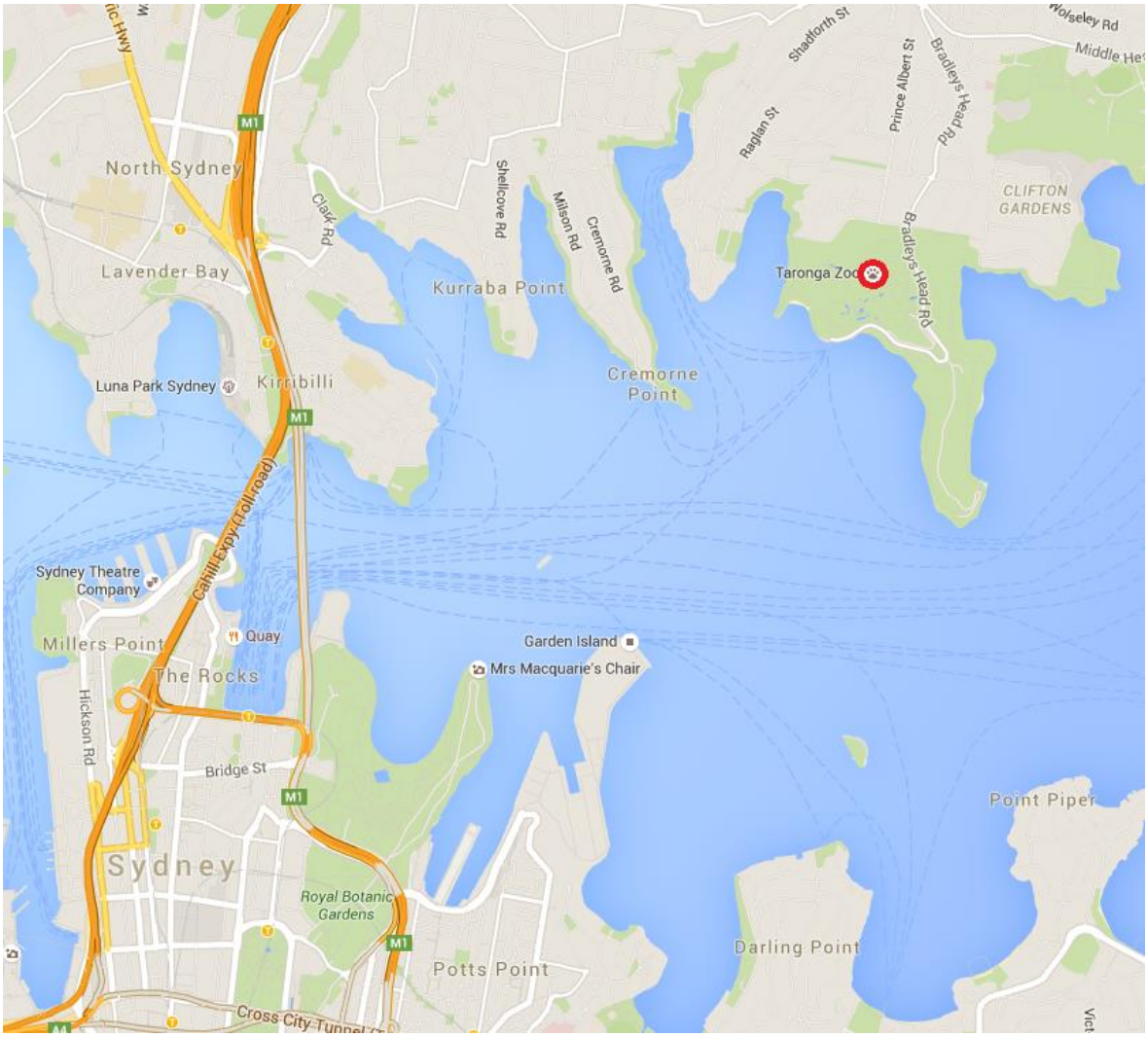
Noise and Vibration

Update the Australia Habitat and Taronga Wildlife Retreat Noise and Vibration Assessment, prepared by Renzo Tonin and Associates and dated 14 March 2016 to include quantified assessment of likely construction and operational noise and whether that demonstrates compliance with relevant noise criteria, as sought by the Environmental Protection Authority.

1.5 Site description

Taronga Zoo is located approximately 4km north east of the Sydney CBD and 12km north east of Sydney airport, situated within the Municipality of Mosman local government area (LGA) (refer to Figure 1 below).

Figure 1: Site location and context



The Australia Habitat and Taronga Wildlife Retreat will occupy an area of approximately 9,500 m^2 along the eastern boundary of the site (see Figure 2).

Figure 2: Australia Habitat and Taronga Wildlife Retreat development area

1.6 Project description

The proposed works are to be delivered over two stages as follows:

Stage 1

- Construction of a series of two to four storey accommodation pods comprising a total of 62 rooms (including four suites).
- Construction of a new four storey kitchen and dining facility to service the existing Taronga Centre and proposed eco-tourist facility.
- Construction of a guest lounge to accommodate reception, bar, guest interaction facilities with adjacent platypus exhibit and animal encounter facilities.
- Demolition of existing Harbourview Garden Court and replacement by the construction of a new Terrace.
- Realignment of existing turning circle at the entrance to existing Function Centre.
- Construction of various wildlife exhibits.

Stage 2

- Upgrades to the Taronga Centre entry which seeks to improve accessibility for guests by introduction of foyers and lift access within existing buildings.

While the upgraded entry will form part of the planning process, the associated works will not be completed at the same time as the Taronga Wildlife Retreat (Stage 1).

2 Surrounding noise sensitive receivers

The most potentially affected land uses surrounding the development have been identified as residential premises, approximately 300m to the north and east of the development site (see Figure 3). Representative receivers have been selected and are detailed in Table 1 below.

Table 1: Identified receivers

Receiver		Assessment location
ID	Address	
R1	7 Whiting Beach Road	Front yard
R2	2 Bradleys Head Road	First floor window
R3	1 Bradleys Head Road	First floor window
R4	2 Buena Vista Avenue	First floor windows
R5	1 Buena Vista Avenue	First floor windows
R6	4 Burrawong Avenue	First floor windows
R7	1 Burrawong Avenue	Top floor windows
R8	48 Iluka Road	Top floor windows

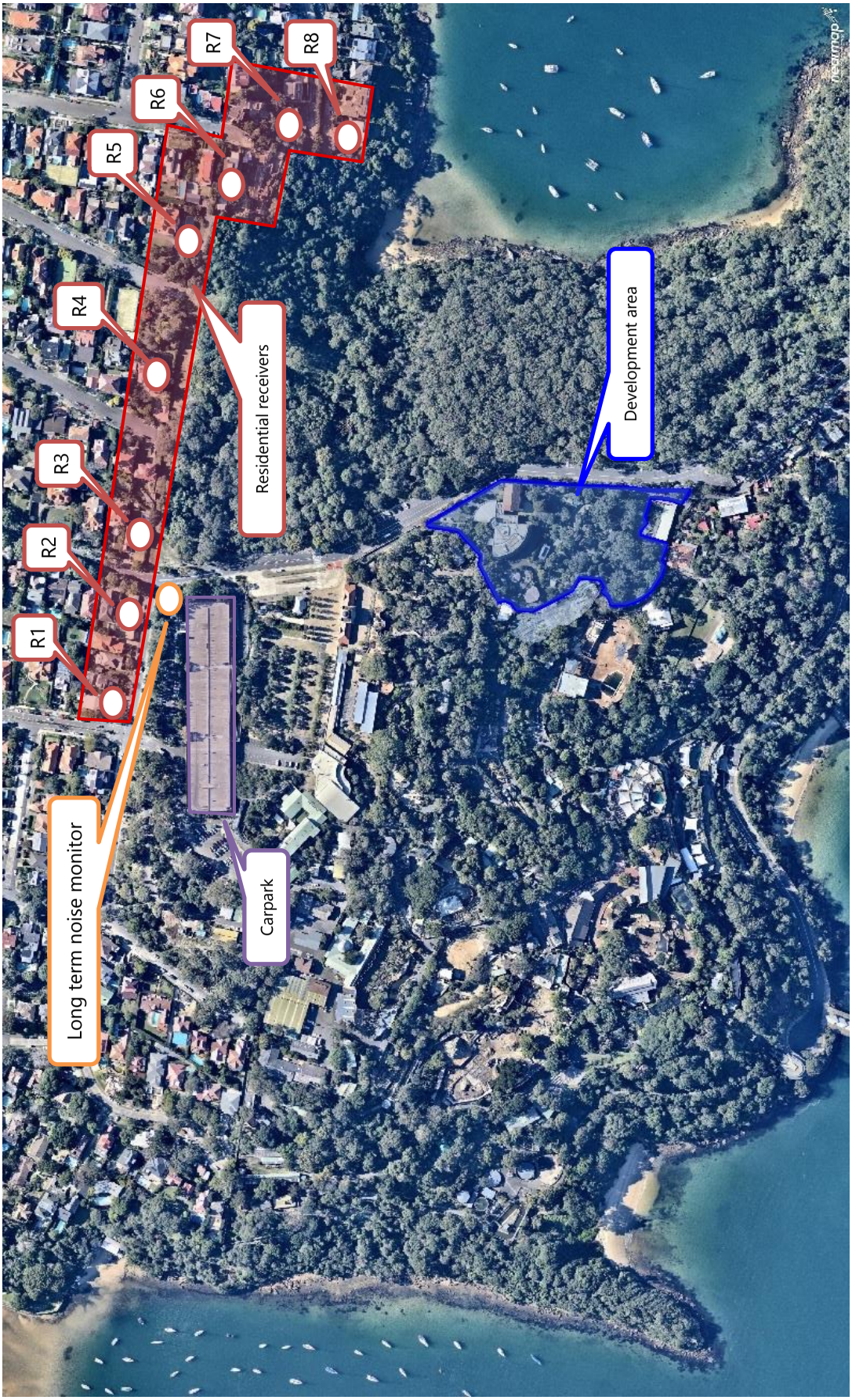


Figure 3: Site and receiver locations

3 Existing acoustic environment

Criteria for the assessment of operational noise are usually derived from the existing noise environment of an area, excluding noise from the subject development.

Appendix B of the NSW EPA *Industrial Noise Policy* (INP) outlines two methods for determining the background noise level of an area, being 'B1 – Long-term background noise method' and 'B2 – Short-term background noise method'. This assessment has used long-term noise monitoring.

As the noise environment of an area almost always varies over time, background and ambient noise levels need to be determined for the operational times of the proposed development. For example, in a suburban or urban area the noise environment is typically at its minimum at 3am in the morning and at its maximum during the morning and afternoon traffic peak hours. The INP outlines the following standard time periods over which the background and ambient noise levels are to be determined:

- Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
- Evening: 18:00-22:00 Monday to Sunday & Public Holidays
- Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays

The operational noise criteria as detailed in Section Operational noise criteria of this report defines an assessment time period of 12:00 midnight to 7:00am. Therefore, this assessment considers a shoulder period of 10:00pm to 12:00 midnight and a modified night period of 12:00 midnight to 7:00am.

3.1 Noise measurement location

Long term noise monitoring was conducted from 15 July to 26 July 2016 at the corner of Bradleys Head Road and Whiting Beach Road. The noise monitor was installed on the Taronga site adjacent to 2 Bradleys Head Road, in the free field. It was noted during the site inspection that the ambient noise environment was controlled by traffic from surrounding roads and nature. The measurement location is shown in Figure 3.

A Taronga Zoo Noise Management Plan for Concert Events was prepared by Air Noise Environment [ref: Noise Management Plan: Concert Events, dated 26th May 2014] in which long term noise monitoring was conducted at a number of locations at nearby residences. Two of the long term noise monitors were installed at 1 Bradleys Head Road adjacent Taronga Zoo and 3 Burrawong Avenue approximately 350m to the east of Taronga Zoo. Results from the noise monitoring show that the ambient background noise level for receivers of Burrawong Avenue and surrounding roads to the east of Taronga Zoo is approximately 2dB higher in each time period than on Bradleys Head Road.

This assessment has conservatively adopted the background noise levels measured from the long term noise monitor on Bradleys Head Road for all residential receivers.

3.2 Long-term noise monitoring results

Table 2 presents the overall and 1-1 octave band Rating Background Levels (RBL) for each assessment period, determined in accordance with the INP. The long-term noise monitoring methodology is detailed in Appendix B, and noise level-vs-time graphs of the data are included in Appendix C.

Table 2: Long-term noise monitoring results

Period	Descriptor	Overall dBA	Octave band centre frequency – Hz (dBZ)								
			31.5	63	125	250	500	1k	2k	4k	8k
Day	RBL L_{90}	43	54	54	47	40	38	36	32	24	17
Evening	RBL L_{90}	37	50	51	44	37	33	30	23	21	16
Shoulder	RBL L_{90}	35	49	49	43	36	31	27	20	19	16
Night	RBL L_{90}	34	46	46	41	35	31	27	22	18	16

Notes: Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
Evening: 18:00-22:00 Monday to Sunday & Public Holidays
Shoulder: 22:00-12:00 midnight Monday to Sunday & Public Holidays
Night: 12:00-07:00 Monday to Sunday & Public Holidays
As required by the INP, the external ambient noise levels presented are free-field noise levels. [ie. no façade reflection]

4 Operational noise assessment

4.1 Operational noise criteria

The restaurant, bar and terrace components of the proposal will be part of a licenced premises. Noise emission from licensed premises in NSW, such as restaurants, bars and clubs, should aim to comply with the standard noise criteria set by Liquor and Gaming NSW (L&GNSW). The L&GNSW criteria applies to all noise emission associated with activities from the licensed area of the premises, including music and patron noise, but excludes mechanical services equipment.

L&GNSW, through the Liquor Act 2007, is the regulatory authority that deals with noise pollution issues pertaining to licensed premises. L&GNSW recommends the use of their standard noise criteria when assessing noise impact from licensed premises and when determining the occurrence of noise nuisance and annoyance. Noise emissions are assessed in terms of the following 'Standard Noise Condition':

> *"The LA10* noise level emitted from the licensed premises shall not exceed the background noise level in an Octave Band Centre Frequency (31.5Hz – 8kHz inclusive) by more than 5dB between 7:00am and 12:00 midnight at the boundary of any affected residence.*
>
> *The LA10* noise level emitted from the licensed premises shall not exceed the background noise level in an Octave Band Centre Frequency (31.5Hz – 8kHz inclusive) between 12:00 midnight and 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 12:00 midnight and 7:00am.*
>
> *Interior noise levels which still exceed safe hearing levels are in no way supported or condoned by the NSW Office of Liquor, Gaming and Racing.*
>
> *This is a minimum standard. In some instances the Board may specify a time earlier than midnight in respect of the above condition.*
>
> **For the purposes of this condition, the LA10 can be taken as the average maximum deflection of the noise emission from the licensed premises."*

For the determination of octave band criteria, octave band noise levels measured by the long-term noise logger have been utilised. The assessment periods for the proposed operations are;

- 7am - 6pm
- 6pm - 10pm
- 10pm - 12:00am
- 12:00am - 7am

The long term noise logger measurements were analysed between the above time periods to establish the L&GNSW noise goals and are set out in Table 3 below.

Table 3: L&GNSW noise goals

Assessment period	Octave band centre frequency - Hz (dBZ)								
	31.5	63	125	250	500	1k	2k	4k	8k
7am – 6pm	59	59	52	45	43	41	37	29	22
6pm - 10pm	55	56	49	42	38	35	28	26	21
10pm - 12am	54	54	48	41	36	32	25	24	21
12am - 7am	46	46	41	35	31	27	22	18	16
12am - 7am (inaudibility)*	48	36	31	25	21	17	12	8	7

Note: * For the assessment of inaudibility Renzo Tonin and Associates adopt a design criterion of 10dB below the background noise level in each octave band for intermittent noise sources such as patrons and music.

^ Where the background -10dB value is lower than the threshold of hearing, the threshold value in accordance with AS3657.1 has been used.

4.2 Operating hours

From review of the proposal, the primary sources of operational noise will be from the restaurant, terrace and guest lodge bar.

The development is proposed to operate with the following hours:

- Taronga Wildlife Retreat (accommodation) 24 hours per day, 7 days per week
- Guest Lodge (Lobby/Reception) 24 hours per day, 7 days per week
- Restaurant (Dining Hall) 6am – 1am, 7 days per week
- Guest Lodge (Bar Area) 6am – 1am, 7 days per week
- Terrace 6am – 1am, 7 days per week

4.3 Noise sources

4.3.1 Terrace function space

The terrace function space and dining area is for general purpose use. The space is located on the upper level of the proposed restaurant and has a capacity of 150 people. The internal sound pressure level that has been used for this assessment is detailed in Table 4 below and has been obtained from measurements conducted from previous projects undertaken by Renzo Tonin and Associates.

Table 4: Terrace function space internal pressure level L10

Noise source	Descriptor	Overall	Octave band centre frequency – Hz, dB(Z)								
		dB(A)	31.5	63	125	250	500	1k	2k	4k	8k
Hotel bar, Approx. 100 people + dance music through PA	L_{10}	90	74	82	79	78	83	86	85	82	76

Noise breakout calculations assume that the southern doors of the function space to the outdoor terrace space are fully operable and are 100 percent open.

4.3.2 Terrace outdoor area

Noise emanating from the terrace will primarily be due to people talking. The following table presents a typical noise level spectrum for a raised voice from one person at a distance of 1 metre away.

Table 5: Patron sound pressure levels at 1m

Noise Source	Descriptor	Overall	Octave band centre frequency – Hz, dB(Z)								
		dB(A)	31.5	63	125	250	500	1k	2k	4k	8k
Raised (male) voice	L_{10}	75	-	-	56	65	72	71	66	60	51

Notes: Source reference – Handbook of Acoustical Measurements and Noise Control, Third Edition, Cyril M. Harris.

A Speaker's vocal effort is also affected by ambient noise. In ambient noise levels above 50dB(A), a normal-hearing person typically raises his or her voice. On the average, voice levels are raised approximately 3 to 6dB for every 10dB increase in noise level above 50dB(A).

For this assessment, it has been assumed that up to 80 people will occupy the outdoor terrace space at any given time, and of those 80 people, 40 of them will be talking at any given time. The equivalent sound power level when adjusted for the number of people on the outdoor terrace is provided below.

Table 6: Outdoor terrace sound power level

Noise source	Descriptor	Overall	Octave band centre frequency - Hz, dB(Z)								
		dB(A)	31.5	63	125	250	500	1k	2k	4k	8k
40 x raised (male) voice	L_{10}	99	-	-	64	73	80	79	74	68	59

4.3.3 Guest lodge

The guest lodge bar area has a capacity of 100 people. For the purpose of this assessment, the internal noise level is assumed to be the same as the terrace function space. It has also been assumed that up to 80 people will occupy the external deck area of the bar at any given time. For internal breakout calculations, it has been assumed that the doors and windows to the guest lodge remain closed.

4.3.4 Restaurant

The main restaurant area is located on level 3 of the restaurant building. The drawings indicate that this space will be fully enclosed. It is therefore not anticipated to be a significant noise contribution at the

nearest affected receivers. All openable windows of the restaurant would need to be shut no later than 12:00 midnight.

4.4 Prediction methodology

The noise predictions were carried out using computational noise modelling software 'CadnaA', which takes into account ground topography, attenuation due to distance and acoustic shielding from intervening structures to the receivers. The calculation standard ISO 9613 was used for the predictions, which takes into account temperature inversion and downwind conditions. A ground absorption ratio of 0.75 has been used.

4.5 Noise prediction results

Noise modelling has been conducted of a worst case scenario where the terrace and guest lodge are operating at full capacity. Table 7 presents the predicted noise emission levels at the identified assessment locations against the established noise goals. The results have been summarised at the bottom of the table, with the maximum predicted noise level in each octave band of any receiver presented. Predictions at the receivers were analysed and it was found that INP modifying factors, including low frequency modifying factor were not required to be applied.

Table 7: Operational noise level predictions

Receiver		Overall dBA	Octave band centre frequency – Hz (dBZ)								
ID	Address		31.5	63	125	250	500	1k	2k	4k	8k
L&GNSW noise goals	7am - 6pm	-	59	59	52	45	43	41	37	29	22
	6pm-10pm	-	55	56	49	42	38	35	28	26	21
	10pm-12am	-	54	54	48	41	36	32	25	24	21
	12am -7am	-	46	46	41	35	31	27	22	18	16
	12am - 7am (inaudibility)	-	48	36	31	25	21	17	12	8	7
S1	7 Whiting Beach Road	26	14	19	16	20	25	22	14	1	-27
S2	2 Bradleys Head Road	31	17	23	20	24	30	27	21	10	-16
S3	1 Bradleys Head Road	32	18	24	21	25	31	28	22	13	-12
S4	2 Buena Vista Avenue	30	18	24	19	24	29	27	20	10	-17
S5	1 Buena Vista Avenue	30	19	25	19	24	29	27	20	9	-20
S6	4 Burrawong Avenue	32	19	26	20	25	30	28	22	10	-18
S7	1 Burrawong Avenue	32	20	26	20	24	30	28	22	11	-18
S8	48 Iluka Road	33	20	27	21	24	30	30	24	13	-13
Maximum noise level prediction for all residences		33	20	27	21	25	**31**	**30**	**24**	13	-12

Notes:

^ Red font indicates exceedance of the inaudibility night time criteria

^ **Red bold** font indicates exceedance of the night time and inaudibility criteria

4.6 Discussion of results

The predicted noise levels show compliance with the relevant L&GNSW criteria for the day, evening and shoulder time periods. During the night time, exceedances of up to 13dB are predicted in the mid frequencies. For residences to the east on Iluka Road and Burrawong Avenue, these exceedances are due to noise breakout from the internal terrace function space, along with use patron use of the external terrace area. Noise breakout though the facade glazing of the restaurant, function space and guest lodge are not significant noise contributions at the residences.

For residences of Whiting Beach Road and Bradleys Head Road, exceedances are from a combination of use of the outdoor deck area of the guest lodge in addition to the terrace breakout and outdoor space.

4.7 Recommendations

4.7.1 Time restrictions to outdoor areas

It is recommended that use of external areas, including the terrace outdoor area and the guest lodge deck be limited to 12:00 midnight. Doors and windows of the terrace, restaurant, and guest lodge should also be closed at 12:00 midnight.

With the above restrictions to outdoor area use and all doors and windows to the terrace, restaurant and guest lodge closed after 12:00 midnight, noise levels are predicted to comply with the relevant criteria during all time periods at all surrounding residences.

4.7.2 Noise monitoring program

The EPA have requested that a noise monitoring program be implemented after the commencement of operation of each project to verify that measured noise levels do no exceed the predicted noise levels. Noise monitoring should therefore be conducted at locations near to the residential receivers identified in Section Surrounding noise sensitive receivers of this report.

4.7.3 Loading dock

Given the distance from the site to the nearest residences, noise associated with the loading dock would not be as issue. However, vehicles using the loading dock and waste collection activities should be limited to 'day-time' as detailed in Section Existing acoustic environment of this report.

5 Car park assessment

5.1 Noise criteria

5.1.1 NSW Industrial Noise Policy (INP)

Operational noise from the carpark is assessed against the NSW Industrial Noise Policy (INP). The assessment procedure has two components:

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

5.1.1.1 Intrusive noise impacts

According to the INP, the intrusiveness of a noise source may generally be considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (represented by the LAeq descriptor) does not exceed the background noise level measured in the absence of the source by more than 5dB(A). The intrusiveness criterion is summarised as follows:

- LAeq,15minute $\leq$ Rating Background Level (RBL) + 5dB(A)

Table 8: Residential noise criteria

Time of Day	Rating Background Level (RBL) L_{A90}	Intrusiveness Criterion (RBL + 5)
Day	43	48
Evening	37	42
Night	34	39

5.1.1.2 Protecting noise amenity

The Amenity Criteria are determined in accordance with Chapter 2 of the NSW INP. The INP recommends base acceptable noise levels for various receivers, including residential, commercial, industrial receivers and sensitive receivers such as schools, hospitals, churches and parks. These base noise criteria are then lowered by up to 10dB depending on the extent of existing industrial noise impact upon the receiver. Higher levels of existing industrial noise therefore result in stricter Amenity Criteria applied to any new industrial development. In this way the cumulative impacts of existing and known future industrial noise sources are minimised.

To limit continuing increases in noise levels, the maximum ambient noise level within an area from industrial noise sources should not normally exceed the acceptable noise levels specified in Table 2.1 of the policy, the applicable parts of which are reproduced in Table 9 below.

Table 9: Amenity criteria

Type of Receiver	Indicative Noise Amenity Area	Time of Day	Recommended LAeq(Period) Noise Level	
			Acceptable	Recommended Maximum
Residence	Suburban	Day	55	60
		Evening	45	50
		Night	40	45
School classrooms - internal	All	Noisiest 1 hour period when in use	35	40
Place of worship - internal	All	When in use	40	45
Active recreation area (e.g. school playground, golf course)	All	When in use	55	60
Commercial premises	All	When in use	65	70

Note:

Daytime 7.00 am to 6.00 pm; Evening 6.00 pm to 10.00 pm; Night-time 10.00 pm to 7.00 am

On Sundays and Public Holidays, Daytime 8.00 am - 6.00 pm; Evening 6.00 pm - 10.00 pm; Night-time 10.00 pm - 8.00 am.

The LAeq index corresponds to the level of noise equivalent to the energy average of noise levels occurring over a measurement period.

5.1.1.3 Modifying factor adjustments

Where the character of the noise in question is assessed as particularly annoying (i.e. if it has an inherently tonal, low frequency, impulsive or intermittent [applied to night time only] character), then an adjustment of 5dB(A) for each annoyance aspect, up to a total of 10dB(A), is to be added to the measured value to penalise the noise for its potential increase in annoyance. No modifying factors have been applied for this car park assessment.

5.1.1.4 Project specific noise goals

In accordance with the INP, the project specific noise goals are the most stringent of the intrusive and amenity criteria. The project specific noise goals for this project are shown in Table 10.

Table 10: Project specific noise goals

Receiver	LAeq,15min		
	Day	Evening	Night
Residential	48	42	39

5.1.2 Sleep disturbance criteria

The proposed development operates after 10:00pm and therefore has the potential to cause sleep disturbance issues. Noise from short term impact sounds such as car door slams and engine starts are the potentially most likely cause of sleep disturbance. The EPA has made the following policy statement with respect to sleep disturbance:

"Peak noise level events, such as reversing beepers, noise from heavy items being dropped or other high noise level events, have the potential to cause sleep disturbance. The potential for high noise level events at night and effects on sleep should be addressed in noise assessments for both the construction and operational phases of a development. The INP does not specifically address sleep disturbance from high noise level events.

DEC reviewed research on sleep disturbance in the NSW Environmental Criteria for Road Traffic Noise (ECRTN) (EPA, 1999). This review concluded that the range of results is sufficiently diverse that it was not reasonable to issue new noise criteria for sleep disturbance.

From the research, DEC recognised that current sleep disturbance criterion of an LA1, (1 minute) not exceeding the LA90, (15 minute) by more than 15 dB(A) is not ideal. Nevertheless, as there is insufficient evidence to determine what should replace it, DEC will continue to use it as a guide to identify the likelihood of sleep disturbance. This means that where the criterion is met, sleep disturbance is not likely, but where it is not met, a more detailed analysis is required.

The detailed analysis should cover the maximum noise level or LA1, (1 minute), that is, the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the appendices to the ECRTN. Other factors that may be important in assessing the extent of impacts on sleep include:

- *how often high noise events will occur;*
- *time of day (normally between 10pm and 7am); and*
- *whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).*

The LA1, (1 minute) descriptor is meant to represent a maximum noise level measured under 'fast' time response. DEC will accept analysis based on either LA1, (1 minute) or LA, (Max)."

The NSW EPA confirm that a sleep disturbance criterion of $L_{A1(1min)} \leq L_{A90(15min)} + 15dB(A)$, should only be used as a first step guide and where the criteria is not met, more detailed analysis is required. The Application Notes of the NSW Industrial Noise Policy (2010) note the detailed analysis should include:

- the extent to which the maximum noise level exceeds the background level
- the number of times this happens during the night-time period, and
- the time of day (normally between 10pm and 7am).

In addition, reference is made to Appendix B of the NSW ECRTN, which summarises the findings of international research undertaken on sleep disturbance from noise (up until 2009) and concludes:

"Considering all of the foregoing information the following conclusions can be drawn:

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

In regard to external noise levels, the maximum internal noise level 55dB(A) referenced in the ECRTN is equivalent to 65dB(A) outside an open window. It is noted that a 10dB(A) reduction from outside to inside is common and typical noise reduction via an open window. The 65dB(A) external noise limit is consistent with the findings of Griefahn [*Acoustics Australia vol 20 No 2 August 1992 pp 43-47*].

In summary, the sleep disturbance criteria of $L_{A1(1min)} \leq L_{A90(15min)}$ + 15dB(A) is to be used for initial assessment, however consideration is also given to the 'upper' limit criteria of 65dB(A) in accordance with the ECRTN. It is noted that the background $L_{A90(15min)}$ noise level used for establishing the sleep disturbance criteria does not need to exclude other noise from the subject premise.

The sleep disturbance criteria for the project are presented in Table 11 below.

Table 11: Sleep disturbance criteria

Sleep disturbance criteria, LA1,1minute		
Time	**LA90(15min)* + 15dB(A)**	**Upper limit**
10:00pm – 7:00am	39 + 15 = 54	65

Notes:

* The LA90 background noise level were determined through analysis of the long term noise monitoring data aver the relevant time period.

5.2 Car park assessment

5.2.1 Car park traffic volumes

The traffic report prepared by GTA consultants indicates that the development will not increase traffic volumes during the evening or night time period. Nevertheless, consistent with EPA requirements, an assessment of the car park has been conducted

The traffic report prepared by GTA consultants details the following with respect to usage of the development.

Regular night time wedding events associated with the Zoo involve the use of the function centre. The use of the function centre is typically succeeded by wedding ceremonies held in the Harbourview Garden Court where the Retreat building is being proposed. It is advised that wedding ceremonies in the Zoo generally involve:

- *Approximately 60 wedding ceremonies per year*
- *Up to 140 guests*
- *The use of the Garden Court between 3pm and 6pm.*

Moving forward, the construction of the Retreat building, which also comprises a restaurant/terrace, will be capable of accommodating:

- *The wedding ceremonies which are currently held at the Harbourview Garden Court*
- *The Retreat guests who participate in the Retreat program.*

The wedding ceremonies and dinner reception generally occur in the following timelines:

- *wedding ceremony: 3:00pm – 6:00pm (as existing)*
- *wedding reception: 7:00pm – 11:00pm (as existing)*

Guests associated with the wedding ceremony typically arrive between midday and 1pm and would roam around the Zoo (eg. photography) after the ceremony before moving on to the existing function centre to proceed with the dinner reception.

Guests associated with the Retreat program are allowed to 'check in' between 2pm and 6pm. It is anticipated that the majority of arrivals would occur between 3pm and 5pm as the program is proposed to commence at 6.15pm. All Retreat guests would remain at the Zoo campus overnight and depart the next day.

Having regard for the manner in which the existing wedding events and the proposed Retreat operate, it is apparent that:

- *Guests associated with the wedding events typically arrive by midday and depart in the late evening (as with existing).*
- *Guests associated with the Retreat program typically arrive between 3pm and 5pm and would not depart until the next day.*

It is apparent that The Retreat will not impose any additional traffic activities during the evening over what is already existing as a result of the wedding events.

In addition, we have been advised by GTA consultants that weddings in the function centre would have occupancy rates of approximately 2.5 persons per car on average. This would equate to 56 cars using the multistorey carpark per wedding. It is understood that the Mosman Council paid parking along Bradleys Head Road to the south of the carpark is also commonly used for the function centre. For the purpose of this assessment, it has conservatively been assumed all 56 cars would leave the multistorey carpark at the end of the weddings, spaced over one hour during the night period after 10:00pm.

5.2.2 Car park noise levels

Noise generated by car park activities which may contribute to the overall L_{Aeq} noise level emission from the site includes vehicle doors closing, vehicle engines starting, vehicles accelerating and vehicles moving. To assess this noise, the L_{Aeq} noise level was determined for the relevant time period based on the number of vehicle activities expected to occur during that period at the nearest affected residential

premises. Sound Exposure Level (SEL) measurements from our database and library files were used for the assessment.

The sound power levels generated by car park activities on site as used in the predictive noise modelling for this project are presented in Table 12.

Table 12: Carpark noise levels

Noise source	Metric	Octave band centre frequency (Hz) - dBZ									Total dB(A)
		31.5	63	125	250	500	1000	2000	4000	8000	
Door Slam, Lw	SEL	103	97	92	85	82	80	78	74	68	86
Engine Start, Lw	SEL	106	100	94	88	85	86	86	83	78	92
Moving Veh/m, Lw	SEL	92	93	81	76	75	71	72	67	63	78
Door Slam, Lw	L_{Amax}	113	108	102	95	93	91	88	84	79	96

5.2.3 Car park noise predictions

Based upon the traffic data provided by GTA consultants and noise levels and assumptions listed above, calculations of carpark noise were predicted to the surrounding residences. The most affected residence was found to be 2 Bradleys Head Road. At the second floor windows on the south facade of the dwelling, the $L_{Aeq,15min}$ noise level as a result of use from the cark park was predicted to be 31dB(A). This noise level complies with the INP night time noise goal.

In terms of sleep disturbance, the LAMax noise level from the carpark was predicted to be 52dB(A) at the most affected residence. This noise level complies with the $L_{A1(1min)} \leq L_{A90(15min)}$ + 15dB(A) criteria of 54dB(A).

6 Road traffic generated by development

6.1 Noise criteria

Noise impact as a result of increased traffic generated on the surrounding road network is assessed in accordance with The NSW *Road Noise Policy* (RNP) (NSW EPA, 2012). Table 3 of the RNP sets out the assessment criteria for residences to be applied to particular types of project, road category and land use. These criteria are for assessment against facade corrected noise levels when measured in front of a building facade. In Table 3, freeways, arterial roads and sub-arterial roads are grouped together and attract the same criteria. The roads surrounding Taronga Zoo are classified sub-arterial roads under the RNP.

Table 13: Road traffic noise criteria for surrounding residential receivers

Road category	Type of project/land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	Night (10:00pm-7:00am)
Freeway/arterial/sub-arterial roads	Existing residences affected by additional traffic on existing freeways / arterial / sub-arterial roads generated by land use developments	$L_{Aeq,(15\ hour)}$ 60 (external)	$L_{Aeq,(9\ hour)}$ 55 (external)

Where existing traffic noise levels are above the noise assessment criteria, the primary objective is to reduce these through feasible and reasonable measures to meet the assessment criteria. A secondary objective is to protect against excessive decreases in amenity as the result of a project by applying the relative increase criteria.

For existing residences and other sensitive land uses affected by *additional traffic on existing roads generated by land use developments*, any increase in the total traffic noise level should be limited to 2dB above that of the corresponding 'no build option'.

6.2 Traffic noise assessment

Noise predictions are based on a method developed by the United Kingdom Department of Environment entitled "Calculation of Road Traffic Noise (1988)" known as the CoRTN (1988) method. This method has been adapted to Australian conditions and extensively tested by the Australian Road Research Board and as a result it is recognised and accepted by the NSW Environment Protection Authority.

Assuming all 56 vehicles leave over a one-hour period and exit via Bradleys Head Road, a worst case noise level of 55dB$L_{Aeq,1hour}$ was predicted at most affected facade for residences of Bradleys Head Road. This noise level includes a +2.5dB facade correction. Taking into account that the RNP criteria for Bradleys Head Road is a $L_{Aeq,9\ hour}$ assessment period, we confirm that traffic noise from the development complies with the assessment criteria.

7 Construction noise and vibration assessment

7.1 Construction noise criteria

The NSW *Interim Construction Noise Guideline* (ICNG, 2009) provides guidelines for assessing noise generated during the construction phase of developments.

The key components of the guideline that are incorporated into this assessment include:

- Use of L_{Aeq} as the descriptor for measuring and assessing construction noise.

  NSW noise policies, including the INP, RNP and RING have moved to the primary use of L_{Aeq} over any other descriptor. As an energy average, L_{Aeq} provides ease of use when measuring or calculating noise levels since a full statistical analysis is not required as when using, for example, the L_{A10} descriptor.

- Application of reasonable and feasible noise mitigation measures
- As stated in the ICNG, a noise mitigation measure is feasible if it is capable of being put into practice, and is practical to build given the project constraints.
- Selecting reasonable mitigation measures from those that are feasible involves making a judgement to determine whether the overall noise benefit outweighs the overall social, economic and environmental effects.

The ICNG provides two methods for assessment of construction noise, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement and prediction of noise levels, and assessment against set criteria. A qualitative assessment is recommended for small projects with a duration of less than three weeks and focuses on minimising noise disturbance through the implementation of reasonable and feasible work practices, and community notification.

A quantitative assessment is carried out herein, consistent with the ICNG and submission requirements.

Table 14, reproduced from the ICNG, sets out the noise management levels and how they are to be applied for residential receivers.

Table 14: Noise management levels at residential receivers

Time of day	Management level $L_{Aeq\ (15\ min)}$ *	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 *[of the ICNG.*

* Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 15 presents the construction noise management levels established for the nearest noise sensitive residential receivers based upon the noise monitoring outlined in Section Long-term noise monitoring results of this report.

Table 15: Construction noise management levels at residential receivers

Noise catchment area	L_{A90} rating background level (RBL)			Noise management level $L_{Aeq(15min)}$[1]		
	Day	Evening	Night	Day	Evening	Night
All surrounding residences	43	37	34	53	42	39

Notes: 1. Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5m above ground level. If the property boundary is more than 30m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 16 sets out the ICNG noise management levels for other noise sensitive receiver locations. As identified for residential receivers, a 'highly affected' noise objective of $L_{Aeq(15min)}$ 75dB(A) is adopted for all noise sensitive receivers, with exceedances addressed as described in Table 14.

Table 16: Noise management levels at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq\ (15\ min)}$
Classrooms at schools and other educational institutions	Internal noise level	45 dB(A)
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A)
Active recreation areas	External noise level	65 dB(A)
Passive recreation areas	External noise level	60 dB(A)
Community centres	Depends on the intended use of the centre.	Refer to the 'maximum' internal levels in AS2107 for specific uses.
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

Notes: Noise management levels apply when receiver areas are in use only.

7.2 Construction activities

The plant and equipment that are likely to be used during the construction of the proposed mixed use development are provided in Table 17 below.

Table 17: Demolition, excavation and construction equipment & sound power levels, dB(A) re 1pW

Activity	Plant/equipment	Sound Power Level, dB(A)
Demolition	Truck - dump	108
	30 tonne excavator with bucket	107
	Excavator mounted hydraulic breaker	120*
	Saw	120*
	Bobcat	102
	Assumed activity noise level	**123**
Excavation	Excavator mounted hydraulic breaker	120*
	Piling drilling rig	111
	Truck - dump	108
	30 tonne excavator with bucket	107
	Assumed activity noise level	**121**
Construction	Mobile crane	110
	Truck – cement mixer	108
	Cherry picker	102
	Concrete pump	102
	Concrete vibrator	100
	Assumed activity noise level	**113**

Activity	Plant/equipment	Sound Power Level, dB(A)

Notes:

* Includes 5dB penalty for impulsiveness

The sound power levels for the majority of activities presented in the above table are provided by the client, based on maximum levels given in Table A1 of Australian Standard 2436 - 2010 'Guide to Noise Control on Construction, Demolition and Maintenance Sites', the ICNG, information from past projects and/or information held in our library files.

7.3 Construction noise results

Noise levels at any receiver locations resulting from construction works would depend on the location of the receiver with respect to the area of construction, shielding from intervening topography and structures, and the type and duration of construction being undertaken. Furthermore, noise levels at receivers would vary significantly over the total construction program due to the transient nature and large range of plant and equipment that could be used.

Table 18 presents noise levels likely to be experienced at the nearby affected receivers based on the construction activities, and plant and equipment associated with the proposed site compound at a range from the furthest to the closest proximity to each receiver location. Noise levels were calculated taking into consideration attenuation due to distance between the construction works and the receiver locations and any intervening structures.

Table 18: Predicted $L_{Aeq(15min)}$ noise levels for typical construction plant, dB(A)

Activity		Predicted LAeq(15min) construction noise levels							
		R1	R2	R3	R4	R5	R6	R7	R8
Noise management level	Day	53	53	53	53	53	53	53	53
	Evening	42	42	42	42	42	42	42	42
	Night	39	39	39	39	39	39	39	39
Demolition		40 - 48	41 - 55	47 - 55	43 - 54	41 - 53	43 - 54	41 - 54	41 - 55
Excavation		38 - 46	39 - 53	45 - 53	41 - 52	39 - 51	41 - 52	39 - 52	39 - 53
Construction		30 - 38	31 - 45	37 - 45	33 - 44	31 - 43	33 - 44	31 - 44	31 - 45

7.4 Discussion of construction noise results

Based on the predicted construction noise levels presented in the table above, the construction management levels at all receiver locations would generally comply at surrounding receivers during the day period for all activities. An exceedance of up to 2dB is predicted during the demolition stage during the day which is considered minor. Noise management levels would generally be exceeded during the evening and night time periods should they occur.

Whilst noise levels are generally predicted to comply with the noise goals during the day, it is recommended that a feasible and reasonable approach towards noise management measures be applied to reduce noise levels as much as possible to manage the impact from construction noise.

Further details on construction noise mitigation and management measures are provided in Section Noise and vibration control measures.

7.5 Construction vibration criteria

7.5.1 Disturbance to buildings occupants

Assessment of potential disturbance from vibration on human occupants of buildings is made in accordance with the DECC '*Assessing Vibration; a technical guideline*' (Department of Environment and Conservation (NSW), 2006). In accordance with the guideline, assessment against the human exposure criteria is typically reserved for long-term vibration impacts such as that associated with operational phases of development rather than construction works. Furthermore, for the subject development, works are sufficiently removed from nearby residential development, and management of impacts upon the Zoo will be most criteria.

Notwithstanding the above, the criteria are presented for reference.

The guideline provides criteria which are based on the British Standard BS 6472-1992 '*Evaluation of human exposure to vibration in buildings (1-80Hz)*' (Bristish Standards Institution, 1992). Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent'. Table 19 provides definitions and examples of each type of vibration.

Table 19: Types of vibration (Department of Environment and Conservation (NSW), 2006)

Type of vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).

Type of vibration	Definition	Examples
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

The preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced in Table 20.

Table 20: Preferred and maximum levels for human comfort

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration (weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day- or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028
Workshops	Day- or night-time	0.04	0.029	0.080	0.058
Impulsive vibration (weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day- or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92
Workshops	Day- or night-time	0.64	0.46	1.28	0.92

Notes:
1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specify above. Stipulation of such criteria is outside the scope of their policy and other guidance documents (e.g. relevant standards) should be referred to. Source: BS 6472-1992

The acceptable vibration dose values (VDV) for intermittent vibration are defined in Table 2.4 of the guideline and are reproduced in Table 21

Table 21: Acceptable vibration dose values for intermittent vibration (m/s$^{1.75}$)

Location	Daytime[1]		Night-time[1]	
	Preferred value	Maximum value	Preferred value	Maximum value
Critical areas[2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Notes:
1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous of impulsive criteria for critical areas.
Source: BS 6472-1992

7.5.2 Building damage

Given the distance to surrounding development, potential damage as a result of vibration would only concern the nearby structures within the Zoo. While not specifically required by the SEARs, guidance has been provided for protection of existing structures.

Potential structural damage of buildings as a result of vibration is typically managed by ensuring vibration induced into the structure does not exceed certain limits set out in British Standard 7385 Part 2 (Bristish Standard Institution, 1993) and/or German Standard DIN4150-3 (DIN, 1999). Currently there is no existing Australian Standard for assessment of structural building damage caused by vibration energy.

Within British Standard 7385 Part 1: 1990, different levels of structural damage are defined:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition the formation of hairline cracks in mortar joints of brick/concrete block construction.*
- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

The vibration limits in Table 1 of British Standard 7385 Part 2 (Bristish Standard Institution, 1993) are for the protection against cosmetic damage, however guidance on limits for minor and major damage is provided in Section 7.4.2 of the Standard:

> *7.4.2 Guide values for transient vibration relating to cosmetic damage*
>
> *Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 1. In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding*

to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm (zero to peak) should be used.

Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 1, and major damage to a building structure may occur at values greater than four times the tabulated values.

Within DIN4150-3 (DIN, 1999), damage is defined as "*any permanent effect of vibration that reduces the serviceability of a structure or one of its components"* (p.2). The Standard also outlines:

"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if

- *cracks form in plastered surfaces of walls;*
- *existing cracks in the building are enlarged;*
- *partitions become detached from loadbearing walls or floors.*

These effects are deemed 'minor damage. " (DIN4150.3, 1990, p.3)

While the DIN Standard defines the above damage as 'minor', based on the definitions provided in BS7385, the DIN standard is considered to deal with cosmetic issues rather than major structural failures.

7.5.2.1 British Standard

British Standard 7385: Part 2 '*Evaluation and measurement of vibration in buildings*', can be used as a guide to assess the likelihood of building damage from ground vibration. BS7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

The cosmetic damage levels set by BS 7385 are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular building types. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

BS7385 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4Hz to 250Hz, being the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The values set in the Standard relate to transient vibrations and to low-rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%.Table 22 sets out the BS7385 criteria for cosmetic, minor and major damage.

Regarding heritage buildings such as the Locomotive Shed, British Standard 7385 Part 2 (1993) notes that "*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*" (p.5).

Where the Locomotive Shed is not considered structurally unsound, the management of potential effects of vibration could consider general criteria rather than Category 3 requirements under DIN 4150-3.

Table 22: BS 7385 structural damage criteria

Group	Type of structure	Damage level	Peak component particle velocity, mm/s		
			4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic	50		
		Minor*	100		
		Major*	200		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor*	30 to 40	40 to 100	100
		Major*	60 to 80	80 to 200	200

Notes: Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.

* Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

7.5.2.2 German Standard

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure*' (DIN 4150-3), also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are generally recognised to be conservative.

DIN 4150-3 presents the recommended maximum limits over a range of frequencies (Hz), measured in any direction, and at the foundation or in the plane of the uppermost floor of a building or structure. The vibration limits increase as the frequency content of the vibration increases. The criteria are presented in Table 23.

Table 23: DIN 4150-3 structural damage criteria

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (eg buildings under a preservation order)*	3	3 to 8	8 to 10	8

Notes: * - Refer also to British Standard 7385 Part 2 (1993)

7.6 Noise and vibration control measures

The CMP prepared by Compass Project Management acknowledges a need to minimise impacts upon the operation of the Zoo, for both visitors and wildlife, noting that acoustic treatment of equipment will be mandated or consideration of quieter methodology (e.g. use rock saws instead of rock hammers) or establishment of an acoustic treated area for cutting of materials if it cannot be carried out off-site. By actively seeking to minimise noise onto the operating zoo, noise impacts to the distance residential receivers, will be effectively managed.

With regard to the wildlife, if measures to equipment are limited and alternative processes not possible, animals in the vicinity which are observed to be sensitive to the works may be relocated for a period if practical.

In addition to the items listed in the CMP, the following at-source control and management measures should be considered for the management of noise from construction works to reduce potential noise impacts. The management measures are focused on minimising unnecessary noise generation from the site and the extent and duration of peak noise levels.

Table 24: Construction noise management measures

Measure	Detail
Source controls	
Noise barriers	Where possible, stage development so that structures provide acoustic shielding to sensitive receiver locations. Construct any solid site hoarding as soon as practical. Where possible, stationary equipment or loading areas should be located to make most use of the solid hoarding. Barriers or enclosures around stationary plant should also be considered where it is required to be located in close proximity to sensitive receivers.
Location equipment	Loading/unloading zones and stationary plant such as generators should where practicable be located away from the most sensitive receivers.
Equipment selection	Use the quietest and least vibration emitting construction methods where feasible and reasonable.
Limit equipment in use	Only the equipment necessary for the construction works will be used at any time. Avoid any unnecessary noise when carrying out manual operations and when operating plant
Limit activity duration	Any equipment not in use for extended periods shall be switched off. For example, heavy vehicles should switch engines off while being unloaded.

Measure	Detail
Reversing alarms	Alternative reverse alarm, such as non-tonal 'quackers' should be installed where feasible and reasonable.
Management measures	
Implement community consultation measures	Inform community of construction activity and potential impacts
Develop good relations	Good relations with building occupants should be established at the beginning of the works and be maintained throughout the project, as this is of paramount importance. Keeping people informed of progress and taking complaints seriously and dealing with them expeditiously is critical. The person selected to liaise with the building occupants should be adequately trained and experienced in such matters.
Work staging	Where practical, stage works so that intrusive works are carried out at least noise sensitive periods.
Site inductions	All employees, contractors and subcontractors are to receive a Project induction. The environmental component may be covered in toolboxes and must include: • all relevant project specific and standard noise and vibration mitigation measures • relevant licence and approval conditions • permissible hours of work • any limitations on high noise generating activities • location of nearest sensitive receivers • construction employee parking areas • designated loading/unloading areas and procedures • site opening/closing times (including deliveries), and • environmental incident procedures
Complaints management procedure	A management procedure would need to be put in place to deal with noise complaints that may arise from construction activities. Each complaint would need to be investigated and appropriate noise amelioration measures put in place to mitigate future occurrences, where the noise in question is in excess of allowable limits.
Noise monitoring	Noise and vibration monitoring should be carried out for any identified sensitive works, where monitoring could be used to proactively identify noisy works that may be otherwise managed and mitigated.

Regarding vibration, Table 25 below presents the recommended minimum working distances for high vibration generating plant.

Table 25: Recommended minimum working distances for vibration intensive plant

Plant item	Rating / description	Min. working distance, m	
		Cosmetic damage[2]	Human response[3]
Bobcat	Travelling	1 (nominal)	Avoid contact with structure
Jackhammer	Hand held	1 (nominal)	Avoid contact with structure
Excavator	<=30 Tonne (travelling/ digging)	5	15
Truck Movements[1]	Travelling loaded	5	10

Notes:
3. Renzo Tonin & Associates project files, databases & library
4. Based on DIN4150.3 Group 1 Buildings
5. For residential receivers

Due to the large separation distances between construction works and residential receivers, all buffer distances will be complied with and therefore no vibration impacts are expected.

8 Conclusion

Renzo Tonin & Associates has completed an assessment of noise and vibration in regard to the operation and construction phases of proposed Australia Habitat and Taronga Wildlife Retreat in order to address the Secretary's Environmental Assessment Requirements (SEARs) and relevant responses to the original SSDA from the NSW Environmental Protection Agency (EPA) and Department of Planning and Environment (DoPE).

The findings of this report are:

Operational noise:

The predicted noise levels show compliance with the relevant L&GNSW criteria for the day, evening and shoulder time periods. During the night time, exceedances are predicted only when windows and terrace doors are open.

Recommendations have been presented in Section Recommendations to mitigate noise emissions to achieve relevant L&GNSW criteria. These include restricted use after midnight of outdoor areas and shutting windows and doors from areas with noise generating actives, such as the restaurant, terrace and guest lodge bar.

Car park:

Noise generated from use of the car park is predicted to comply with the NSW INP criteria during all periods of use.

Sleep disturbance from use of the car park is not predicted to be an issue.

Site generated traffic:

Site generated traffic noise from use of the development is predicted to comply with the NSW RNP criteria.

Construction noise:

Construction noise is predicted to generally comply during the daytime period at surrounding residences. Construction noise management measures are provided in Section Noise and vibration control measures of this report.

Construction vibration:

The nearest residence is approximately 300 metres from the development site. Construction vibration is not predicted to be an issue. Potential impact as a result of vibration would only concern the nearby structures within the Zoo.

References

1. NSW Department of Environment and Climate Change 2011 Road Noise Policy (RNP)
2. NSW Environment Protection Authority 2000 Industrial Noise Policy (INP)
3. NSW Department of Environment and Climate Change 2009 Interim Construction Noise Guideline (ICNG)
4. NSW Department of Environment and Conservation Assessing Vibration – A Technical Guideline (AVATG)
5. British Standard BS 6472-2008, 'Evaluation of human exposure to vibration in buildings (1-80Hz)
6. German Standard DIN 4150-3: 1999-02 - 'Structural vibration - Effects of vibration on structures'

APPENDIX A Glossary of terminology

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment period	The period in a day over which assessments are made.
Assessment point	A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.
Background noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L90 noise level (see below).
Decibel [dB]	The units that sound is measured in. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB CBD mall at lunch time 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dB The sound of a rock band 115dB Limit of sound permitted in industry 120dB Deafening
dB(A)	A-weighted decibels. The A- weighting noise filter simulates the response of the human ear at relatively low levels, where the ear is not as effective in hearing low frequency sounds as it is in hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.
dB(C)	C-weighted decibels. The C-weighting noise filter simulates the response of the human ear at relatively high levels, where the human ear is nearly equally effective at hearing from mid-low frequency (63Hz) to mid-high frequency (4kHz), but is less effective outside these frequencies.
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
L_{Max}	The maximum sound pressure level measured over a given period.
L_{Min}	The minimum sound pressure level measured over a given period.

L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L_{90}	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L90 noise level expressed in units of dB(A).
L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound level meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound pressure level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound power level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.

APPENDIX B Noise monitoring methodology

B.1 Noise monitoring equipment

A long-term unattended noise monitor consists of a sound level meter housed inside a weather resistant enclosure. Noise levels are monitored continuously with statistical data stored in memory for every 15-minute period.

Long term noise monitoring was conducted using the following instrumentation:

Description	Type	Octave band data	Logger location(s)
RTA06 (NTi Audio XL2, with low noise microphone)	Type 1	1/3	1

Notes: All meters comply with AS IEC 61672.1 2004 "Electroacoustics - Sound Level Meters" and designated either Type 1 or Type 2 as per table, and are suitable for field use.

The equipment was calibrated prior and subsequent to the measurement period using a Bruel & Kjaer Type4231 calibrator. No significant drift in calibration was observed.

B.2 Meteorology during monitoring

Measurements affected by extraneous noise, wind (greater than 5m/s) or rain were excluded from the recorded data in accordance with the NSW INP. Determination of extraneous meteorological conditions was based on data provided by the Bureau of Meteorology (BOM), for a location considered representative of the noise monitoring location(s). However, the data was adjusted to account for the height difference between the BOM weather station, where wind speed and direction is recorded at a height of 10m above ground level, and the microphone location, which is typically 1.5m above ground level (and less than 3m). The correction factor applied to the data is based on Table C.1 of ISO 4354:2009 '*Wind actions on structures*'.

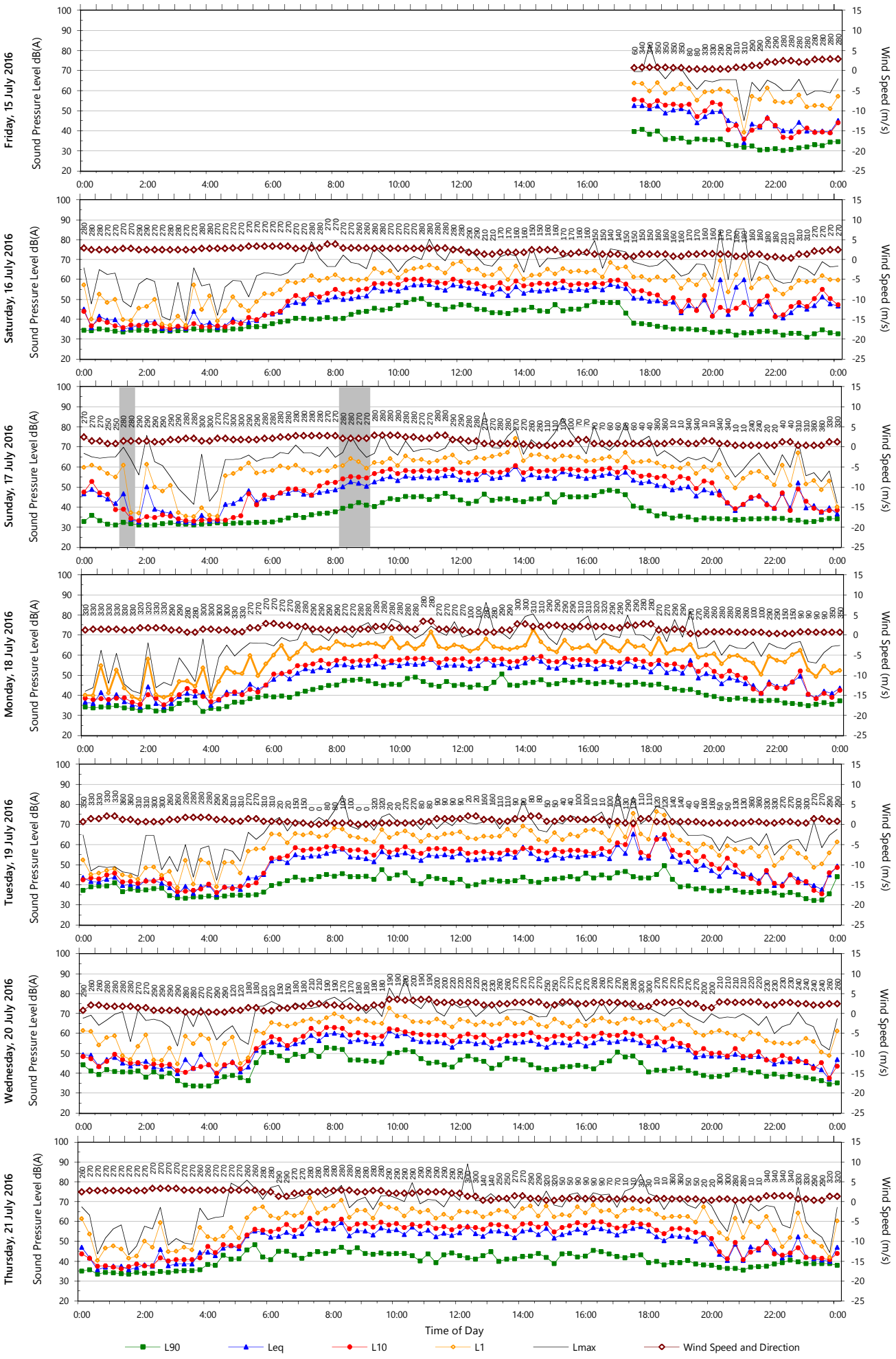
B.3 Noise vs time graphs

Noise almost always varies with time. Noise environments can be described using various descriptors to show how a noise ranges about a level. In this report, noise values measured or referred to include the L_{10}, L_{90}, and L_{eq} levels. The statistical descriptors L_{10} and L_{90} measure the noise level exceeded for 10% and 90% of the sample measurement time. The L_{eq} level is the equivalent continuous noise level or the level averaged on an equal energy basis. Measurement sample periods are usually ten to fifteen minutes. The Noise -vs- Time graphs representing measured noise levels, as presented in this report, illustrate these concepts for the broadband dB(A) results.

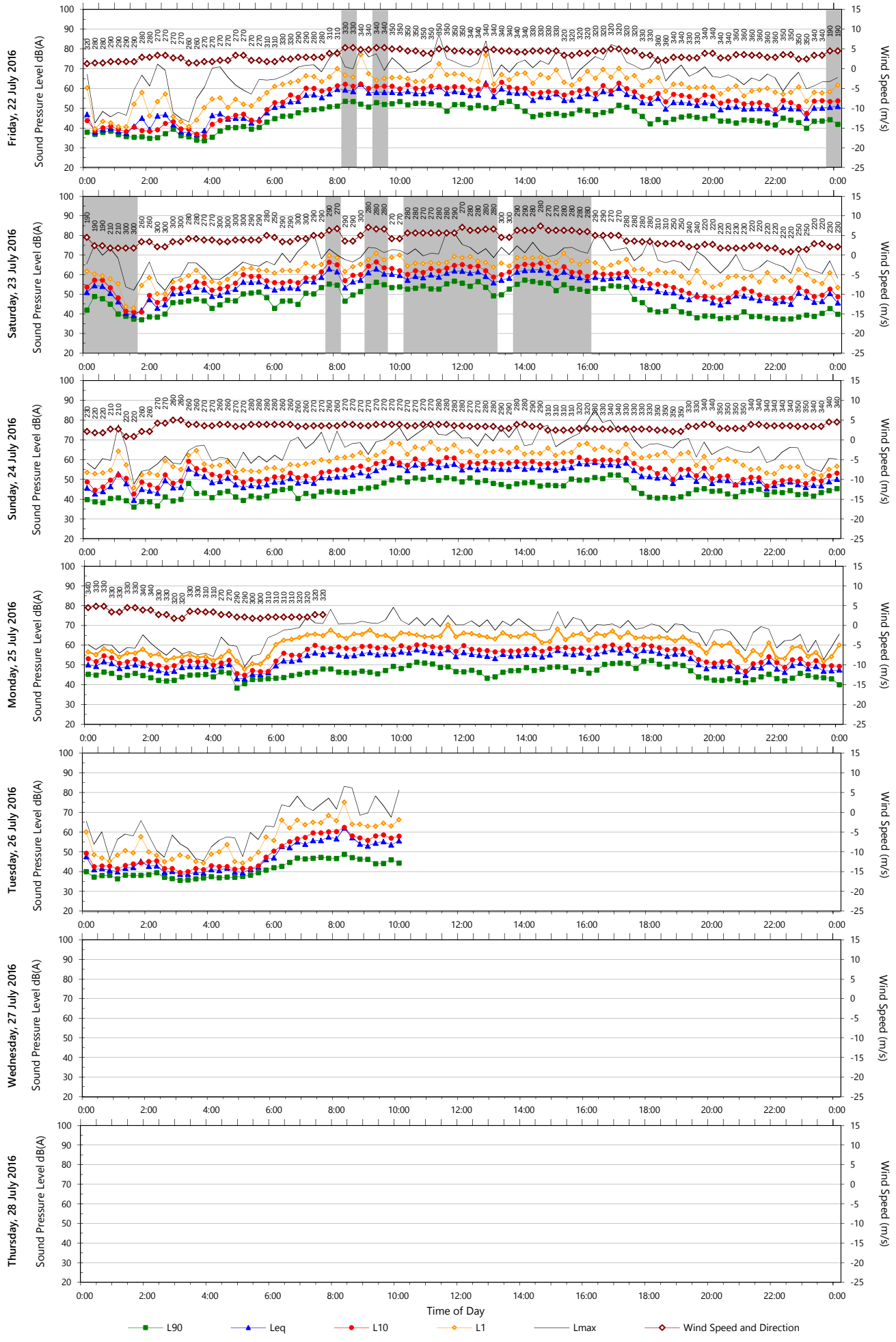
APPENDIX C Noise monitoring graphs

Unattended Monitoring Results

Location: Taronga Zoo



Data File: 2016-07-15_SLM_000_123_Rpt_Report.txt



Data File: 2016-07-15_SLM_000_123_Rpt_Report.txt

Template: QTE-26 (rev 11) Logger Graphs Program