Health Infrastructure

Royal Prince Alfred Hospital

Noise and Vibration Impact Assessment for SSDA

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Job number 280318

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1 Introduction

Arup has been engaged by Health Infrastructure to undertake a noise and vibration impact assessment to support the State Significant Development Application (SSDA) related to the proposed redevelopment of the Royal Prince Alfred (RPA) Hospital.

The Application (SSD-47662959) seeks approval for the construction of the RPA Hospital Redevelopment as described in Section 2 of this report.

The Secretary's environmental assessment requirements (SEARs) for the proposed redevelopment requires the following for noise and vibration:

> *Provide a noise and vibration assessment prepared in accordance with the relevant NSW Environment Protect Authority (EPA) guidelines. The assessment must detail construction and operational noise and vibration impacts on nearby sensitive receivers and structures and outline the proposed management and mitigation measures that would be implemented.*

This document provides noise and vibration advice on the following:

Item	Section of report
Operational noise	
Building services – noise impact on adjacent sensitive receivers and mitigation measures	Section 5.4.1
Loading dock – noise impact on adjacent sensitive receivers	Section 5.4.2
Off-site traffic generated by the development – noise impact on adjacent sensitive receivers	Section 5.4.3
HLS operation – noise impact on adjacent sensitive receivers due to helicopter movements	Sections 5.4.4, 5.4.5
Construction noise and vibration	
Identification of work equipment and machinery for construction	Section 6.7
Consideration of noise impacts within the proposed construction hours for the proposed works	Section 6.9
Consideration of vibration impacts for the proposed works	Section 6.11
Consideration of noise impacts due to construction traffic	Section 6.10
Further assessment/justification required if demolition/noisy works are proposed outside of standard construction hours[1]	Sections 6.8.2, 6.8.3
Preliminary discussion of construction noise and vibration mitigation and management	Section 6.12

Item	Section of report
Preliminary noise and vibration monitoring methodology for highly sensitive receivers	Section 6.12.6

Notes:

1. Standard construction hours (as per the Interim Construction Noise Guidelines) are: Monday – Friday: 7am to 6pm; Saturday: 8am to 1pm; Sunday and public holidays: no work

This noise and vibration impact assessment considers the polices, guidelines and standards outlined in Section 1.1.

1.1 Relevant documentation

The assessment of construction noise impacts has been carried out in accordance with the NSW Interim Construction Noise Guidelines [1]. As sensitive receivers will be impacted for greater than 3 weeks, a quantitative assessment is required.

The assessment of operational noise impacts must be in accordance with the NSW EPA Noise Policy for Industry (NPfI) [2].

Potential impacts from vibration during construction and/or operation has been quantified as per Assessing Vibration: a technical guideline [3].

Other standards, policies and guidelines referenced in this report include:

- BS 7385-2: 1993 Evaluation and measurement for vibration in buildings – Pt2: Guide to damage levels from groundborne vibration, (1993) [4]
- DIN 4150-3: 1999 Structural vibration – Effects of vibration on structures, (1999) [5]
- ASHRAE Handbook, Chapter 49 – Noise and vibration control (2019) [6]
- DIN 4150-2: 1999 Structural vibration – Human exposure to vibration in buildings [7]

2 Description of development

2.1 Site description

The Royal Prince Alfred (RPA) Hospital campus is located in Sydney's inner west suburb of Camperdown, within the City of Sydney Local Government Area. The campus is situated between the University of Sydney to the east and the residential area of Camperdown to the west. A north-south arterial road (Missenden Road) divides the campus into two distinct portions, known as the East and West Campuses. The northern boundary of the campus is defined by the Queen Elizabeth II Rehabilitation Centre and the southern extent of the campus is defined by Carillon Avenue.

The works are proposed to both the East and West Campuses, as well as some off-site works occurring within the University of Sydney.

The site comprises the following land titles:

East campus:

- Lot 1000 DP 1159799 (12 Missenden Road, Camperdown, 2050).

West campus:

- Lot 11 DP 809663 (114 Church Street, Camperdown, 2050); and
- Lot 101 DP 1179349 (68-81 Missenden Road, Camperdown 2050).

Off-site works are proposed on University of Sydney land, known as Lot 1 DP 1171804 (3 Parramatta Road, Camperdown, 2050) and Lot 1001 DP 1159799 (12A Missenden Road, Camperdown, 2050).

Lot boundaries are shown in Figure 1.

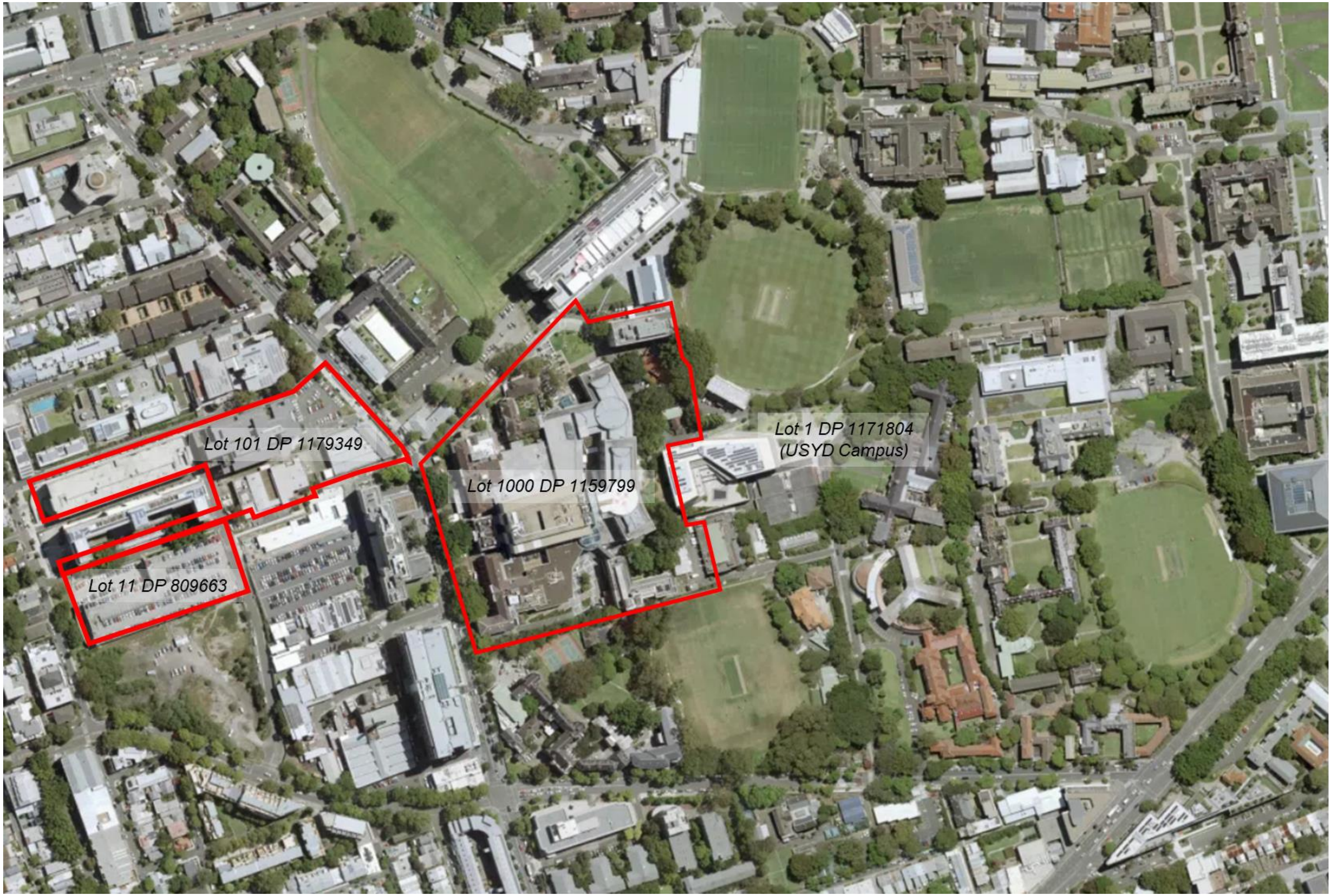

Figure 1: Site map - lot boundaries

2.2 Project background

In March 2019, the NSW Government announced a significant $750 million investment for the redevelopment and refurbishment of the RPA Hospital campus. The Project will include the development of clinical and non-clinical services infrastructure to expand, integrate, transform and optimise current capacity within the hospital to provide contemporary patient centred care, including expanded and enhanced facilities.

The last major redevelopment of RPA Hospital was undertaken from 1998 to 2004 projected to 2006 service needs. Since then, significant growth has been experienced in the volume and complexity of patients, requiring significant investment to address projected shortfalls in capacity and to update existing services to align with leading models of care.

The redevelopment of RPA Hospital has been the top priority for the Sydney Local Health District since 2017 through the Asset Strategic Planning process, to achieve NSW Health strategic direction to develop a future focused, adaptive, resilient and sustainable health system.

2.3 Scope of works

Development consent is sought for:

Alterations and additions to the RPA Hospital East Campus, comprising:

- Eastern wing: A new fifteen (15) storey building with clinical space for Inpatient Units (IPU's), Medical Imaging, Delivery, Neonatal and Women's Health Services, connecting to the existing hospital building and a rooftop helicopter landing site (HLS);
- Eastern extension: A three (3) storey extension to the east the existing clinical services building to accommodate new operating theatres and associated plant areas;
- Northern expansion: A two (2) storey vertical expansion over RPA Building 89 accommodating a new Intensive Care Unit and connected with the Eastern Wing;
- Internal refurbishment: Major internal refurbishment to existing services including Emergency Department and Imaging, circulation and support spaces;
- Enhanced Northern Entry/ Arrival including improved pedestrian access and public amenity;
- Demolition of affected buildings, structures and trees;
- Changes to internal road alignments and paving treatments; and
- Landscaping works, including tree removal, tree pruning, and compensatory tree planting including off-site on University of Sydney land.

Ancillary works to the RPA Hospital West Campus, comprising:

- Temporary helicopter landing site above existing multi storey carpark;
- Re-routing of existing services; and
- Associated tree removal along Grose Street.

The hospital will remain operational during construction works, with decantation taking place as needed to accommodate the works.

3 Surrounding land uses

The site is surrounded by:

- Other buildings on the RPA campus
- Commercial building to the east
- University of Sydney buildings and amenity areas:
  - St. John's College and St. John's Oval to the northeast
  - St. Andrew's College and St. Andrew's Oval to the southeast
  - CreateSpace and Susan Wakil Health Building to the east
  - Charles Perkins Centre to the east

St. John's and St. Andrew's include student dormitories.

Several buildings on the RPA campus are noted as having heritage significance. Refer to the Statement of Heritage Significance for details on the heritage status of buildings on the RPA campus. The nearest most potentially affected off-site land uses surrounding the development have been identified in Figure 2, which shows the location of the RPAH main building (the subject site) and identifies the surrounding buildings which are also part of the RPA campus.

Table 1 summarises the location of the nearest most potentially affected sensitive receivers.

Table 1: Sensitive receiver locations

ID	Receiver	Description
SS	Hospital wards within the subject site, i.e. RPA Main Building, Tissue Pathology and Diagnostic Oncology Building and Gloucester House	Hospital Ward (Subject site)
R1	St. John's College	Residential
R2	St Andrew's College	Residential
R3	Queen Mary Building, 106-112 Church St	Residential
R4[1]	115 Church Street	Residential
E1	CreateSpace and Susan Wakil Health Building, University of Sydney	Classroom
E2	Charles Perkins Centre, University of Sydney	Classroom
E3	Surgical and Robotic Training Institute	Classroom
A1	St. John's Oval	Active Recreation
A2	St Andrew's Oval	Active Recreation
A3	University Oval No. 1	Active Recreation
C1	7-Eleven Camperdown	Commercial
C2	King George V Building (hospital administration)	Commercial
C3	ANSTO Cyclotron	Commercial
C4	Capital Infrastructure and Engineering	Commercial

ID	Receiver	Description
H1	Chris O'Brien Lifehouse	Hospital Ward
H2	Building 12 (future location of Anatomical Pathology department)	Commercial
H3	Professor Marie Bashir Centre	Hospital Ward
H4	RPAH Medical Centre	Hospital Ward
H5	Radiation Oncology Department	Hospital Ward
H6	Centenary Institute[2]	Hospital Ward
H7	Naamuru Parent and Baby Unit	Hospital Ward

Notes:

1. Receiver R4 is included for assessment of generator noise from the temporary HLS only
2. Centenary Institute is within the same lot as the subject site, but warrants separate assessment due to the sensitivity of some of the spaces within the building

Figure 2: Site, sensitive receiver and noise monitoring locations

4 Existing noise environment

4.1 Noise measurement locations

Noise measurements are ideally carried out at the nearest or most potentially affected locations surrounding a development. Representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

Unattended noise monitoring was undertaken by Arup at St. Andrew's College and St. John's College. These colleges contain student dormitories and are therefore the most sensitive residential receivers surrounding the main hospital site.

The long-term measurement locations are outlined in Table 2 and shown in Figure 2.

Table 2: Noise monitoring locations

ID	Address
L1	St. John's College
L2	St. Andrew's College

4.2 Long-term noise measurement results

Long-term noise monitoring was carried out at L1 and L2 from Thursday, 18 August 2022 to Monday, 29 August 2022.

Table 3 presents the overall single Rating Background Levels (RBL) and representative ambient L_{Aeq} noise levels for each assessment period, determined in accordance with the NPfI [2].

Table 3: Long-term noise monitoring results, dB(A)

Location	Time period	Rating background noise levels, dBL_{A90}	Ambient dBL_{Aeq} noise levels
L1	Day	52	58
	Evening	51	56
	Night	49	55
L2	Day	51	60
	Evening	51	56
	Night	50	56

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
Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays
As required by the NPfI, the external ambient noise levels presented are free-field noise levels (i.e. no façade reflection)

The clock on the noise monitor at L2 was not set to the correct time; as a result, noise data recorded by the monitor is time-shifted by 6 minutes. After every weather event, an additional time period is conservatively excluded from the data. This is to ensure that noise level data recorded during an adverse weather event is not erroneously included in the assessment.

There was some adverse weather during the monitoring period. Nevertheless, sufficient meteorologically unaffected noise data was collected at each location for the daytime, evening and night-time periods; in accordance with the NPfI, data for at least seven meteorologically unaffected daytime, evening and night-time periods was collected.

Noise level vs. time graphs are included in Appendix D.

5 Operational noise and vibration

The primary operational noise sources with the potential to impact upon surrounding noise sensitive uses has been identified as building services (i.e. mechanical, electrical and hydraulic plant and equipment) and vehicular movements on site.

5.1 Building services noise criteria

Operational noise emissions from the project are to be assessed in accordance with the Noise Policy for Industry (NPfI), which is primarily concerned with controlling intrusive noise impacts in the short-term for residences and maintaining long-term noise level amenity for residences and other land uses.

The NPfI sets out the procedure to determine the project noise trigger levels relevant to an industrial development. The project noise trigger level is a level that, if exceeded would indicate a potential noise impact on the community and so ‘trigger’ a management response.

5.1.1 Intrusive noise trigger level

The intrusiveness noise trigger level is applicable to residential premises only and is summarised as follows:

- $L_{Aeq,15minute} \leq$ Rating Background Level (RBL) plus 5 dB

  (where $L_{Aeq,15minute}$ represent the equivalent continuous noise level of the source)

5.1.2 Recommended and project amenity noise level

To limit continuing increases in noise levels from application of the intrusiveness level alone, the ambient noise level within an area from **all** industrial noise sources combined should remain below the recommended amenity noise levels specified in Table 2.2 of the NPfI where feasible and reasonable. An extract from the policy is given below in Table 4.

Table 4: NPfI Recommended Amenity Noise Levels (RANLs)

Receiver	**Noise amenity area**	**Time of Day**	**Recommended amenity noise levels (RANLs) L_{Aeq}, dB(A)**
Residential	Urban	Day	60
		Evening	50
		Night	45
School classroom - internal	All	Noisiest 1-hour period when in use	35 (see notes for table)

Receiver	Noise amenity area	Time of Day	Recommended amenity noise levels (RANLs) L_{Aeq}, dB(A)
Hospital ward Internal External	 All All	 Noisiest 1-hour Noisiest 1-hour	 35 50
Place of worship – internal	All	When in use	40
Active recreation area (e.g. school playground, gold course)	All	When in use	55
Commercial premises	All	When in use	65

Notes: The recommended amenity noise levels (RANLs) refer only to noise from industrial sources. However, they refer to noise from all such sources at the receiver location, and not only noise due to a specific project under consideration. The levels represent outdoor levels except where otherwise stated.

1. The NPfI defines day, evening and night time periods as:
   - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays.
   - Evening: the period from 6 pm to 10 pm.
   - Night: the remaining period.

(These periods may be varied where appropriate. In the case where existing schools are affected by noise from existing industrial noise sources, the acceptable L_{Aeq} noise level may be increased to 40 dB $L_{Aeq(1hr)}$

The area surrounding the site can be categorised as **Urban** under the NPfI.

The NPfI sets the PANLs to $L_{Aeq(period(traffic))}$ minus 15 dB(A) in the case that the level of transport $L_{Aeq(period(traffic))}$ exceeds the RANL by 10 dB or more. As the $L_{Aeq(period)}$ does not exceed the RANL by 10 dB or more, the PANLs will be set to the RANL – 5 dB.

Table 5 summarises the RANLs and the PANLs applicable for the project.

Table 5: NPfI RANLs and PANLs

Receiver	Indicative Noise Amenity Area	Time of day[1]	Recommended Amenity Noise Level (RANL) $L_{Aeq(period)}$	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$
R1, R2, R3, R4	Urban	Day	60	55
		Evening	50	45
		Night	45	40
E1, E2, E3	N/A[2]	Classroom – noisiest 1 hour, when in use	40 (internal) 50 (external)[3]	35 (internal) 45 (external)
A1, A2, A3	N/A[2]	When in use	55	50
C1, C2, C3, C4	N/A[2]	When in use	65	60

Receiver	Indicative Noise Amenity Area	Time of day[1]	Recommended Amenity Noise Level (RANL) $L_{Aeq(period)}$	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$
SS, H1, H2, H3, H4, H5, H6, H7	N/A[2]	Hospital ward – noisiest 1 hour	35 (internal) 50 (external)	30 (internal) 45 (external)

Notes:

1. The NPfI defines day, evening and night-time periods as:
   - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays.
   - Evening: the period from 6 pm to 10 pm.
   - Night: the remaining period.
2. N/A = not applicable
3. External criteria set to 10 dB above the internal criteria to represent noise reduction through an open window. Since the classrooms are impacted by noise from the existing RPA building, internal criteria have been set according to note in Table 4.

5.1.3 Sleep disturbance

The NSW NPfI recommends the following screening criteria for the assessment of potential sleep disturbance, for the period between 10 pm and 7 am:

- $L_{Aeq,15min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, and/or;
- L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is the greater

5.1.4 NPfI Project specific noise levels

In addition to the above, the NPfI has standardised the time periods for the intrusiveness and amenity noise levels assuming that the $L_{Aeq,15min}$ is taken to be equal to the $L_{Aeq, period}$ + 3 decibels (dB). This standard adjustment has been applied to receivers in this report.

Arup believes that this correction should not apply to $L_{Aeq, 1hour}$ criteria for classrooms and hospital wards, however advice from EPA is that the + 3 dB correction applies to all categories of receivers.

Project Noise Trigger Levels (PNTLs) for residential receivers represent the lower of the intrusive criteria and the adjusted $L_{Aeq,15min}$ amenity criteria.

The derived criteria for each receiver are given in Table 6.

Table 6: NPfI Project specific noise levels

Recv.	Time of day[1]	Project Specific Noise Levels				
		Intrusive noise trigger level $L_{Aeq(15min)}$	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$	Project Amenity Noise Level (PANL) $L_{Aeq(15min)}$	Project Noise Trigger Level (PNTL) $L_{Aeq(15min)}$	Sleep Disturbance $L_{Amax(night)}$
R1, R3[3], R4[3]	Day	57	55	58	57	N/A[2]
	Evening	56	45	48	48	N/A[2]
	Night	54	40	43	43	65
R2	Day	56	55	58	56	N/A[2]
	Evening	56	45	48	48	N/A[2]
	Night	55	40	43	43	65
E1, E2, E3	Classroom – noisiest 1 hour, when in use	N/A[2]	35 (internal) 45 (external)	38 (internal) 48 (external)	38 (internal) 48 (external)	N/A[2]
A1, A2, A3	When in use	N/A[2]	50	53	53	N/A[2]
C1, C2, C3, C4	When in use	N/A[2]	60	63	63	N/A[2]
SS, H1, H2, H3, H4, H5, H6, H7	Hospital ward – noisiest 1 hour	N/A[2]	30 (internal) 45 (external)	33 (internal) 48 (external)	33 (internal) 48 (external)	N/A[2]

Notes:

1. The NPfI defines day, evening and night-time periods as:
   - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays.
   - Evening: the period from 6 pm to 10 pm.
   - Night: the remaining period.
2. N/A = not applicable
3. Intrusive noise trigger levels established based on measurements at L1

5.1.5 Emergency operations

There are no standard criteria for emergency plant operation noise egress. Targets are typically required to be justified and approved with the planning authority and may vary dependent on the likelihood of operation or need for regular testing. While there is potential for no specific noise criteria to be applied, it is prudent to apply a target to avoid excessive emission, even if limited to infrequent testing.

It is proposed in the first instance to adopt the **daytime PANL + 5 dB** as the design target, however this can be reviewed following assessment of works, with consideration given to the feasibility of mitigation measures required to achieve the targets.

For the purpose of external noise egress criteria, generators are included under 'emergency plant'.

5.2 Helicopter noise criteria

There are no current regulations that specifically assess helicopter noise emissions or noise emissions from emergency vehicles in NSW.

However, noise criteria provide a useful reference for quantifying impacts on nearby sensitive receivers, Table 7 presents proposed helicopter noise criteria.

The proposed criteria have been derived from a review of relevant standards and guidelines as well as precedent projects in NSW that have applied helicopter noise criteria, detailed in Appendix C.

Table 7: Proposed helicopter noise criteria for surrounding noise sensitive receivers.

Usage of premises and zoning	$L_{Aeq,T}$		$L_{Amax, T}$ [2]	
	Daytime[1]	**Night-time**[1]	**Daytime**[1]	**Night-time**[1]
Residential areas	60	50	85	80

Note:

1. Daytime is understood to be between 0700 and 1900 hours and night-time between 1900 and 0700 hours.
2. Special consideration may be given to the operation of aerial ambulances. For this reason, $L_{Aeq,T}$ (Hel), either night or day, must be satisfied, but L_{Amax} (Hel) is not specified for aerial ambulances. Criteria is presented for information only.

5.3 Traffic noise criteria

5.3.1 Impact to surrounding receivers

Increased traffic generated on the surrounding road network due to the operation of the development is assessed in accordance with the NSW *Road Noise Policy* (RNP) [8]. Table 3 of the RNP which sets out the assessment criteria for particular types of project, road category and land use, shown in Table 8 below.

Table 8: Road traffic criteria for traffic generating development - residential receivers.

Road category	**Type of project / land use**	**Assessment criteria – dB(A)**	
		Day (7:00am-10:00pm)	**Night (10:00pm-7:00am)**
Local roads – Missenden Road	Existing residences affected by additional traffic on existing local roads generated by land use developments	$L_{Aeq,(15\ hour)}$ 55 (external)	$L_{Aeq,(9\ hour)}$ 50 (external)

Road category	Type of project / land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	Night (10:00pm-7:00am)

Note:
These criteria are for assessment against façade corrected noise levels when measured in front of a building façade.

Regarding the application of the assessment, the RNP states:

> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

5.3.2 Impact to the development

The *NSW State Environmental Planning Policy (Transport and Infrastructure) 2021* (SEPP) [9] and the supplementary guideline, Department of Planning and Environment's publication *Development near Rail Corridors and Busy Roads – Interim Guideline* [10] provides guidance concerning the assessment of road and rail traffic noise.

The SEPP came into force in NSW on 1 January 2008 to facilitate the effective delivery of infrastructure across the State. Relevant to the acoustic assessment are the following clauses:

> *2.120 Impact of road noise or vibration on non-road development*
>
> 1. *This section applies to development for any of the following purposes that is on land in or adjacent to the road corridor for a freeway, a tollway or a transitway or any other road with an annual average daily traffic volume of more than 20,000 vehicles (based on the traffic volume data published on the website of TfNSW) and that the consent authority considers is likely to be adversely affected by road noise or vibration—*
>   a) *residential accommodation,*
>   b) *a place of public worship,*
>   c) *a hospital,*
>   d) *an educational establishment or child care facility.*

While the SEPP [9] applies only to roads with an AADT greater than 20,000 vehicles, the *Development in Rail Corridors and Busy Roads – Interim Guideline* [10] also recommends adoption of these clauses for roads greater than 20,000 vehicles.

The Guideline clarifies the time period of measurement and assessment. Section 3.4 '*What Noise and Vibration Concepts are Relevant*' and Table 3.1 of Section 3.6.1 confirms that noise assessment is based over the following time periods:

- Daytime 7:00am - 10:00pm $L_{Aeq(15hr)}$

- Night-time 10:00pm - 7:00am $L_{Aeq(9hr)}$

The noise criteria nominated in the SEPP apply to internal noise levels with windows and doors closed. Where the noise assessment is based on measurements/predictions at external locations, equivalent external noise criteria have been established. The equivalent external noise criterion is used to determine which areas of the development may require acoustic treatment in order to meet the internal noise requirements of the SEPP. The equivalent external goals have been determined on the following basis:

- The SEPP states: "*If internal noise levels with windows or doors open exceed the criteria by more than 10dBA, the design of the ventilation for these rooms should be such that occupants can leave windows closed, if they so desire, and also to meet the ventilation requirements of the Building Code of Australia*." The internal criteria with windows open is therefore 10dB(A) above the criteria explicitly outlined in the SEPP.
- The generally accepted noise reduction through an open window from a free-field external position is 10dB(A). Windows/doors are assumed to be open no more than 5% of room floor area, in accordance with the Building Code of Australia (BCA) ventilation requirements.

Table 9 presents the SEPP internal noise criteria for hospital buildings.

Table 9: Road traffic intrusion noise criteria.

Non-residential building	Area designation	Internal noise level[1]
Hospitals	Wards	35
	Other noise sensitive areas	45

Note:

1. Airborne noise is calculated as L_{eq} (9h) (night) and L_{eq} (15h) (day).

5.4 Operational noise review

5.4.1 Building services

Building services equipment has not been selected at this early stage of design. Therefore, detailed acoustic design will be required following confirmation of the building services equipment selections. General recommendations are provided in this report commensurate with an early stage of planning (i.e. SSDA).

Preliminary guidance concerning building services noise control is as follows:

- Acoustic assessment of building services equipment should be undertaken during the detailed design phase of the development to ensure that the cumulative noise of all equipment does not exceed the Project Specific Noise Levels (Table 6).
- Building services noise emissions can be controlled by appropriate system design and implementation of common engineering methods, which may include:

- Procurement of ‘quiet’ plant.
- Acoustic louvres.
- Commercially available acoustic attenuators for air discharge and air intakes of plant.
- Acoustically lined and lagged ductwork.
- Acoustic barriers between plant and sensitive neighbouring premises.
- Partial or complete acoustic enclosures over plant.

Main building

Table 10: Building services noise assessment - main building

Location	Plant	Recommended mitigation	Other comments
Plantrooms within eastern extension, new east wing and vertical extension	• Various plant within plantrooms – selections TBC. • New and relocated plantroom louvres.	Noise levels cannot be determined at this stage of design. Mitigation TBC during future design stages.	It is expected that noise mitigation measures (for example, acoustic louvres / acoustic treatment to equipment in the plantroom / acoustic finishes within the plantroom) can readily be incorporated into the design if required to address noise levels at the nearest sensitive receivers
East side of the existing roof on Level 11	• 8 new exhaust air fan outlets. • 1 PAC unit. Selections TBC.		
Roof of east extension	• 3 exhaust air fans. • 1 compressor. Selections TBC.		
L7 roof	Existing data centre chiller (to be relocated to the east of its current location)	None expected to be required.	The relocation is not expected to result in a significant increase in noise levels at the nearest affected receivers.

Location	Plant	Recommended mitigation	Other comments
Level 15 (roof) of new East wing	• Exhaust fans (selections TBC). • Three cooling towers (CTs) • Three heat pumps. • Five generators (maximum of 4 running at the same time). Preliminary selections for cooling towers and heat pumps are given in Table 11.	CTs, generators and heat pumps to be located in wells / behind barriers (at least 5 m height with minimum surface mass of 5 kg/m^2). 'Quieter' selections will be required for CTs and heat pumps. Attenuators may be required on heat pump fans. Generator selection to achieve the following: • Exhaust: 69 dB(A) at 1 m • Engine + radiator fan combined: 76 dB(A) at 1 m	The nearest sensitive receiver is Centenary Institute and St. John's College. Noise predictions indicate that the criteria at Centenary Institute and St. John's will be exceeded without the recommended mitigation. It is understood that the recommended mitigation is considered feasible at this stage and so it is expected that noise criteria can be achieved.
Various locations along northern / eastern façade & roof of main building.	Diversion of ventilation risers as required.	TBC during future design stages	It is expected that noise mitigation measures (for example, in-duct attenuators / lined ductwork / acoustic screens / selection of 'quieter' equipment) can readily be incorporated into the design if required to address noise levels at the nearest sensitive receivers.

Table 11: Preliminary rooftop plant sound power levels

Plant item	Preliminary selection	Overall sound power, dB(A)	Octave band sound power level, dB, Hz							
			63	125	250	500	1k	2k	4k	8k
Cooling tower	PCT1010-P3-L	96	103	104	99	92	89	86	81	77
Heat pump	NX2-Q-G06 / A / 0606	99	101	100	98	96	95	90	84	78

Lambie Dew Drive

Table 12: Services noise assessment - Lambie Dew Drive

Location	Plant	Recommended mitigation	Other comments
Johns Hopkins Drive	Temporary substation (basis of design: Schneider L Type 1000kVA)	None expected to be required	Noise from this transformer has been assessed and is predicted to be 40 dB at the boundary of the nearest sensitive receiver (R1 – note that the dormitory building is 55 m away from the boundary).
Johns Hopkins Drive	Fire booster pump	None expected to be required	The new fire booster pump location is closer to residential receiver R1 compared to the previous location. The fire booster pump would only be used in the event of a fire emergency. The NPfI does not apply to emergency plant.

Temporary HLS

Table 13: Building services noise assessment – temporary HLS

Location	Plant	Recommended mitigation	Other comments
Northern end of the car park rooftop	Car park exhaust system – design TBC during future design stages. An assessment has been done for a nominal fan discharging to the roof with sound power level of 94 dB(A)	Attenuator expected to be required, depending on sound power levels of final fan selections (if any).	Noise predictions indicate that the night-time criteria at the Queen Mary Building can be met with the use of an attenuator. It is understood that the recommended mitigation is considered feasible.
Lift lobby façade louvres	None – lift lobby will be naturally ventilated	N/A	-

Location	Plant	Recommended mitigation	Other comments
Outside southwest corner of car park, at ground level	Generator (initial selection Cat DE55E0)	As required to achieve the following: • Exhaust: 76.3 dB(A) at 1 m • Engine + radiator fan combined: 76.7 dB(A) at 1 m	Generator engine will be within enclosure (e.g. CAT LEHE0788 enclosure). The enclosed generator engine can comply with the nominated criteria. It is expected that the an exhaust muffler will be required and can readily be integrated into the design.

5.4.2 Loading dock noise

It has been advised by SCT Consulting that it is understood that the number of vehicles accessing the loading dock below the proposed east extension is expected to increase by approximately as 40% as an initial estimate, totalling 48 delivery vehicles throughout the day. Review of the latest loading dock design indicates that the loading dock will be able to cater a maximum of 2 Heavy Rigid Vehicles (HRV) and 4 Medium Rigid Vehicles (MRV).

Service vehicle delivery schedules are not yet available at this stage of the project (as is typical). Therefore, a preliminary assessment has been conducted, assuming 2 HRVs and 4 MRVs arriving at the loading dock at the same time within a 15-minute period. This assumption is used to assess a worst-case scenario of 2 HRVs and 4 MRVs arriving and reversing into the loading dock at the same time during the day period.

Predictions have been made using the sound power levels shown in Table 14 taken from the Arup sound power level database for a typical articulated vehicle.

Table 14: Loading dock noise sources and sound power levels.

Element	Overall sound power level, $dBL_{Aeq,15\ min}$	Octave band (Hz)							
		63	125	250	500	1k	2k	4k	8k
		Sound power level, dB(Z)							
Truck Arriving – 5 km/h	64 (L_w/m)	71	62	63	60	59	58	52	46
Reversing Alarm – 5 km/h	64 (L_w/m)	70	69	60	58	57	59	48	39

Table 15 shows predicted results at the worst-affected receiver E1 located about 35 meters away from the loading dock

Table 15: Predicted noise impact from loading dock operations.

Receiver ID	Assessment period	Distance to receiver	Project Noise Trigger Level (PNTL) $L_{Aeq,15min}$	Predicted noise level, $L_{Aeq,15min}$
E1	Day	35m	48 (external)	37

It is noted that no loading dock activities are understood to take place outside of the daytime period. From the modelling, the loading dock operations are not expected to significantly impact the worst-affected receiver.

5.4.3 Off-site traffic generated by the development

Existing traffic count during peak hours at Missenden Road have been provided by SCT Consulting.

Table 16 present a simplified conservative assessment of potential day and night increase in traffic noise from RPA. This assessment is considered conservative as the increases in light and heavy vehicle traffic noise will not arithmetically add up since heavy vehicles are louder than light vehicles, however the assessment represents a maximum potential increase in traffic noise.

Table 16: Off-site traffic assessment

	Day (15 hour)			Night (9 hour)		
	Light vehicles	**Heavy vehicles**	**Total**	**Light vehicles**	**Heavy vehicles**	**Total**
Projected existing Missenden Road volume	8492	565	9058	1917	128	2045
Traffic generated by RPA	2975	48	3023	672	0	672
Increase in traffic noise level due to development, dBA	**1.3**	**0.4**	**1.7**	**1.3**	**0.0**	**1.3**

Considering the existing traffic numbers along Missenden Road, the additional traffic created by development is predicted to increase the $L_{Aeq(15\ hour)}$ noise levels by 1.1 dB and the $L_{Aeq(9\ hour)}$ noise levels by 1.0 dB. This is less than the 2 dB ‘minor impact’ criteria, and therefore represents an insignificant effect on the ambient noise environment.

5.4.4 Helicopter noise – temporary HLS

A temporary HLS is proposed to service the hospital for emergency medical retrievals and patient transport services during construction works, due to the unacceptable risk to helicopter operations and construction worker safety that would result from the continued use of the existing HLS during the undertaking of the works.

The location of the temporary HLS and the nearest receivers is show in Figure 3.

Figure 3: Location of temporary HLS and assessment location for nearest receivers

The risks and constraints posed by retaining the existing HLS during construction works include:

- Constraint on the type of cranes used;
- Cranes would need to cease operation and be raised into a vertical position each time an aircraft approaches from or takes off to the north;
- Helicopters would then fly between the two craned (in a 55m gap), in all conditions day or night;
- Construction work would need to cease, all working decks vacated and materials tied down; and
- One crane would need to be dismantled when the new East tower reaches Level 11, impacting the overall construction efficiency.

Construction Advisor Lend Lease has advised that these constraints are not manageable or viable, and even if they were put in place, the risks to public, staff and construction workers would be too significant.

The temporary HLS is located to the west of the main hospital building, on the eastern end of the roof of an existing multi-storey car park. The proposed location of the helicopter landing site is shown in Figure 2. It is expected that the temporary HLS will be in operation for 2 years.

Potential noise impacts of the proposed helicopter landing site have been assessed by generating L_{Aeq} and L_{Amax} contours using the United States Federal Aviation Administration's (US FAA) AEDT software version 3.0d. AEDT is the current industry standard software used for modelling aircraft noise. The results have been analysed and presented using a Geographic Information System (GIS) for accurate projection of contours onto maps.

5.4.4.1 Design helicopter

The Agusta AW139 has been identified by the aviation consultant as the design helicopter [11].

Noise data for the Agusta AW139 is not available in the AEDT database. A substitute helicopter, Aerospatiale SA330J, was used, being comparable in size, maximum load and engine type to the AW139.

However, the SA330J is considered to be noisier than the AW139 because the SA330J:

- has slightly higher-powered engines than the AW139,
- is of a considerably older design (more than 30 years older) than the AW139 and, accordingly, is not as aerodynamically efficient as the AW139, and
- the engines on the SA330J are more powerful than those of the AW139 and the exhausts are angled outwards (as opposed to upwards on the AW139).

As a result, the noise profile of the SA330J is considered a conservative estimate.

5.4.4.2 Movements

Data from 2018 – 2021 shows that RPA transferred an average of 107 patients per year; mostly inbound (Figure 4). It is therefore assumed that a temporary HLS would be used approximately nine – ten times per month on average (or once every three days). The percentage of landings that occur during the night-time period (10 pm – 7 am) varies from 27% to 42% (Figure 5).

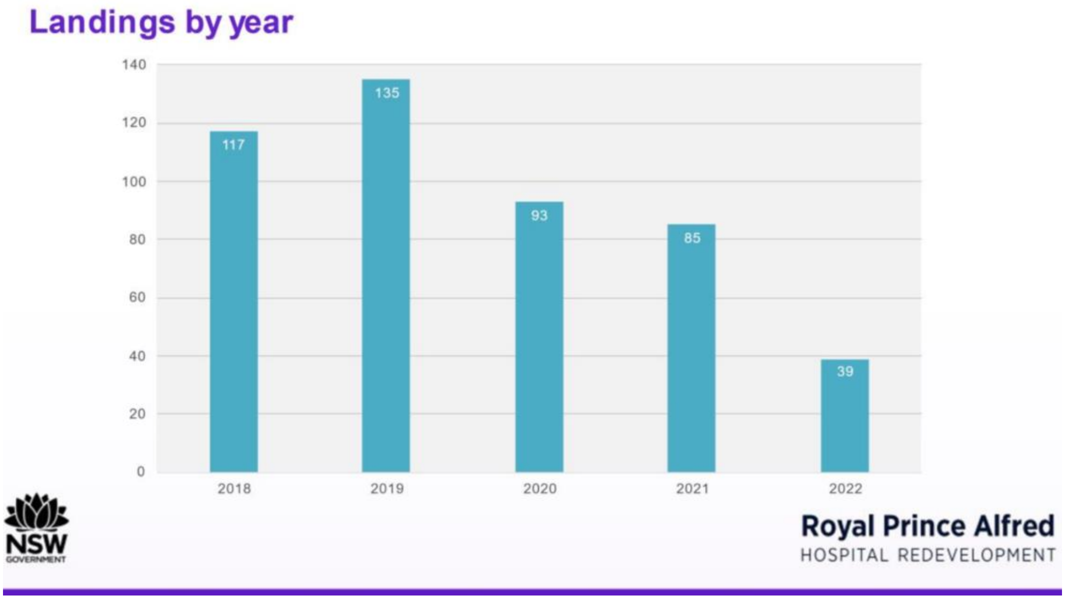

Figure 4: Year on year data showing average patient transfers

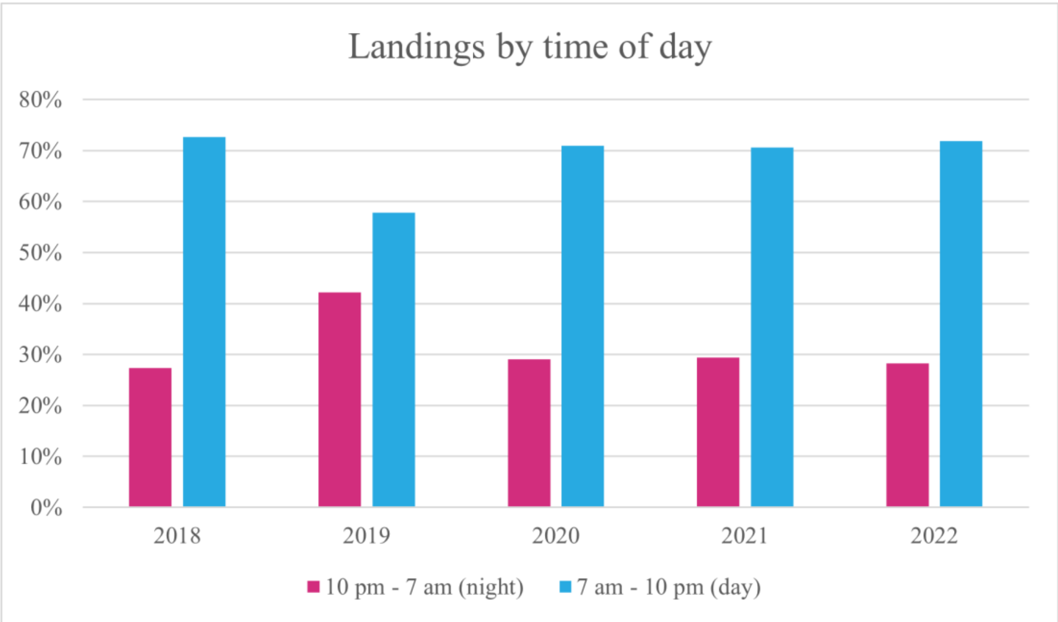

Figure 5: Percentage of landings occurring during daytime and night-time periods

For the purposes of this assessment an *average* day has been modelled as having one retrieval per day, noting that each retrieval includes one approach and one departure movement. In assessing potential sleep disturbance impacts, the assessment has considered operations during the night period as defined by the NSW *Noise Policy for Industry*.

5.4.4.3 Flight track and distribution

Figure 6 illustrates four reference flight tracks that have been developed for Performance Class 1 helicopter operations[1] at the temporary HLS. The building to the north of the temporary HLS is the nearest sensitive receiver (residential receiver R3; approximately 27 metres from the HLS at the closest point).

The worst-case departure / arrival scenarios are used for the basis of this assessment:

1. Arrival from west, departure to northeast
2. Arrival from northeast, departure to west

The distribution of helicopter movements for these flights tracks has been provided by AviPro and is presented in Table 17. From the provided information, an even split between the approach and departure tracks has been assessed.

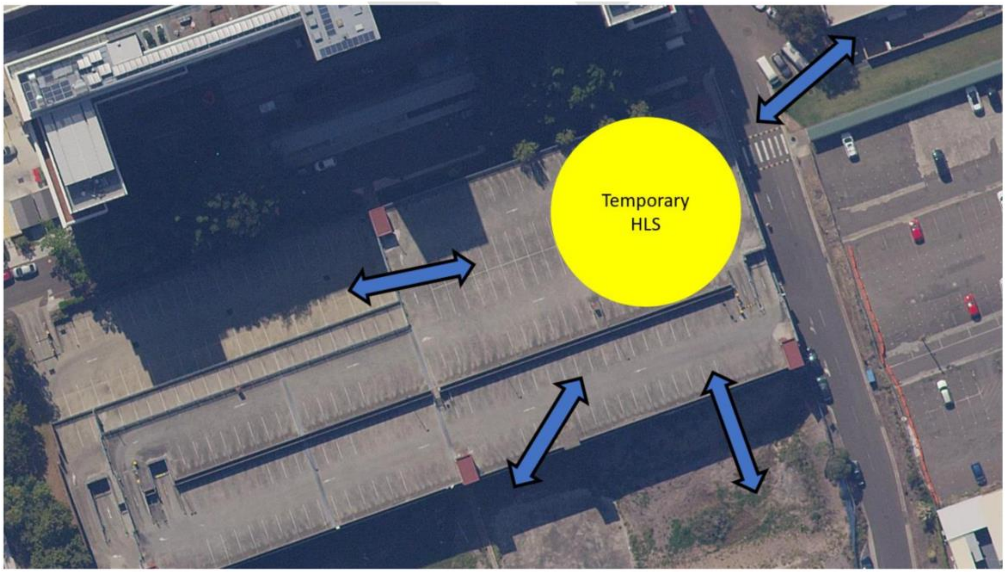

Figure 6: Approach and departure paths for temporary HLS [11]

Table 17: Flight track distributions

Operation	Direction	Distribution
Approach	From West	50%
	From Northeast	50%
Departures	To West	50%
	To Northeast	50%

[1] The Australian Civil and Aviation Safety Authority (CASA) [22] defines Performance Class 1 helicopter operations as "*helicopter operations with performance such that, dependant on when the failure occurs in the case of a critical engine failure, the helicopter is able to land on the rejected take-off area, or safely continue the flight to an appropriate landing area and land safely using the remaining engine or engines.*"

5.4.4.4 Proximity to Sydney (Kingsford-Smith) Airport

The AviPro Concept Design Report provides the following information on the duration of helicopter noise events [11]:

The following is a normal activity breakdown:

Arriving helicopter:

1 minute – helicopter circles, approaches and lands

2 minutes – engine temperature stabilisation and then shut down

Departing helicopter:

2 minutes – helicopter starts

1 minute – helicopter hovers, backs-up (climbs backwards) and departs

Because RPA is so close to Sydney (Kingsford-Smith) Airport (and therefore in close proximity to large aircraft being offered Air Traffic Control (ATC) separation (from other aircraft) services, it can take considerably longer during the hours of operation of the aerodrome to receive an ATC clearance to depart the site. This won't be the case during the Sydney (Kingsford-Smith) Airport curfew period (2300-0600).

The AEDT software assumes the following noise profile for the model helicopter (these settings cannot be customised):

Arriving helicopter:

3 seconds – vertical descend

30 seconds – flight idle

30 seconds – ground idle

Departing helicopter:

30 seconds – ground idle

30 seconds – flight idle

3 seconds – vertical ascend

The above is further illustrated in the diagram in Appendix E.

It is noted that, due to proximity to the airport, nearby receivers may experience a different noise profile for helicopter retrieval missions compared to the modelled noise profile.

5.4.4.5 Helicopter noise predictions and analysis

Predicted results for the nearest residential receivers are shown in Table 19 for equivalent continuous sound levels or average (L_{Aeq}) and Table 19 for maximum levels (L_{Amax}).

It is reiterated that there are no current regulations that specifically assess helicopter noise emissions in NSW and that the L_{max} criteria is not applicable to emergency medical helicopters under AS2363. However, the assessment presented below is useful to inform potential impacts to the most-affected receivers, particularly potential sleep disturbance. In particular, the L_{Aeq} assessment describes the average noise level for a single short-term event (5-10 minutes) over a 12-hour period.

It is also reiterated that, as noted in Section 5.4.4.1, the reference helicopter used in the noise assessment (SA330J) is considered to be noisier than the design helicopter (AW139).

Assessment

Exceedances of L_{Aeq} and L_{Amax} criteria are predicted for both day and night-time periods. L_{Amax} values represent the absolute maximum noise levels that may be experienced by the affected receivers.

Regarding potential sleep disturbance impacts, historical data indicates that most helicopter movements occur during the day-time period; nevertheless, regular sleep disturbance impacts are expected.

Table 18: Predicted results from helicopter noise assessment - L_{Aeq}

Receiver	**Distance, m**	**W Approach NE Departure**				**NE Approach W Departure**			
		Day		**Night**		**Day**		**Night**	
		dBL_{Aeq}	***Criteria***	**dBL_{Aeq}**	***Criteria***	**dBL_{Aeq}**	***Criteria***	**dBL_{Aeq}**	***Criteria***
R3	27	66	*60*	66	*50*	67	*60*	67	*50*
H7[2]	30	65	*60*	65	*50*	66	*60*	66	*50*

Note:

1. Red highlighted cells indicate an exceedance of criteria.
2. H7 is assessed as residential due to the nature of the space; i.e. contains rooms for families to live in temporarily

Table 19: Predicted results from helicopter noise assessment - L_{Amax}

Receiver	**Distance, m**	**W Approach NE Departure**				**NE Approach W Departure**			
		Day		**Night**		**Day**		**Night**	
		dBL_{Amax}	***Criteria***	**dBL_{Amax}**	***Criteria***	**dBL_{Amax}**	***Criteria***	**dBL_{Amax}**	***Criteria***
R3	27	106	*85*	106	*80*	105	*85*	105	*80*
H7[2]	30	108	*85*	108	*80*	107	*85*	107	*80*

Note:

1. Red highlighted cells indicate an exceedance of criteria.
2. H7 is assessed as residential due to the nature of the space; i.e. contains rooms for families to live in temporarily

5.4.4.6 Discussion

Predictions indicate that noise from emergency medical helicopters will impact the nearest sensitive receivers.

Several mitigation measures have been explored to minimise the impacts of the proposed temporary HLS, as summarised in Table 20.

Table 20: Analysis of mitigation options for the temporary HLS

Item	Mitigation option	Comment
1.	Architectural treatment at affected residents north of the HLS	Treating individual residential receivers is not practical and may have significant cost implications to the project. It would require residents to have their dwelling closed and sealed, which may not be typical.
2.	Noise barriers at the northern site boundary	Noise barriers would only be effective in minimising potential impacts of helicopter idling at the helipad, which is less significant compared with the helicopter overflight approaching/departing the hospital. In addition, noise barriers pose a potential conflict with clearance requirements.
3.	Relocation of the HLS	The proposed location is deemed to be the only feasible alternate location on or near the RPA campus. See discussion below.
4.	Helicopter size restrictions	It is not feasible to only allow specific types of helicopter to service RPA. Most aeromedical fleets employ AW139 as their standard aerial medical helicopter. See discussion below.
5.	Approach and departure paths restrictions	The approach and departure path of helicopters are determined by the helicopter pilot accounting safety and environmental conditions. See discussion below.

The following outlines understanding of key considerations in justifying the current helipad location, with additional discussion regarding the assessment.

Item 3: Helicopter landing site analysis

The temporary HLS location was selected after considering multiple options during the preliminary design stage. SLHD, NSW Air Ambulance, NETS and Toll were consulted during the location selection process. This HLS location is deemed the most feasible due to the following considerations:

- The site offers at least two approach and departure paths only slightly greater than the desired maximum angle of 2.6 degrees
- Existing features in place such as concrete hardstand, floodlights, electrical reticulation, fire hydrants
- Minimal disturbance required to flora and fauna

Of the other locations considered:

- Alternate location 1 (St John’s Oval):

- Is the current back-up location
- Is located on University of Sydney land and regular use could result in disruption of games or closure of the sports field
- Has an unsuitable surface for a permanent HLS

- Alternate location 2 (empty lot to the south of the multi-storey car park) :
    - Is also close to residential receivers (approx. 50 m)
    - Requires some clearing of vegetation
    - Has no electrical reticulation
    - The two approach and departure paths greatly exceed the desired maximum angle of 2.6 degrees.

In regard to impacts on the Naamuru Parent and Baby Unit, it is noted that there are only eight bedrooms in the facility. The temporary relocation of the HLS will result in a reduction of noise exposure for a greater number of vulnerable patients within the RPAH main building.

Item 4: Design helicopter

As noted previously, the helicopter noise impact analysis in this report used a similar sized helicopter (SA330J) for noise modelling rather than the actual Design Helicopter (AW139) due to limitations of the noise database within the AEDT software. Section 5.4.4.1 outlines why the AW139 is expected to be quieter than the SA330J.

Item 5: Approach and departure paths

The helicopter noise assessment has been based on the worst-case flight paths affecting receiver R3. Maximising the use of southeast and southwest approach/departure paths shown in Figure 6 will aid in reducing noise impact to receiver R3.

It is understood that the four flight paths shown in Figure 6 are not mandatory for all approaches / departures and that the approach and departure paths would be ultimately determined by the helicopter pilot considering safety and environmental conditions.

As noted in Avipro’s Concept Design Report Part E3,

The average, annual prevailing winds for Sydney Airport will be broadly representative of the winds that will be experienced at RPAH. They can be very variable across the day and for this reason, having a number of possible approach and departure directions is not only desirable but mandatory. This is achievable. The four paths [mentioned above] are not finite. There is an additional path to the South-East that could be used in good visibility (there is a large chimney in that direction). In the mornings, approaches and departures would, ideally, be flown into the north-east, and very occasionally into the south-west.

5.4.5 Helicopter noise – HLS on roof of east building

Allowance is being made for a HLS on the roof of the new East building, approximately 85 m to the northeast of the existing HLS.

It has not yet been decided whether the existing HLS will be decommissioned after the works have been completed or whether pilots would be able to choose which HLS to use.

Regardless, it is understood that there is no significant proposed change in helicopter flight paths / movements after works have been completed.

Table 21 shows the expected increase in noise levels at the most affected nearby receivers, for each helicopter movement at the proposed new HLS. Other nearby receivers are expected to experience no change in noise exposure or a reduction in noise exposure.

Table 21: Expected increase in noise levels for each helicopter movement at new HLS

Receiver	**Description**	**Expected increase in noise level, dB(A)**
R1	St. John’s College	1
E1	CreateSpace and Susan Wakil Health Building, University of Sydney	5
E2	Charles Perkins Centre, University of Sydney	3
A1	St. John’s Oval	2
A3	University Oval No. 1	9
H6	Centenary Institute	7

6 Construction noise and vibration

This assessment has been made with reference to the preliminary Construction Management Plan (CMP) by Lendlease [12]. The CMP will be further developed as the construction methodologies and processes are confirmed during the design development process. This assessment should be used to inform the proposed work practices and management measures contained in future iterations of the CMP.

6.1 Construction noise criteria – external receivers

6.1.1 Interim Construction Noise Guidelines

The ICNG provides recommended noise levels for airborne construction noise at sensitive land uses. The guideline provides construction noise management levels above which all feasible and reasonable work practices should be applied to minimise the construction noise impact. The ICNG works on the principle of a 'screening' criterion – if predicted or measured construction noise exceeds the ICNG levels then the construction activity must implement all 'feasible and reasonable' work practices to reduce noise levels.

The ICNG provides two methods for assessing construction noise, varying typically based on the project duration, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement of background noise levels for determination of noise management levels and prediction of construction noise levels. 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.

The size and scale of the works covered in this report and the indicative construction schedule warrant a quantitative assessment including prediction of construction noise levels. A preliminary screening quantitative assessment has been carried out, however, it is expected that a more detailed quantitative assessment be undertaken prior to commencement of works, to confirm mitigation and management processes.

6.2 City of Sydney Construction Code

City of Sydney (CoS) CBD Construction Code [13] nominates acoustic criteria to be achieved at the nearest nominated occupancy according to Table 22. Although CoS are not the approval authority for this development, the works do take place within the boundaries of the CoS Council. The ICNG, however, will be used to establish Noise Management Levels (NMLs) for these works.

Table 22: CoS Construction Code Criteria

Day	Time Zone	Category	Noise Criteria
Monday to Friday	00:00 – 0700 07:00 – 08:00 08:00 – 17:00 17:00 – 23:00 23:00 – 24:00	4 1 1 2 4	Background + 0 dBA Background + 5 dBA Background + 5 dBA + 5 dBA to be determined on a site basis Background + 3 dBA Background + 0 dBA
Saturday	00:00 – 0700 07:00 – 08:00 08:00 – 19:00 19:00 – 23:00 23:00 – 24:00	4 1 1 2 4	Background + 0 dBA Background + 5 dBA Background + 5 dBA + 5 dBA to be determined on a site basis Background + 3 dBA Background + 0 dBA
Sunday and Public Holidays	00:00 – 0700 07:00 – 17:00 17:00 – 24:00	4 3 4	Background + 0 dBA Background + 3 dBA Background + 0 dBA

6.2.1 Management levels

The ICNG sets out management levels for noise at noise sensitive receivers, and how they are to be applied. These noise management levels (NMLs) for residential receivers and other sensitive receivers are reproduced in Table 23 and in Table 24 respectively.

Table 23: Construction noise management levels (NMLs) at residential receivers

Time of day	NML[1] $L_{Aeq\ (15\ min)}$	How to apply
Recommended standard hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm 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 $L_{Aeq\ (15\ min)}$ 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.

Time of day	NML[1] $L_{Aeq\ (15\ min)}$	How to apply
	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: 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 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.

Notes:

1. 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 24: Construction noise management levels (NMLs) at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq(15\ min)}$[1]
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)

Land use	Where objective applies	Management level $L_{Aeq(15\ min)}$[1]

Notes:

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

For work within standard construction hours, if after implementing all 'feasible and reasonable' noise levels the site still exceeds the noise affected level, the ICNG does not require any further action – since there is no further scope for noise mitigation.

For out-of-hours work, the ICNG uses a noise level 5 dB above the noise-affected level as a threshold where the proponent should negotiate with the community. While there is no 'highly-noise affected level' outlined in the ICNG for out-of-hours work, this report adopts the terminology where the construction noise level is 5 dB above the noise affected level for residential receivers.

6.2.2 Project construction noise targets

Based on the measured background noise levels presented in Table 3 and the criteria methodology presented above, Table 25 outlines the construction noise management levels applicable to demolition, excavation and construction.

Table 25: Construction noise management levels (NMLs)

Receiver	Where objective applies	Noise management level, dB$L_{Aeq(15\ min)}$			
		Standard hours[1]		Outside standard hours[2]	
		Noise affected	Highly noise affected	Noise affected	Highly noise affected
R1, R3[3]	External	62	75	54	59
R2	External	61	75	55	60
E1, E2, E3	Internal External[4]	45 55	-	45 55	-
A1, A2, A3	External	65	-	65	-
C1, C2, C3, C4	External	70	-	70	-
SS, H1, H2, H3, H4, H5, H6, H7	Internal External[4]	45 55	-	45 55	-

Notes:

1. Monday to Friday 7 am to 6pm; Saturday 8am to 1pm; Sunday and Public Holidays no work
2. Noise management level based on night period (i.e. 10 pm to 7 am) background noise level
3. Criteria for R3 based on RBL measured at L1
4. External noise level based on an assumed 10dB reduction through open window

6.3 Construction noise criteria – internal receivers

Managing construction noise and vibration within an occupied building is challenging. There is no standard guidance or code for managing construction noise and vibration impact to internal spaces, and there is no ideal approach that reliably avoids construction noise disturbance to building occupants without significantly impeding progression of works.

Effective management of construction noise and vibration to internal spaces is not as simple as setting criteria, monitoring levels, and implementing mitigation measures when criteria is exceeded. Noise sensitivity is subjective; exceeding standard criteria does not necessarily constitute disturbance. In addition, achieving set criteria is not always practicable.

Setting criteria that appropriately accounts for the varying characteristics of construction noise (i.e. short term impulsive events or more constant lower-level sources) is also complex. In addition, the use of monitors to measure exposure in occupied spaces is often not representative of the construction activity, as exceedances may be easily triggered by non-construction sources (particularly people and noise-generating equipment at the monitoring location). Furthermore, it may be impractical to comply with the preferred criteria, which if imposed, may unduly prohibit works from occurring.

It is recommended that the approach to managing internal noise (as outlined in the Construction Noise and Vibration Management Plan (CNVMP)) should aim to identify actual noise disturbance via effective complaint communication processes, instead of relying on noise level criteria.

Further details regarding the management of internal noise levels are discussed in Sections 6.9.2 and 6.12.4.

6.4 Construction noise criteria – highly sensitive receivers

Continuous noise monitoring will take place within the nominated highly sensitive spaces of concern for the duration of the works. Highly sensitive spaces may be located within the main hospital building or within other buildings in the surrounding area (for example, animal houses).

Noise monitoring methodology is outlined in Section 6.12.6.

Receivers which are considered highly sensitive to noise include:

- Animal houses

Given the unique noise level requirements for animal facilities and lack of published noise criteria in AS 2107:2016 specific to animal houses, we consider it most appropriate to cite multiple sources for establishing criteria.

Arup have reviewed the following documents that are directly relevant to noise impacts on animals:

- *Australian code for the care and use of animals for scientific purposes* (2013)
- US National Institutes of Health *Design Requirements Manual*

- UK *Code of Practice for the Housing and Care of Animals Used in Scientific Procedures* (1996).

We understand that the animal facilities of concern contain rodents, pigs and baboons.

The primary noise objective with rodent animal facilities is to control the impact of short-term noise sources that are significantly higher than the ambient noise level in the facility, as this can potentially result in severe behavioural issues with rodents. At this stage, it is believed that adopting a similar noise criteria for pig and baboon animal houses is a suitable conservative approach; this will be verified by Arup prior to commencement of noise monitoring.

Based on Arup's experience in assessing impacts on rodent animal facilities, we consider the criteria nominated in Table 26 to be appropriate.

Table 26: Preliminary noise management levels for animal houses

Receiver type	**Noise Management Level**
Animal houses	50 dB $L_{Aeq,15min}$ 65 dB L_{Amax}

Arup have found that, in practice, baseline noise levels within animal houses are sometimes much higher than those specified in Table 26. This can lead to frequent "false alarms". Therefore, suitable noise management levels for each animal house of concern will be established prior to the commencement of construction work. Baseline noise levels should be measured to inform the establishment of appropriate criteria.

6.5 Construction noise criteria - traffic

Increased traffic generated on the surrounding road network due to the construction activities of the RPAH redevelopment is assessed in accordance with the NSW *Road Noise Policy* (RNP) [8]. Table 3 of the RNP, which sets out the assessment criteria for types of project, road category and land use, shown in Table 27 below.

Table 27: Road traffic criteria for traffic generating development – residential receivers.

Road category	**Type of project / land use**	**Assessment criteria – dBL_{Aeq}**	
		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)

Note:
These criteria are for assessment against façade corrected noise levels 1 metre in front of a building façade.

Regarding the application of the assessment, the RNP states:

In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

6.6 Construction vibration criteria

6.6.1 Disturbance to building occupants

Potential vibration disturbance to human occupants of buildings is made in accordance with the NSW DEC Guideline [3]. The criteria outlined in the guideline is based on BS 6472-1992 [14]. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent', as described in Table 28.

Table 28: Types of vibration – Definition

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).
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.

Table 29 reproduces the ‘Preferred’ and ‘Maximum’ values for continuous and impulsive vibration from Table 2.2 of the Guideline.

Table 29: Preferred and maximum vibration acceleration levels for human comfort, m/s^2

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
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

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
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 specified above. Alternative criteria are outside the scope of the policy and other guidance documents should be referred to.

Table 30 reproduces the ‘Preferred’ and ‘Maximum’ values for intermittent vibration from Table 2.4 of the Guideline.

Table 30: Acceptable vibration dose values (VDV) 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

6.6.2 Criteria for highly sensitive receivers

Continuous vibration monitoring will take place within the nominated highly sensitive spaces of concern for the duration of the works. Highly sensitive spaces may be located within the main hospital building or within other buildings in the surrounding area (for example, animal houses).

Vibration monitoring methodology is outlined in Section 6.12.6.

Receivers which are considered highly sensitive to vibration include:

- Animal houses
- Spaces housing highly sensitive equipment, in particular (but not limited to):
  - High-resolution imaging equipment, such as MRI machines, CT scanners, cyclotrons and X-ray machines
  - High magnification microscopy equipment (including optical and electron microscopes)
  - Buildings housing sensitive computer or telecommunications equipment may also require assessment against stricter criteria than those nominated for building damage or human comfort.

Animal houses

At this stage, it is believed that adopting a similar vibration criteria for all animal houses is a suitable conservative approach; this will be verified by Arup prior to commencement of vibration monitoring.

Vibration levels have been shown to affect stress hormone levels, weight, and pregnancy in rats and mice and may induce mothers to cannibalise their pups. Genetic research requires relatively uninterrupted breeding over several generations so that loss of animals can have a very significant impact on research.

Until recently little guidance was available in codes of practices for animal research facilities, although the adverse impact of high vibration levels were noted. The US guideline National Institutes of Health Guideline “Design requirements manual for NIH Biomedical and Animal Research Facilities” published in 2010 does provide some recommended vibration limits for the design of animal houses which are now being more widely adopted.

Table 31: US NIH Guideline Vibration Design Criteria for Normal Use

Location	Criteria
Animal House General	0.1mm/s [similar to Curve 1 AS2670.2]
Animal Behaviour and Holding Rooms	0.05mm/s [similar to Curve VC-A AS2670.2]

Based on Arup’s previous project experience and using the latest NIH guidance, we are proposing the following vibration criteria for the animal houses. Given that other laboratory spaces in the RPA campus are equally or more sensitive than the animal house this criterion should not further limit construction activities.

Table 32: Proposed animal house construction vibration criteria

Location	Criteria
Animal House	Curve 1 Australian Standard AS2670.2

	(3rd octave band RMS velocity < 0.1mm/s) AND Transient peak velocity to be below 1.0mm/s

Sensitive equipment

An investigation of all vibration sensitive equipment and locations of animal houses should take place during development of the detailed Construction Noise and Vibration Management Plan.

Suitable noise and vibration criteria will be established prior to the commencement of construction work. Baseline noise and vibration levels should also be measured to inform the establishment of appropriate criteria.

While the acceptable vibration levels for such equipment are recommended to be obtained from the instrument manufacturers, generic criteria such as the ASHRAE Vibration Criteria for Vibration Sensitive Equipment (VC-curves) can be adopted for planning purposes.

6.6.3 Structural damage

6.6.3.1 Definition

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard 7385 Part 2 [4] and/or German Standard DIN4150-3 [5]. British Standard 7385 Part 1: 1990, defines different levels of structural damage as:

- *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.*

Table 1 of British Standard 7385 Part 2 (1993) sets limits for the protection against cosmetic damage, however the following guidance on 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, 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', the description aligns with BS7385 cosmetic damage, rather than referring to structural failures.

6.6.3.2 British standard BS7835-2

BS7385-2 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4–250 Hz, and a maximum displacement value below 4 Hz is recommended. Table 33 sets out the BS7385 criteria for cosmetic, minor and major damage.

Table 33: BS7385-2 structural damage criteria

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

Notes:

1. 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.
2. Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

All levels relate to transient vibrations in low-rise buildings.

Continuous vibration can give rise to dynamic magnifications that may require levels to be reduced by up to 50%. Activities considered to have the potential to cause dynamic loading in some structures (e.g. residences) include rock breaking/hammering and sheet piling activities. On the basis that the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range) a conservative vibration damage screening level per receiver type is given below:

- Reinforced or framed structures: 25.0 mm/s PCPV
- Unreinforced or light framed structures: 7.5 mm/s PCPV

At locations where the predicted and/or measured vibration levels are greater than above, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

6.6.3.3 German standard DIN 4150

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure'* [5] are generally recognised to be conservative and is often referred to for the purpose of assessing structurally sensitive buildings.

Heritage buildings and structures should not be assumed to be more sensitive to vibration unless they are found to be structurally unsound and should otherwise be assessed in accordance with BS7385-2. If a heritage building or structure is found to be structurally unsound (following inspection) DIN 4150-3 line 3, as outlined in Table 34, provides a conservative cosmetic damage objective that should be adopted unless alternative limits are justified by a dilapidation or structural survey. The sensitivity of heritage buildings and other potentially at-risk structures are subject to confirmation by the contractor prior to start of any works.

Table 34: DIN 4150-3 structural damage guideline values

Line	Type of structure	Peak component particle velocity (PCPV), mm/s				
		Vibration at the foundation at a frequency of			At horizontal plane of highest floor	In the vertical direction, at floor slabs
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz[1]	All frequencies	All frequencies
3	Structures that because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (e.g. listed buildings under a preservation order)[3]	3	3 to 8	8 to 10	8	20[2]

Line	Type of structure	Peak component particle velocity (PCPV), mm/s				
		Vibration at the foundation at a frequency of			At horizontal plane of highest floor	In the vertical direction, at floor slabs
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz[1]	All frequencies	All frequencies

Notes:

1. At frequencies above 100 Hz, the values given in this column may be used as minimum values.
2. Guideline value might have to be lowered to prevent minor damage
3. Line 1 refer to buildings used for commercial purposes, industrial buildings and buildings of similar design, while Line 2 refers to residential buildings and buildings of similar design and/or occupancy

6.6.4 Buried services

Proposed works are not expected to impact upon buried services.

DIN 4150-2:1999 sets out guideline values for vibration effects on buried pipework (see Table 35).

Table 35: Guideline values for short-term vibration impacts on buried pipework

	Pipe material	Guideline values for vibration velocity measured on the pipe, mm/s
1	Steel (including welded pipes)	100
2	Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
3	Masonry, plastic	50

Notes:

For gas and water supply pipes within 2m of buildings, the levels given in DIN4150-3 [5] should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

In addition, specific limits for vibration affecting high-pressure gas pipelines is provided in the UK National Grid's *Specification for Safe Working in the Vicinity of National Grid High Pressure Gas Pipelines and Associated Installations – Requirements for Third Parties* (report T/SP/SSW/22, UK National Grid, Rev 10/06, October 2006). This specification states that no piling is allowed within 15 m of a pipeline without an assessment of the vibration levels at the pipeline. The PPV at the pipeline is limited to a maximum level of 75 mm/s, and where PPV is predicted to exceed 50 mm/s the ground vibration is required to be monitored.

Other services that maybe encountered include electrical cables and telecommunication services such as fibre optic cables. While these may sustain vibration velocity levels from between 50 mm/s and 100 mm/s, the connected services such as transformers and switchgear, may not. Where encountered, site specific vibration assessment in consultation with the utility provider should be carried out.

6.6.5 Decantation of highly sensitive equipment

If there is an intention to relocate highly sensitive equipment (such as MRIs) to different existing floors during the works, a vibration assessment of the existing floors must be undertaken to determine whether they are suitable.

6.7 Construction stages and activities

As detail of the construction noise equipment/plant to be used is not known at the time, assumptions have been made based on sources normally found on similar construction sites.

Figure 7 and Figure 8, taken from the Preliminary Construction Management Plan prepared by Lendlease [12] show the primary locations of works. Other locations of works are:

- Ambulance bay works along Missenden Road
- Temporary HLS works (at location shown in Figure 2 – works expected to take place from May 2023 – October 2023)

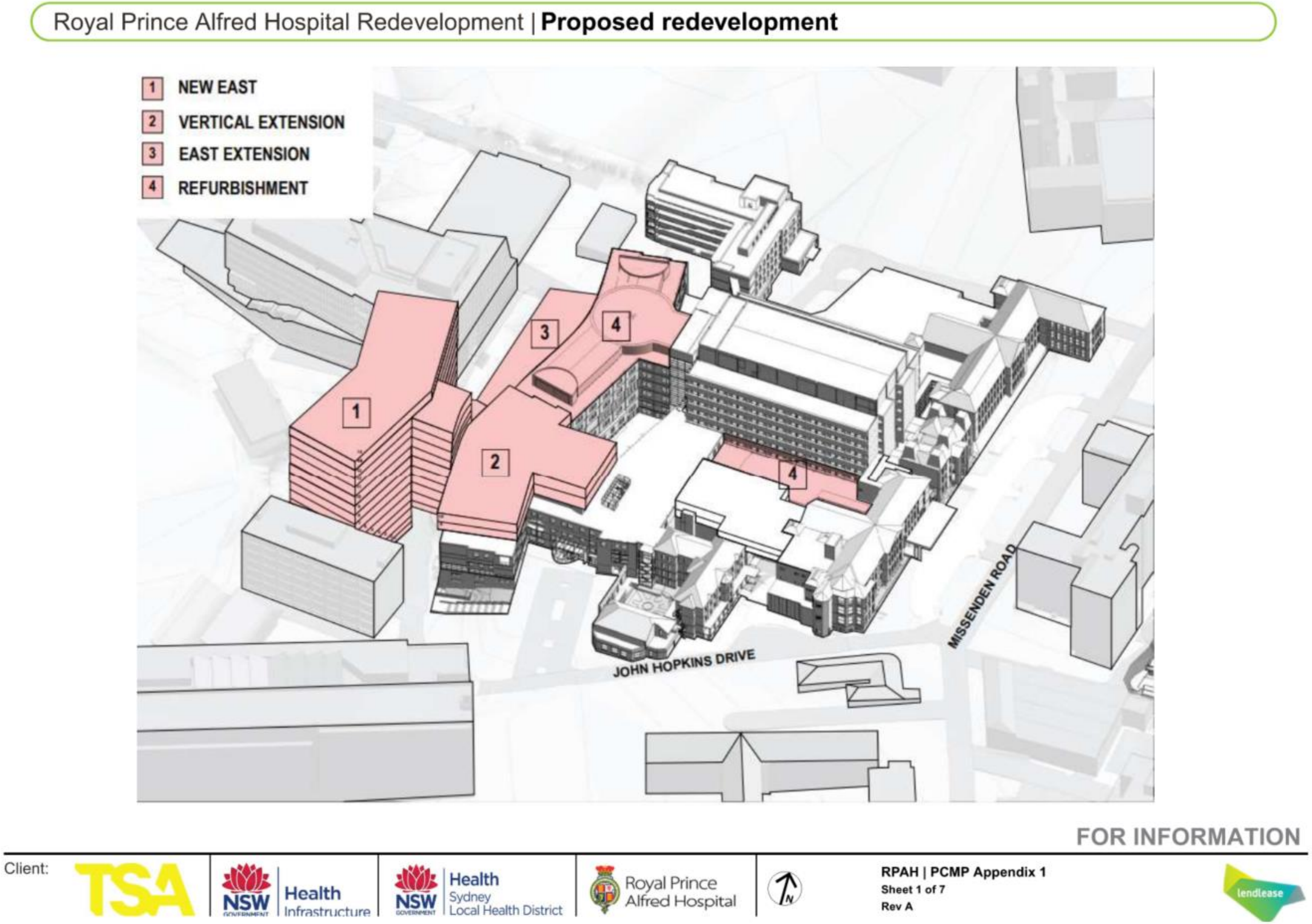

Figure 7: Locations of proposed redevelopment [12]

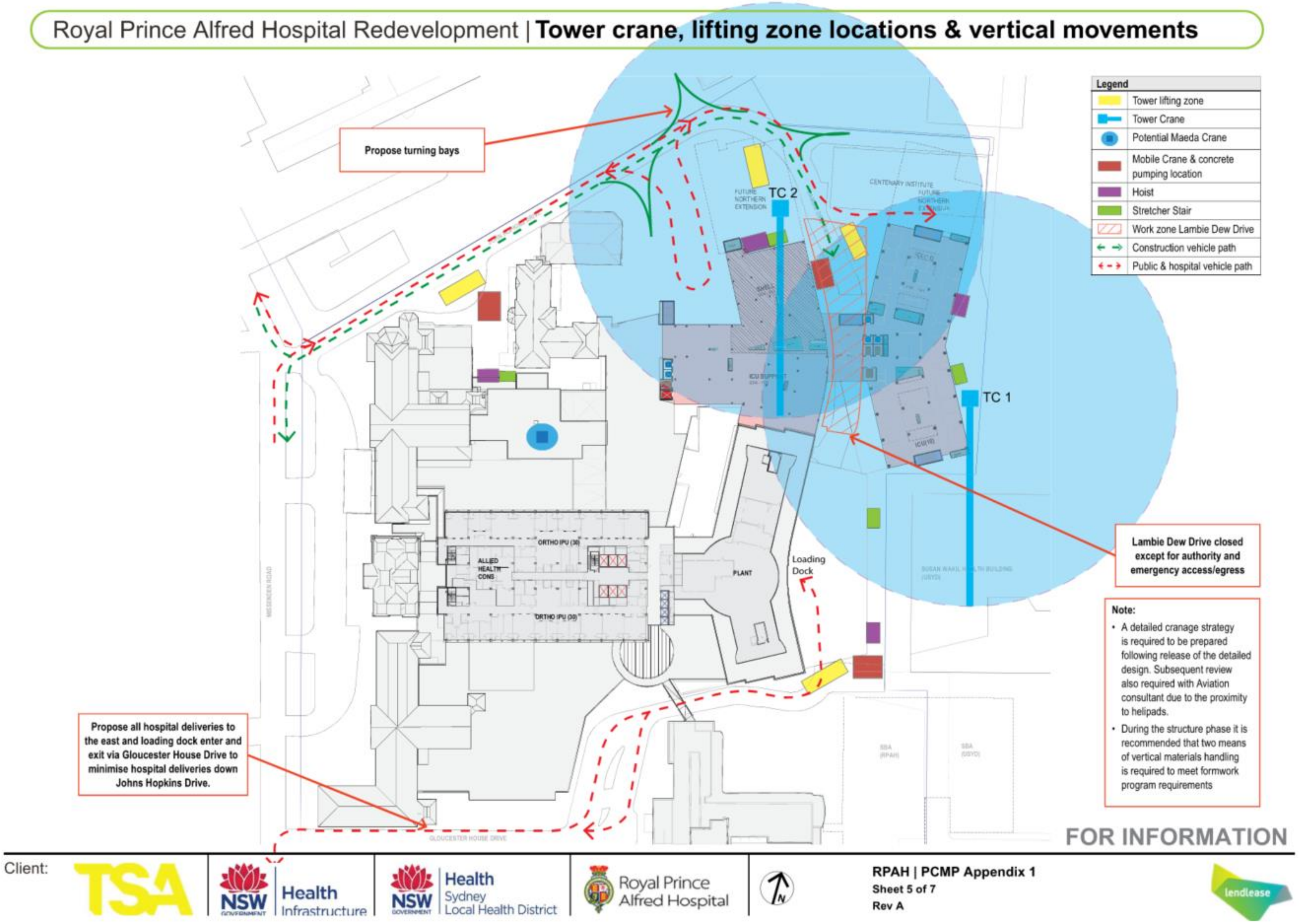

Figure 8: Locations of cranes and lifting zones [12]

Table 36 gives a high-level outline of the general stages of work, an outline of the expected construction activities and the anticipated airborne noise levels for indicative plant items. The list has been informed by the preliminary CMP.

The detailed CMP (which will be prepared by the appointed contractor post-SSDA) will need to be reviewed by an acoustic consultant, especially in relation to potential impacts on highly noise and vibration sensitive receivers (including imaging equipment); alternative construction equipment with lower noise or vibration emissions may be necessary.

Equipment sound power levels (L_w) have been sourced from AS2436 – 2010 Guide to noise and vibration control on construction, demolition and maintenance sites. It should be noted that during the different construction stages, it is unlikely that all machinery would be operating at the same time (like the modelling assumes), but taking a 'worse-case' scenario approach helps to identify where noise impacts could be a concern and assists in the design of mitigation measures.

The works involve:

- Demolition, construction and fit-out works within the main hospital building, including the addition of extensions to the east and north and ambulance bay works to the west
- Construction and fit-out of a new building to the east of the existing hospital
- Demolition of affected buildings, structures and trees
- Road works, including realignment and paving works
- Landscaping
- Construction of temporary helipad (and necessary services) on roof of the multi-storey car park to the west of the main hospital building

As the refurbishment works affect internal receivers only, a quantitative assessment is not provided. Discussion of impacts on internal receivers is covered in Section 6.9.2.

It is emphasised that all the equipment listed in Table 36 is not expected to operate continuously for 15-minutes and concurrently. A conservative adjustment for duration has been applied in the predicted construction noise levels. The adjustment assumes each item of equipment operates for 75% of the 15-minute assessment period. The time-adjusted levels are also shown in Table 36.

Table 36: Summary of works, noise generating activities and indicative plant items

Project scope item	Significant noise generating activity	Indicative plant items	Sound power level (per unit), dBL_{Aeq}	Time-adjusted sound power level (per unit), dBL_{Aeq}
East extension, New east wing	Demolition works, construction works, piling, waste and tree removal	Compactor	120[1]	119[1]
		Concrete pump truck	113	112
		Concrete saw[2]	122	121
		Crane (Franna)	98	97
		Crane (Mobile)	113	112
		Handheld tools – electric	110	109
		Grader	115	114
		Jack Hammer[2]	126[1]	125[1]
		Bulldozer	114	113
		Excavator tracked (hydraulic) – 30t[2]	122	121
		Front end loader	112	111
		Dump truck	117	116
		Chainsaw 4-5hp	114	113
		Tub grinder/mulcher 40-50hp	116	115
		Piling rig (impact)[2]	134[1]	133[1]
		Rock breaker[2]	118	117
		Trucks (misc.) x2	107	106
		Vibratory roller	112	112
Vertical extension	Demolition works, construction works, removal of waste	Compactor	120[1]	119[1]
		Concrete pump truck	113	112
		Concrete saw[2]	122	121
		Crane (Franna)	98	97
		Crane (Mobile)	113	112
		Handheld tools – electric	110	109
		Grader	115	114
		Jack Hammer[2]	126[1]	125[1]
		Bulldozer	114	113
		Excavator tracked (hydraulic) – 30t[2]	122	121
		Front end loader	112	111
		Dump truck	117	116
		Piling rig (impact)[2]	134[1]	133[1]
		Rock breaker[2]	118	117
		Trucks (misc.) x2	107	106
		Vibratory roller	112	112

Project scope item	Significant noise generating activity	Indicative plant items	Sound power level (per unit), dBL_{Aeq}	Time-adjusted sound power level (per unit), dBL_{Aeq}
Lambie Dew Drive realignment	Excavation of road Road works Excavation and diversion of underground services	Pavement profiler Pavement laying machine Front end loader Generator (diesel) Dump truck Smooth drum roller Asphalt truck and sprayer Backhoe Bulldozer Concrete saw[2] Excavator tracked (hydraulic) – 30t[2] Jack Hammer[2] Franna crane Vacuum truck	117 114 112 113 117 107 107 108 114 122 122 126[1] 98 109	116 113 111 112 116 106 106 107 113 121 121 125[1] 97 108
Temporary HLS	Demolition works, construction works, removal of waste	Concrete pump truck Concrete saw[2] Crane (Franna) Crane (Mobile) Generator (diesel) Handheld tools – electric Jack Hammer[2] Dump truck	113 122 98 113 113 110 126[1] 117	112 121 97 112 112 109 125[1] 116
Ambulance bay	Construction works, removal of waste	Angle grinder Handheld tools – electric x 2 Dump truck	108 110 (each) 117	107 109 (each) 116

Notes:

1. Includes 5 dB penalty for impulsive characteristic
2. Equipment considered to have a “High noise impact” - not included in OOHW assessment

6.8 Construction hours

6.8.1 Out of hours works

Extension of Saturday working hours in line with CoS Construction Code

In addition to the ICNG [3] recommended standard construction hours and in line with "Category 1" working hours in the CoS Construction Code (outlined in Table 22), approval is being sought to extend Saturday construction hours for the following:

- All east campus works:
  - Vertical extension
  - East extension
  - New east wing
  - Ambulance bay works
  - Lambie Dew Drive
  - Refurbishment works

No general extension of hours is sought for the temporary HLS works.

Proposed typical hours of works are presented in Table 37.

Table 37: Proposed standard construction hours

Day	Standard construction hours	Proposed construction hours
Monday to Friday	7 am to 6 pm	7 am to 6 pm
Saturday	8 am to 1 pm	7 am to 7 pm[1]
Sunday and public holiday	No work	No work

Notes:

1. No "high" noise works (demolition, excavation and piling) are proposed outside of the standard ICNG Construction Hours. No temporary HLS works are proposed outside of the standard ICNG Construction Hours.

Out-of-hours refurbishment works

The proposal would seek to conduct out-of-hours fit-out and refurbishment works, as long as the works are being conducted indoors, with base building works completed and no openings / open windows / open doors in the façade near where the works are being conducted.

Other ad hoc out-of-hours works

In addition to the above, it is understood that essential out-of-hours works (OOHW) will likely be required from time to time in order to minimise impact on staff and patients in the hospital.

Approval for ad hoc OOHW is not being sought at this time; approval for these works will be sought on a case-by-case basis as the need arises. Arup recommends that approval be granted for OOHW which cannot take place during standard hours, including demolition works where deemed absolutely necessary.

6.8.2 Justification for extension to operating hours on Saturdays

Given that the site is located within the boundaries of the CoS Council, it is proposed that OOHW could be conducted in accordance with Category 1 working hours as outlined in Table 37. It is also noted that slightly longer hours will shorten the construction duration for an essential service site.

Arup recommends that approval be granted for the extension to operating hours and noted in Table 37, on the condition that high noise impact activities are avoided. In particular, the following activities are excluded:

- Demolition works
- Excavation works
- Piling

A preliminary construction noise assessment for these works is included in Table 38.

6.8.3 Justification for OOH refurbishment and fit-out works

It is noted that approval is generally granted for works to occur outside of standard project construction hours, where there is considered to be a minimal noise impact upon external sensitive receivers, and indoor fit-out and refurbishment would typically meet this criteria.

The contractor is to use discretion when carrying out these OOHW, and avoid using louder plant where it may pose a disruption to nearby external receivers.

As these proposed works are not expected to impact external receivers, a quantitative construction noise assessment is not warranted. The contractor should, however, consider impacts to internal receivers on a case-by-case basis in consultation with HI.

6.9 Construction noise predictions

6.9.1 Noise assessment – external receivers

Predicted construction noise levels, considering standard construction hours and outside standard construction hours, are tabulated in Table 38. Noise levels have been compared to the receiver's relevant Noise Management Level and exceedances have been highlighted.

The magnitude of construction noise impacts is dependent upon several aspects including the intensity, location of activities and the type of equipment used during the construction period. Based on these factors, the predicted construction noise levels are generally conservative and do not represent a constant noise emission that would be experienced by the community on a daily basis throughout the project construction period. The predicted noise levels would only be experienced for limited periods of time when works are occurring and should not be experienced for full daytime or night-time periods.

It is not known at this time where trucks would park during the works. In this preliminary assessment, trucks are included within the general area of works, where noted in Table 36.

Assumed distances from the location of works to nearby sensitive receivers are given in Appendix B.

Table 38: Predicted noise levels at nearest affected off-site receiver locations

Receiver	NML, dBL$_{Aeq(15\ min)}$		Predicted sound level at receiver, dBL$_{Aeq(15\ min)}$				
	Noise affected	Highly noise affected	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay
During standard hours							
R1	62	75	86	108	84	74	57[3]
R2	61	75	81	86	82	57[3]	53[3]
R3	62	75	77	86	55[3]	102	64
E1	45[1]	-	116[2]	95[2]	75[2]	43[2,3]	40[2,3]
E2	45[1]	-	84[2]	102[2]	63[2]	59[2]	40[2,3]
E3	45[1]	-	55[2,3]	65[2,3]	55[2,3]	70[2]	43[2,3]
A1	65	-	86	93	85	55[3]	49[3]
A2	65	-	84	90	85	53[3]	49[3]
A3	65	-	106	89	78	52[3]	49[3]
C1	70	-	86	108	60[3]	74	76
C2	70	-	83	112	57[3]	78	81
C3	70	-	79	88	58[3]	95	68
C4	70	-	63[3]	83	58[3]	74	48[3]
H1	45[1]	-	71[2]	102[2]	50[2,3]	65[2]	60[2]
H2	45[1]	-	73[2]	90[2]	50[2,3]	69[2]	64[2]
H3	45[1]	-	71[2]	80[2]	47[2,3]	75[2]	42[2,3]
H4	45[1]	-	67[2]	58[2,3]	48[2,3]	59[2]	37[2,3]
H5	45[1]	-	69[2]	80[2]	48[2,3]	67[2]	58[2]
H6	45[1]	-	116[2]	77[2]	110[2]	58[2]	40[2,3]
H7	45[1]	-	70[2]	61[2,3]	48[2,3]	88[2]	45[2,3]
SS	45[1]	-	-[5]	-[5]	110[2]	63[2]	100[2]

Receiver	NML, dBL$_{Aeq(15 min)}$		Predicted sound level at receiver, dBL$_{Aeq(15 min)}$				
	Noise affected	Highly noise affected	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay
Outside standard hours (extended Saturday hours)[4]							
R1	54	59	76	96	77	-[6]	57[3]
R2	55	60	70	74	76	-[6]	53[3]
R3	54	59	66	75	49[3]	-[6]	64
E1	45[1]	-	106[2]	83[2]	68[2]	-[6]	40[2,3]
E2	45[1]	-	73[2]	91[2]	56[2]	-[6]	40[2,3]
E3	45[1]	-	44[2,3]	53[2,3]	49[2,3]	-[6]	43[2,3]
A1	65	-	75	81	78	-[6]	49[3]
A2	65	-	73	78	78	-[6]	49[3]
A3	65	-	96	78	71	-[6]	49[3]
C1	70	-	76	96	54[3]	-[6]	76
C2	70	-	73	101	51[3]	-[6]	81
C3	70	-	69	76	51[3]	-[6]	68
C4	70	-	53[3]	72	51[3]	-[6]	48[3]
H1	45[1]	-	60[2]	91[2]	43[2,3]	-[6]	60[2]
H2	45[1]	-	62[2]	78[2]	43[2,3]	-[6]	64[2]
H3	45[1]	-	60[2]	68[2]	41[2,3]	-[6]	42[2,3]
H4	45[1]	-	57[2,3]	46[2]	42[2,3]	-[6]	37[2,3]
H5	45[1]	-	59[2]	68[2]	41[2,3]	-[6]	58[2]
H6	45[1]	-	106[2]	65[2]	104[2]	-[6]	40[2,3]
H7	45[1]	-	60[2,3]	50[2]	42[2,3]	-[6]	45[2,3]
SS	45[1]	-	-[5]	-[5]	104[2]	-[6]	100[2]

Receiver	NML, $dBL_{Aeq(15\ min)}$		Predicted sound level at receiver, $dBL_{Aeq(15\ min)}$				
	Noise affected	Highly noise affected	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay

Notes:

1. Internal noise level
2. Predicted sound pressure level includes -10 dB adjustment accounting for external-to-internal noise reduction (assuming window partially open)
3. Predicted sound pressure level includes -15 dB adjustment accounting for shielding from buildings / changing terrain height
4. Assessment assumes that excavation, demolition and piling works are not being undertaken out of hours, as per Section 6.8.2. Plant items excluded from the assessment are denoted in Table 36
5. Refer to Section 6.9.2 for assessment of internal receivers
6. Out of hours works are not proposed for the temporary HLS

(green)	Predicted sound pressure level ≤ noise affected level
(orange)	Noise affected level < predicted sound pressure level ≤ highly noise affected
(red)	Highly noise affected < predicted sound pressure level

Results show that construction noise is predicted to exceed ‘noise affected’ levels during standard hours and outside standard hours for most receivers, with residential receiver R1, R2 and R3 predicted to be “highly noise affected” for works during standard hours and outside standard hours.

It is reiterated that the predictions represent an expected worst-case scenario and that noise mitigation measures could be undertaken to further mitigate the impact on nearby receivers.

Temporary HLS works are expected to take place over a relatively short period (~5 months) compared to the other locations of works.

In general, construction works are temporary in nature therefore potential noise impact on the community and the surrounding environment will not be permanent or continuous. However, where the predicted $L_{Aeq(15min)}$ noise level is greater than the noise management levels all feasible and reasonable work practices should be applied, however it is unlikely mitigation measures would reduce the received noise levels below the noise management levels in all cases.

Feasible and reasonable work practices vary depending on the nature of the works, site restrictions and equipment used. It is recommended that all *feasible and reasonable* measures to reduce noise impact associated with the construction works be implemented. Examples of suggested measures are provided in Table 39. Noise management practices are also discussed generally in Section 6.12.

Table 39: Preliminary *feasible and reasonable* work practices

Location of works	**Preliminary *feasible and reasonable* work practices**
New east wing Vertical extension Eastern extension Refurbishment works	• Use low-noise construction equipment and/or methods where possible (in particular for piling) • Turn off plant and equipment when not in use • Locate stationary plant (concrete pumps, air-compressors, generators, etc.) as far away as possible from sensitive receivers • Use site sheds and other temporary structures or screens/hoarding to limit noise exposure where possible • Seal openings in the building (temporary or permanent) prior to commencement of internal works to limit noise emission where possible

Location of works	Preliminary *feasible and reasonable* work practices
Lambie Dew Drive Realignment Temporary HLS Ambulance bay	• Use low-noise construction equipment and/or methods where possible • Turn off plant and equipment when not in use • Locate stationary plant (concrete pumps, air-compressors, generators, etc.) as far away as possible from sensitive receivers • Use site sheds and other temporary structures or screens/hoarding to limit noise exposure where possible

6.9.2 Noise assessment – internal receivers

Noise impacts to receivers within the subject site are typically not assessed during project approval noise assessments. Nevertheless, a qualitative assessment of construction noise impacts on internal receivers is presented below.

The works will impact upon internal receivers within the subject site.

The wards, labs and administrative areas within the RPAH main building will remain occupied during the works.

Based on the equipment sound power levels in Table 36, it is expected that occupants of the RPAH main building may be “noise affected” during the course of the works (note that only residential receivers have a “highly noise affected” management level under the ICNG).

As noted in Section 6.3, managing construction noise within an occupied building is challenging.

Staff and management should be consulted during the development of the CNVMP to ensure that suitable noise management strategies (as outlined in Section 6.12.4), are implemented. The CNVMP should outline steps to minimise the impact on staff and patients as far as practicable.

Highly sensitive receivers require special consideration. Refer to Section 6.12.6 for a discussion of the noise and vibration monitoring methodology for these receivers.

6.10 Construction traffic noise assessment

It has been advised by the project team that an estimated 65 construction vehicles will be accessing the site throughout the day during the busiest period of construction of the main works. In the absence of more detailed information, it has been assumed that half of the construction vehicles would comprise of heavy construction vehicles. It is also assumed that all vehicles related to construction activity will be operating within standard construction hours.

Table 40 presents the projected existing day-time traffic volume of Missenden Road, along with the potential increase in traffic noise caused by the proposed construction activity.

Table 40: Construction traffic assessment due to roundabout construction

	Light vehicles	Heavy vehicles	Total
Projected existing Missenden Road volume (15-hour day)	8492	565	9058
Traffic generated by proposed construction works	33	32	65
Potential increase in traffic noise level due to development, dBA	**0.0**	**0.2**	**0.3**

From the predictions, the potential increase in the traffic noise level due to construction traffic is less than 2 dB. Therefore, the proposed construction traffic activity is considered to have a minor impact which not significantly affect the existing acoustic environment.

6.11 Construction vibration

6.11.1 Vibration – minimum working distances

Recommended minimum working distances for vibration intensive plant, which are based on international standards and guidance, are provided in Table 41. Minimum working distances are quoted for:

- Cosmetic damage (based on the British Standard 7385 [4])
- Human comfort (based on the DECCs 'Assessing Vibration; a technical guideline' [3])
- Unsound structures (based on German Standard DIN 4150 [5])

Table 41: Recommended minimum working distances for vibration intensive equipment

Plant item	Rating / description	Minimum working distance (m)			
		Cosmetic damage – screening criteria			Human response
		Industrial and heavy commercial buildings BS 7385 Line 1 - 25 mm/s (See note 1)	**Residential and light commercial buildings** BS 7385 Line 2 - 7.5 mm/s (See note 1)	**Structures unsound** DIN 4150 Line 3 - 3 mm/s	
Vibratory roller	< 50 kN (~ 1 to 2t)	2 m	5 m	11 m	15 m to 20 m
	< 100 kN (~ 2 to 4t)	2 m	6 m	13 m	20 m
	< 200 kN (~ 4 to 6t)	5 m	12 m	26 m	40 m

Plant item	**Rating / description**	**Minimum working distance (m)**			
		Cosmetic damage – screening criteria			**Human response**
		Industrial and heavy commercial buildings BS 7385 Line 1 - 25 mm/s (See note 1)	**Residential and light commercial buildings** BS 7385 Line 2 - 7.5 mm/s (See note 1)	**Structures unsound** DIN 4150 Line 3 - 3 mm/s	
	< 300 kN (~ 7 to 13t)	6 m	15 m	31 m	100 m
	> 300 kN (~ 13 to 18t)	8 m	20 m	40 m	100 m
	> 300 kN (> 18t)	10 m	25 m	50 m	100 m
Hydraulic hammer – Small	300 kg / 5 to 12t excavator	1 m	2 m	5 m	7 m
Hydraulic hammer – Medium	900 kg / 12 to 18t excavator	3 m	7 m	15 m	23 m
Hydraulic hammer – Large	1600 kg / 18 to 34t excavator	9 m	22 m	44 m	73 m
Piling – Vibratory	Sheet piles	9 m	22 m	44 m	73 m
Piling – Bored	≤ 800 mm	1 m (nominal)	2 m	5 m	10 m
Piling – Hammer	12t down force	6 m	15 m	30 m	50 m
Jackhammer	Hand-held	1 m (nominal)	1 m (nominal)	3 m	5 m

Note:

1. Where vibration might give rise to resonant responses in structures

6.11.2 Vibration assessment

The nearest off-site vibration sensitive receiver locations are presented in Table 42.

Table 42: Nearest off-site vibration receivers

ID	**Approx. distance from structure to location of works, m**				
	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay
R1	98	8	70	182	75
R2	190	104	82	240	120
R3	295	100	326	7	190
E1	1	12	61	360	170
E2	42	5	239	316	167

ID	Approx. distance from structure to location of works, m				
	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay
E3	214	68	105	92	116
C1	99	8	182	171	50
C2	141	5	260	113	26
C3	219	80	241	16	114
C4	252	146	242	179	203
H1	186	5	194	164	93
H2	147	20	189	104	57
H3	187	67	255	50	129
H4	280	148	229	335	250
H5	230	66	243	122	120
H6	1	95	1	349	173
H7	202	100	234	12	91
SS	0	0	1	196	1

The results of the construction vibration assessment are presented in Table 43, based on the working distances for the vibration-intensive plant listed in Table 41 and the approximate distances from each receiver to the location of works presented in Table 43.

Table 43: Vibration assessment

Receiver	Cosmetic Damage		Human Comfort	
	Receiver further than min. working distance?	**Equipment of concern**	**Receiver further than min. working distance?**	**Equipment of concern**
R1	No	• Hydraulic hammer – Medium & Large • Vibratory roller (> 100 kN) • Piling – Hammer & Vibratory	No	• Hydraulic hammer • Vibratory roller • Piling
R2	Yes	-	Yes	-
R3	Yes	-	Yes	-
E1	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer

Receiver	Cosmetic Damage		Human Comfort	
	Receiver further than min. working distance?	**Equipment of concern**	**Receiver further than min. working distance?**	**Equipment of concern**
E2	No	• Hydraulic hammer – Medium & Large • Vibratory roller • Piling – Hammer & Vibratory	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer
E3	Yes	-	No	• Hydraulic hammer – Large • Vibratory roller (> 200 kN) • Piling – Vibratory
C1	No	• Hydraulic hammer – Medium & Large • Vibratory roller (> 100 kN) • Piling – Hammer & Vibratory	No	• Hydraulic hammer • Vibratory roller • Piling
C2	No	• Hydraulic hammer – Medium & Large • Vibratory roller • Piling – Hammer & Vibratory	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer
C3	Yes	-	No	• Vibratory roller (> 200 kN)
C4	Yes	-	Yes	-

Receiver	Cosmetic Damage		Human Comfort	
	Receiver further than min. working distance?	**Equipment of concern**	**Receiver further than min. working distance?**	**Equipment of concern**
H1	No	• Hydraulic hammer – Medium & Large • Vibratory roller • Piling – Hammer & Vibratory	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer
H2	No	• Hydraulic hammer – Large • Vibratory roller (> 300 kN) • Piling – Vibratory	No	• Vibratory roller • Hydraulic hammer – Medium & Large • Piling – Hammer & Vibratory
H3	Yes	-	No	• Vibratory roller (>200 kN) • Hydraulic hammer – Large • Piling – Vibratory
H4	Yes	-	Yes	-
H5	Yes	-	No	• Vibratory roller (>200 kN) • Hydraulic hammer – Large • Piling – Vibratory
H6	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer
H7	Yes	-	Yes	-

Receiver	Cosmetic Damage		Human Comfort	
	Receiver further than min. working distance?	**Equipment of concern**	**Receiver further than min. working distance?**	**Equipment of concern**
SS	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer	No	• Hydraulic hammer • Vibratory roller • Piling • Jackhammer

Notes:

1. Red highlighted cells indicate an exceedance of criteria

In Table 43, the worst-case minimum working distances for vibratory rollers, piling equipment and hydraulic hammers have been assumed, which results in a very conservative assessment.

During development of the detailed Construction Noise and Vibration Management Plan an investigation of vibration impact upon existing buildings on the subject site and on all nearby sensitive receivers should take place, including an assessment of any vibration sensitive equipment that could possibly be impacted by the works.

6.12 Construction noise and vibration mitigation

Noise mitigation measures for each major construction activity are discussed in the following sections. These mitigation measures are considered to represent ‘feasible and reasonable’ mitigation measures suitable for implementation during construction of the project.

6.12.1 Construction noise and vibration management plan

For all construction works, the contractor would be expected to prepare a detailed Construction Noise and Vibration Management Plan (CNVMP). This plan should include but not be limited to the following:

- Roles and responsibilities
- Noise and vibration sensitive receiver locations
- Areas of potential impact
- Mitigation strategy
- Monitoring methodology
- Community engagement strategy.

General guidance on the control of construction noise and vibration impacts relevant to this study are discussed in the following sections.

6.12.2 General

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

- Adherence to the standard approved working hours as outlined in the Project Approval, i.e. only approved out-of-hours activities should occur outside of standard working hours.
- Manage noise from construction work that might be undertaken outside the recommended standard hours
- The location of stationary plant (concrete pumps, air-compressors, generators, etc.) as far away as possible from sensitive receivers
- Using site sheds and other temporary structures or screens/hoarding to limit noise exposure where possible.
- Sealing of openings in the building (temporary or permanent) prior to commencement of internal works to limit noise emission.
- The appropriate choice of low-noise construction equipment and/or methods
- Modifications to construction equipment or the construction methodology or programme. This may entail programming activities to occur concurrently where a noisy activity will mask a less noisy activity, or, at different times where more than one noisy activity will significantly increase the noise. The programming should also consider the location of the activities due to occur concurrently.
- Carry out consultation with the community during construction including, but not limited to; advance notification of planned activities and expected disruption/effects, construction noise complaints handling procedures. Note that while community consultation may be included in the Contractor's CNVMP; it is not required.

6.12.3 Universal work practices

The following noise mitigation work practices are recommended to be adopted at all times on site:

- Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise.
- Site managers to periodically check the site and nearby residences for noise problems so that solutions can be quickly applied.
- Avoid the use of radios or stereos outdoors.
- Avoid the overuse of public address systems.
- Avoid shouting and minimise talking loudly and slamming vehicle doors.
- Turn off all plant and equipment when not in use

6.12.4 Managing internal noise and vibration levels

There are pros and cons to relying upon internal criteria for management in the Project context.

Setting numeric criteria as a limit for construction works also necessitates confidence in the ability to comply with the set levels. Prediction of noise transfer through a building is far more difficult than an external environment. The contractor will ultimately need greater certainty that works can reasonably be undertaken.

For spaces which are not highly sensitive, a *qualitative* process informed by pre-work testing is proposed:

- A combination of high-level quantitative assessment, qualitative evaluation and on-site pretesting, is to be used to categorise works in terms of their range of potential impact and align with allowable scheduling of works.
- Outline potential mitigation measures or alternative works procedures
- Develop a detailed staff and contractor engagement and consultation procedure to prewarn of impacting works
- Implement a detailed complaint handling procedure for during works, both between staff and management, and with the head contractor and their subcontractors.

For highly sensitive spaces, refer to Sections 6.12.6.

6.12.5 Vibration – minimum working distances

Recommended minimum working distances for vibration intensive plant which is expected to be required are provided in the standards and guidance listed in Section 6.11.1.

During development of the detailed CNVMP, an investigation of vibration impact upon existing buildings on the subject site and on nearby sensitive receivers should take place. It is expected that vibration monitoring will be required under the CNVMP.

6.12.6 Managing noise and vibration levels - highly sensitive spaces

Construction noise mitigation measures

Where the risk of disturbance due to noise is predicted to be high, we recommend that the following methods are used to control or mitigate impact, where feasible and reasonable:

- Minimum 2 m high solid hoarding/barrier is recommended along construction site boundary. The fence should be constructed of minimum 18 mm thick plywood or an alternate material equivalent surface mass (>10 kg/m²).
- The smallest/quietest equipment practicable for the works should be used. For example:

- Hand tools instead of mechanised plant.
- Slab demolition using alternate methods (avoiding hydraulic/pneumatic hammering wherever possible). These may include shear, pulveriser and ripper attachments fitted onto the excavators to progressively demolish the slab panels for later removal.
- Where hydraulic/pneumatic hammers need to be used, acoustic barriers should be applied to the scaffolding between the works and the receivers, on the level where the works are occurring, and also the two levels below. This barrier should have minimum 4 kg/m^2 surface mass – e.g. mass-loaded vinyl.
- Saw cut and ripping are recommended for excavation in rock work close to areas of concern, instead of breaking/jackhammering/etc. *Note: A 'safety distance' should be determined on-site, based on site noise measurement results to ensure the noise levels do not exceed the Management Levels where practicable.*
- Use of lower noise construction equipment such as bored piling instead of driven piling.

Construction vibration mitigation measures

Where the risk of disturbance due to vibration is predicted to be high, we recommend that the following methods are used to control or mitigate impact:

- Use of alternative lower vibration construction methods, such as using bored piles over driven piles.
- Use of lower vibration equipment. In general equipment that operates higher frequency will result in lower vibrations for instance 40Hz compactor will generate lower vibration levels at a distance from the activity than a 12Hz compactor.
- Arranging a programme of designated times when construction work may exceed the specified criteria.
- In some instances, site planning can be used to keep vibration sources away from more sensitive receivers, for instance truck movements, unloading zones, demolition drop zones etc.
- Provide cushioning in demolition drop zones.

We note that there are some physical methods available to mitigate transmission of construction vibration to surrounding receivers such as in-ground vibration barriers. These are typically very costly and not very reliable, particularly for in ground works such as piling and excavation. We have therefore not recommended these in this instance.

Noise and vibration management strategy

This section of the report provides a preliminary plan for managing noise and vibration during construction. We recommend the use of:

- Initial site-specific noise and vibration measurements for new critical site activities
- Continuous noise and vibration monitoring, where deemed necessary
- Clear management process and communication pathways to allow swift action to be taken to resolve any vibration issues within surrounding buildings.

Initial site-specific vibration measurements

Typical levels of vibration expected on site from various activities can be determined from testing on site.

The actual vibration levels experienced are highly dependent upon the site characteristics e.g. ground stratigraphy, the specific items of equipment being used, and the equipment operator. Early vibration level checks are therefore recommended to be carried out on site at the outset of each key vibration generating activity.

If a comparison with vibration criteria reveals excessive levels, methods of constraint on these activities shall be employed by the Contractor, or a review of the criteria carried out, including discussion with the stakeholders as required.

We recommend construction is planned so that initial tests are done with site activity at the closest location with the option to move to a location at a distance to continue construction to allow time to resolve any issues.

Continuous noise and vibration monitoring and complaint response procedure

Continuous noise vibration monitoring systems will be implemented to ensure compliance and management of noise and vibration levels. These systems will monitor noise and vibration levels due to various factors such as changes in equipment and activities or changes to work procedures which may affect existing noise and vibration control measures.

When noise or vibration levels exceed an agreed threshold, the system will provide notifications to the Main Contractor, Health Infrastructure, and relevant stakeholder representatives.

The trigger levels should be set to the levels set out in Sections 6.4 and 6.6.2 (or other agreed levels determined through future discussions with stakeholders). It will be necessary for the system to undergo a period of ‘tuning’ immediately after installation to ensure that the trigger levels are appropriate and provide notifications that correctly represent the point at which noise or vibration levels are becoming a concern.

If noise or vibration levels are repeatedly exceeding the trigger levels, work should be stopped and appropriate action taken.

Stakeholders should be provided with the contact details of a person within the construction team to enable issues to be swiftly resolved should they occur.

It is recommended that the monitoring have the following features as a minimum requirement:

- Noise
  - Continuous noise monitoring system (Class 1) with notification trigger levels
  - Ability to send notification emails/SMS messages when the prescribed trigger levels are exceeded.
  - Ability to monitor and trigger notifications on broadband L_{Aeq} and broadband L_N noise levels.
  - Recorded noise levels, which are saved and stored at minimum 15 minutes preceding and following a trigger event.
  - Proposed equipment should be reviewed by the noise consultant to ensure the results obtained are readily comparable with criteria and any previous testing results.
- Vibration
  - Continuous vibration monitoring system with notification trigger levels
  - Ability to send notification emails/SMS messages when the prescribed trigger levels are exceeded.
  - Ability to monitor and trigger notifications on peak particle velocity and 3rd Octave Band RMS velocities.
  - Sensitivity to monitor vibration levels of V_{RMS} = 0.05-0.1mm/s. Additional sensitivity may be required to monitor vibration in highly sensitive laboratory spaces such as microscopy labs. This is discussed in further detail below.
  - Recorded vibration time history data for 1 minute following a trigger event
  - Proposed equipment should be reviewed by the vibration consultant to ensure the results obtained are readily comparable with criteria and any previous testing results.

We also recommend that the noise and vibration monitoring systems have the following features to give the benefits noted:

- Online access to monitored data.

We recommend use of a system that uploads data to online portal to allow for swift interrogation of noise and vibration levels following a trigger notification and access by multiple parties.

Sensitive equipment vibration monitoring

We note that standard construction vibration monitoring systems available may not be able to monitor the vibration levels well below human perception that may limit operation of more sensitive laboratory equipment (for example Vibration Curve VC-C). A bespoke system with more sensitive accelerometer may be required to achieve this.

Control of noise following exceedance

If noise management levels are exceeded, *feasible and reasonable* noise mitigation measures should be undertaken to minimise noise impacts are far as practicable.

Feasible and reasonable noise mitigation measures should be put in place in advance for receivers where the predicted noise level exceeds the management level. The mitigation required should be identified by assessing the noise impact for specific construction activities considering:

- Source noise level
- Location / proximity to receiver
- Duration / frequency of works

Control of vibration following exceedance

If measured vibration levels exceed the appropriate criteria, the following measures shall be taken by the Contractor:

- Modifications to construction equipment used
- Modifications to methods of construction
- Changes to hours of activities generating excessive vibration levels

In the short term, relocating construction activity to a location further from the sensitive receivers may allow construction activity to continue minimising delays.

7 Conclusion

Arup has completed a noise and vibration impact assessment for SSDA for the proposed RPA Hospital Redevelopment.

Regarding operations, the assessment concludes that the proposed development is capable of satisfying the standard NSW EPA noise policy requirements for building services noise emissions. Notwithstanding, further detailed acoustic assessment is warranted during the design development, particularly concerning building services noise control. Loading dock operations and off-site traffic generated by the proposed redevelopment are not expected to result in a significant increase in noise at the nearest affected receivers.

Regarding the temporary HLS, noise exposure for nearby residents will be significant, but the proposed location is considered to be the only suitable location on or near the RPA campus after consideration of a range of options. Furthermore, the temporary HLS is:

- critical to support clinical functions
- forecast to have limited (2-3) flights per week
- not a permanent facility

The HLS to the roof of the new East Wing is not expected to significantly impact nearby receivers based on its proximity to the existing HLS (based on the understanding that flight paths / number of helicopter movements will not change significantly from existing).

Regarding construction:

- The proposed works are predicted to result in exceedance of the relevant noise management levels at most off-site assessment locations during standard working hours.
- Approval for OOHW on Saturdays is sought in accordance with City of Sydney Construction Code Category 1 working hours for the east campus works.
- High impact activities are excluded from the proposed OOHW. The proposed works are predicted to result in exceedance of the relevant noise management levels at most off-site assessment locations.
- There is a risk that vibration from certain equipment may exceed human comfort / structural damage guidelines for some receivers.
- Accordingly, mitigation and management procedures will need to be considered for the works. Preliminary mitigations and management measures are recommended in Table 39; the list of suitable measures will be finalised by the contractor (once appointed). However, the predicted exceedances are only expected during periods of intense activity subject to the type of equipment used.

- Construction traffic is not expected to result in a significant increase in noise at the nearest affected receivers.
- During development of the detailed Construction Noise and Vibration Management Plan an investigation of vibration impacts upon the following should take place:
  - the subject site
  - nearby sensitive receivers
  - highly sensitive noise and vibration receivers, including:
    - animal houses
    - vibration sensitive equipment
- A detailed CNVMP for the project should be prepared, in which specific attention should be given to mitigating and managing potential impacts upon the surrounding receiver locations, the occupants within the buildings on the subject site and the highly sensitive noise and vibration receivers. It is expected that the detailed CNVMP would be prepared by the contractor prior to the commencement of works.

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Appendix A

Acoustic Glossary

Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

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.

Rating Background Level (RBL / min$L_{A90,1hour}$)

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. This parameter is denoted RBL in NSW, and min$L_{A90,1hour}$ in QLD.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore, a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting ("A-weighting") to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L_1

The L_1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the L_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB $L_{A1,15min}$ is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

L_{10}

The L_{10} statistical level is often used as the "average maximum" level of a sound level that varies with time.

Mathematically, the L_{10} level is the sound level exceeded for 10% of the measurement duration. L_{10} is often used for road traffic noise assessment. As an example, 63 dB $L_{A10,18hr}$ is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

L_{90}

The L_{90} statistical level is often used as the "average minimum" or "background" level of a sound level that varies with time.

Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

L_{eq}

The 'equivalent continuous sound level', L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

L_{eq} is often used as the "average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB $L_{Aeq.}$ Often the measurement duration is quoted, thus $L_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

L_{max}

The L_{max} statistical level can be used to describe the "absolute maximum" level of a sound or vibration level that varies with time.

Mathematically, L_{max} is the highest value recorded during the measurement period. As an example, 94 dB L_{Amax} is a highest value of 94 dB(A) during the measurement period.

Since L_{max} is often caused by an instantaneous event, L_{max} levels often vary significantly between measurements.

Frequency

Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as "pitch". Sounds towards the lower end of the human hearing frequency range are perceived as "bass" or "low-pitched" and sounds with a higher frequency are perceived as "treble" or "high pitched".

Peak Particle Velocity (PPV)

Peak Particle Velocity (PPV) is the highest velocity of a particle (such as part of a building structure) as it vibrates. Most sound level meters measure *root mean squared* (RMS) values; it is common to approximate the PPV based on an RMS measurement.

PPV is commonly used as a vibration criteria, and is often interpreted as a PPV based on the L_{max} or $L_{max,spec}$ index.

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.

Vibration

Waves in a solid material are called “vibration”, as opposed to similar waves in air, which are called “sound” or “noise”. If vibration levels are high enough, they can be felt; usually vibration levels must be much higher to cause structural damage.

A vibrating structure (eg a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space.

Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.

Appendix B

Distances from location of works to receivers

B1 Distances from location of works to receivers

The assumed distances the location of works and the nearest sensitive receivers are presented in Table 44.

Table 44: Assumed distances from location of works to nearby sensitive receivers

Receiver	Distance (m)				
	East extension / East wing	Vertical extension	Lambie Dew Drive	Temp. HLS	Ambulance bay
R1	98	8	70	182	75
R2	190	104	82	240	120
R3	295	100	326	7	190
E1	1	12	61	360	170
E2	42	5	239	316	167
E3	214	68	105	92	116
A1	109	45	60	298	186
A2	137	68	62	369	197
A3	10	70	135	405	200
C1	99	8	182	171	50
C2	141	5	260	113	26
C3	219	80	241	16	114
C4	252	146	242	179	203
H1	186	5	194	164	93
H2	147	20	189	104	57
H3	187	67	255	50	129
H4	280	148	229	335	250
H5	230	66	243	122	120
H6	1	95	1	349	173
H7	202	100	234	12	91
SS	-	-	1	196	1

Appendix C

HLS noise criteria

C1 HLS noise criteria

There are no current regulations that specifically assess helicopter noise emissions in NSW. This section reviews available and relevant standards and guidelines that are considered most appropriate to assess to helicopter noise impacts. Further, a discussion of previous projects in NSW that have applied these noise criteria is also presented. Based on the review, appropriate helicopter noise criteria for receivers surrounding the temporary HLS have been proposed.

Arup has also proposed these criteria for the Eurobodalla Hospital HLS.

7.1.1 Relevant standards and guidelines for helicopter noise

AS 2021:2015 – Aircraft noise intrusion – Building siting and construction

AS 2021:2015 [15] is a standard developed to assist in building construction and land use planning in the vicinity of airports. It is used to provide guidance to all parties that are associated with urban and regional planning on the siting and construction of new buildings against aircraft noise intrusion and on the acoustical adequacy of existing buildings in areas near aerodromes. However, it is noted that the standard is not intended to be applied for the purposes of assessing the effects of noise from aircraft.

AS 2021 uses the Australian Noise Exposure Forecast (ANEF) contours that are used to predict aircraft noise levels. The standard outlines building site acceptability based on the ANEF zones, where noise levels not exceeding 20 ANEF are generally considered acceptable for residential premises and hospitals, with the full acceptability recommendations from AS 2021 reproduced in Table 45.
It is widely accepted that a general conversion from ANEF to an equivalent continuous sound level over 24 hours ($L_{Aeq,24hr}$) is +35, i.e. ANEF 20 would be equal to 55 $dBL_{Aeq,24hr}$.

Table 45: Building site acceptability based on ANEF zones.

Building type	ANEF Zone of site		
	Acceptable	**Conditionally acceptable**	**Unacceptable**
House, home unit, flat, caravan park	< 20 ANEF	20 – 25 ANEF	> 25 ANEF
Hospital, nursing home	< 20 ANEF	20 – 25 ANEF	> 25 ANEF

The standard also provides recommended maximum indoor design sound levels from an aircraft flyover, reproduced in Table 46.

Table 46: Indoor design sound levels for determination of aircraft noise reduction.

Building type and activity	Indoor design sound level, dBA
Houses, home units, flats, caravan parks	
Sleeping areas, dedicated lounges	50
Other habitable spaces	55
Bathrooms, toilets, laundries	60
Hospitals, nursing homes	
Wards, theatres, treatment, and consulting rooms	50
Laboratories	65
Service area	75

AS 2363:1990 – Acoustics – Measurement of noise from helicopter landing sites (withdrawn)

AS 2363-1990 [16] was published with the intent to formalise measurement and analysis procedures with regards to helicopter landing sites.

Appendix A of AS 2363 provides acceptability criteria for daytime and night time periods, reproduced in Table 47 below. It identifies maximum noise level targets (L_{Amax} (Hel)) and time-averaged sound level targets ($L_{Aeq,T}$ (Hel)) for various development usages. Special consideration may be given to the operation of aerial ambulances. For this reason, $L_{Aeq,T}$ (Hel), either night or day, must be satisfied, but L_{Amax} (Hel) is not specified for aerial ambulances. As all helicopters operating at RPAH temporary HLS will be aerial ambulances, L_{Amax} criteria has been included as guidance however do not strictly apply to this site.

AS 2363 recommends that these levels are not to be exceeded within 30 metres of the building envelope of the most affected receivers.

Table 47: Recommended acceptability criteria for 12-hour periods - AS 2363-1990.

Usage of premises and zoning[1]	$L_{Aeq,T}$ (Hel)[5]		L_{Amax} (Hel)[4]	
	Daytime[2]	Night-time[2]	Daytime[2]	Night-time[2]
Residential and hospital areas	60[3]	50[3]	85	80
Commercial areas	65	65	95	90
Other areas (churches, schools, theatres, etc)	60	60	90	90

Notes:

1. This standard makes no recommendation on limits in industrial areas.
2. As per AS2363:1990, the daytime period is defined to be between 0700 and 1900 hours. It follows that the night-time is between 1900 and 0700 hours.
3. For this area classifications, $L_{Aeq.T}$ (Amb) + 10 dB can be used instead of $L_{Aeq.T}$ (Hel) if the former is lower.
4. Special consideration may be given to the operation of aerial ambulances. For this reason, $L_{Aeq,T}$ (Hel), either night or day, must be satisfied, but L_{Amax} (Hel) is not specified for aerial ambulances.
5. If the existing ambient level exceeds the L_{Aeq} level specified in the table, the introduction of helicopter operations should not raise the level by more than 2dB(A).

7.1.2 Review of precedent projects with helicopter noise criteria in NSW

A review of previous DA reports of projects in NSW that feature helicopter landing sites has been undertaken. The helicopter noise criteria used in the DA reports for these projects are summarised in Table 48.

Majority of the reports reviewed have adopted the acceptability criteria of AS 2021 wherein the "Acceptable" classification of building sites of ANEF 20 was aimed for the nearest surrounding receivers.

A recent case in the NSW Land and Environment Court (Nessdee Pty Ltd v Orange City Council, NSWLEC158 2017 [17]) mentions the use of 13 ANEF which relates to newly exposed residences subjected to aircraft noise, based on studies made during the development of the initial EIS of the second Sydney airport [18]. The studies were made by comparing pre-exposed and newly exposed communities with regards to aircraft noise. It was found that newly exposed communities are more sensitive to noise. However, it is noted that the 13 ANEF criteria was considered onerous by the court ruling.

A proposed helicopter landing site at Gleniffer, NSW [19] adopts criteria from AS:2363-1990, noting that it provides L_{eq} criteria for day and night periods as well as maximum allowable levels. Arup considers this approach reasonable as the L_{eq} parameter is influenced by not only the magnitude of noise impact, but also the frequency and duration of helicopter movements affecting the receivers. The expected frequency of 1 helicopter movement per day is also comparable to the expected frequency of emergency medical retrievals at the RPAH temporary HLS, although it is noted that the total annual movement for the Gleniffer site is considerably less than at RPAH.

Table 48: Review of previous projects with proposed helicopter landing sites

Year	Project name	Project location	Project Type	Approximate no. of missions per day	Continuous noise criteria, $L_{Aeq,T}$	Intermittent noise criteria, L_{max}	Comments
2014	Wolgan Valley Resort [20]	Wolgan Valley, NSW	Commercial	5	Arrival & Departure: 40 $dBL_{Aeq,\ 24\ hr}$ Overflight: 45 $dBL_{Aeq,\ 24\ hr}$	45	Adopted from "Acceptable" building site classification from AS 2021, with modifications
2016	Trinity Point Marina [21]	Trinity Point, NSW	Mixed Development	8	55 $dBL_{Aeq,\ 24\ hr}$	-	Adopted from "Acceptable" building site classification from AS 2021
2017	Highland Heritage Estate [17]	Orange, NSW	Commercial	Less than 20	48 $dBL_{Aeq,\ 24\ hr}$	-	Based on ANEF 13, considering noise sensitive receivers that are newly exposed to aircraft noise.
2020	Hermes Estate [19]	Gleniffer, NSW	Commercial	1	Daytime 60 $dBL_{Aeq,\ 12\ hr}$ Night time: 50 $dBL_{Aeq,\ 12\ hr}$ ANEF 13 equivalent: 48 $dBL_{Aeq,\ 24\ hr}$	85	Adopted from AS 2363 - 1990

7.1.3 Temporary HLS noise criteria

Based on the review of relevant standards and guidelines and the helicopter noise criteria used in previous projects in NSW (Table 48), the following criteria for helicopter noise operations is proposed to be applied to the surrounding noise sensitive receivers surrounding the temporary HLS at RPAH.

Table 49: Proposed helicopter noise criteria for surrounding noise sensitive receivers.

Usage of premises and zoning	**$L_{Aeq,T}$**		**L_{Amax}**	
	Daytime[1]	**Night-time[1]**	**Daytime[1]**	**Night-time[1]**
Residential areas	60	50	85	80

Note:

1. Daytime is understood to be between 0700 and 1900 hours and night-time between 1900 and 0700 hours.

Appendix D

Noise monitoring

D1 Noise monitoring equipment

Unattended monitoring was carried out using the following equipment:

Measurement location	Equipment/model	Serial No.	SLM Type
L1 (St. John's College)	ARL Ngara	878107	Class 1
L2 (St. Andrew's College)	ARL Ngara	8780E7	Class 1

Notes:

All meters comply with AS IEC 61672.1 2013 "Electroacoustics - Sound Level Meters" and designated either Class 1 as per table, and are suitable for field use.

The equipment was calibrated prior to the measurement period using a Bruel & Kjaer Type 4231 calibrator.

D2 Extraneous/weather affected data

Measurement samples affected by extraneous noise, wind (greater than 5 m/s) or rain were excluded from the recorded data in accordance with the procedures outlined in Fact Sheet A of the NSW Noise Policy for Industry (NPfI).

Data provided by the Bureau of Meteorology (BOM), for the nearest representative weather station to noise monitoring location(s). Wind speed data was adjusted to account for the difference in measurement height and surrounding environment between the BOM weather station (measured 10 m above ground) and the microphone location based on Table C.1 of ISO 4354:2009 '*Wind actions on structures*'.

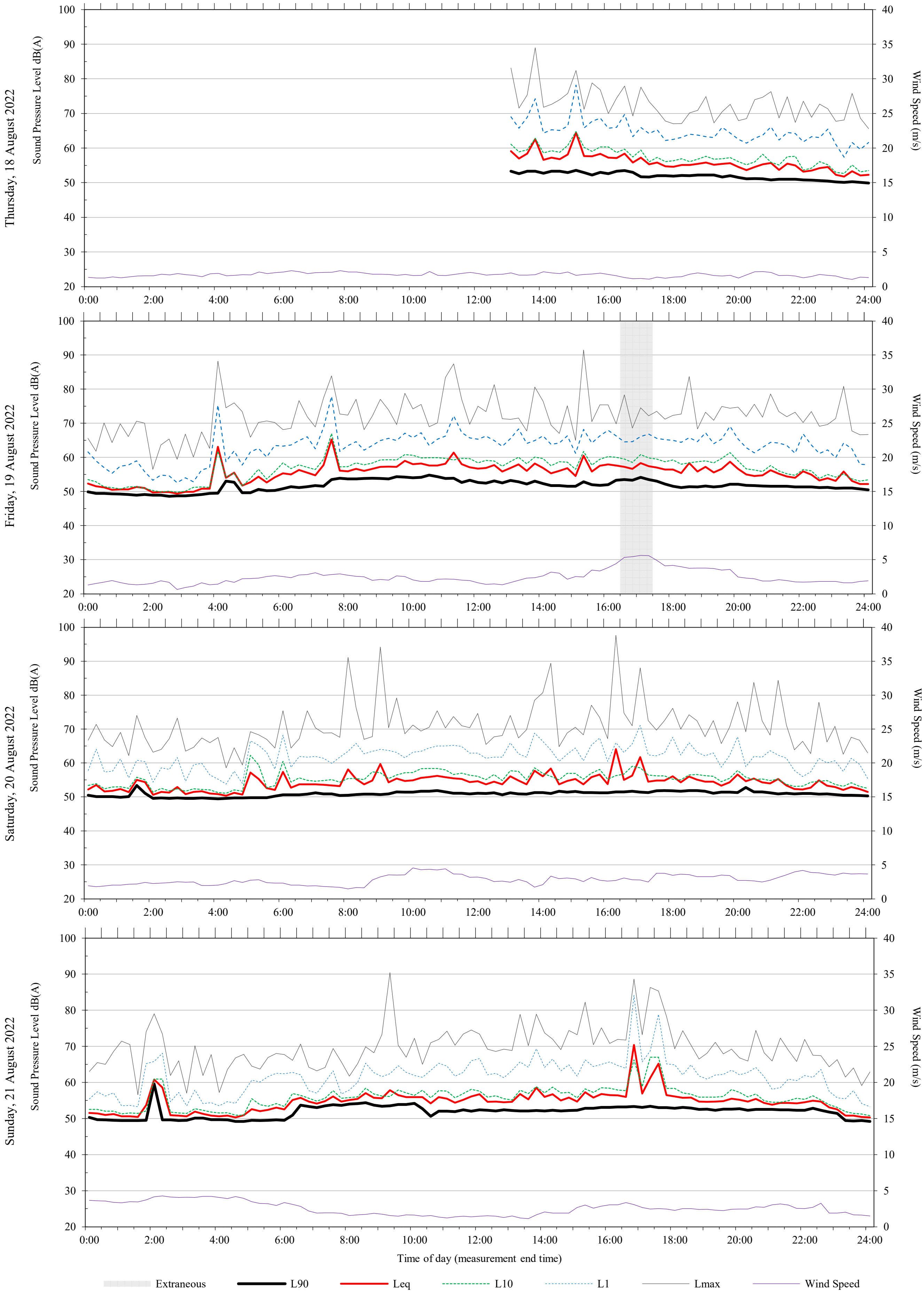
D3 Logger graphs

The following noise level vs time graphs present overall dB(A) levels recorded by the unattended logger(s) for a range of noise descriptors, including L_{Aeq}, L_{A90}, L_{A10} and L_{Amax}. While line graphs are presented, sampling is at 15-minute intervals.

Wind speeds are also show where relevant, and periods of excluded data are shaded grey.

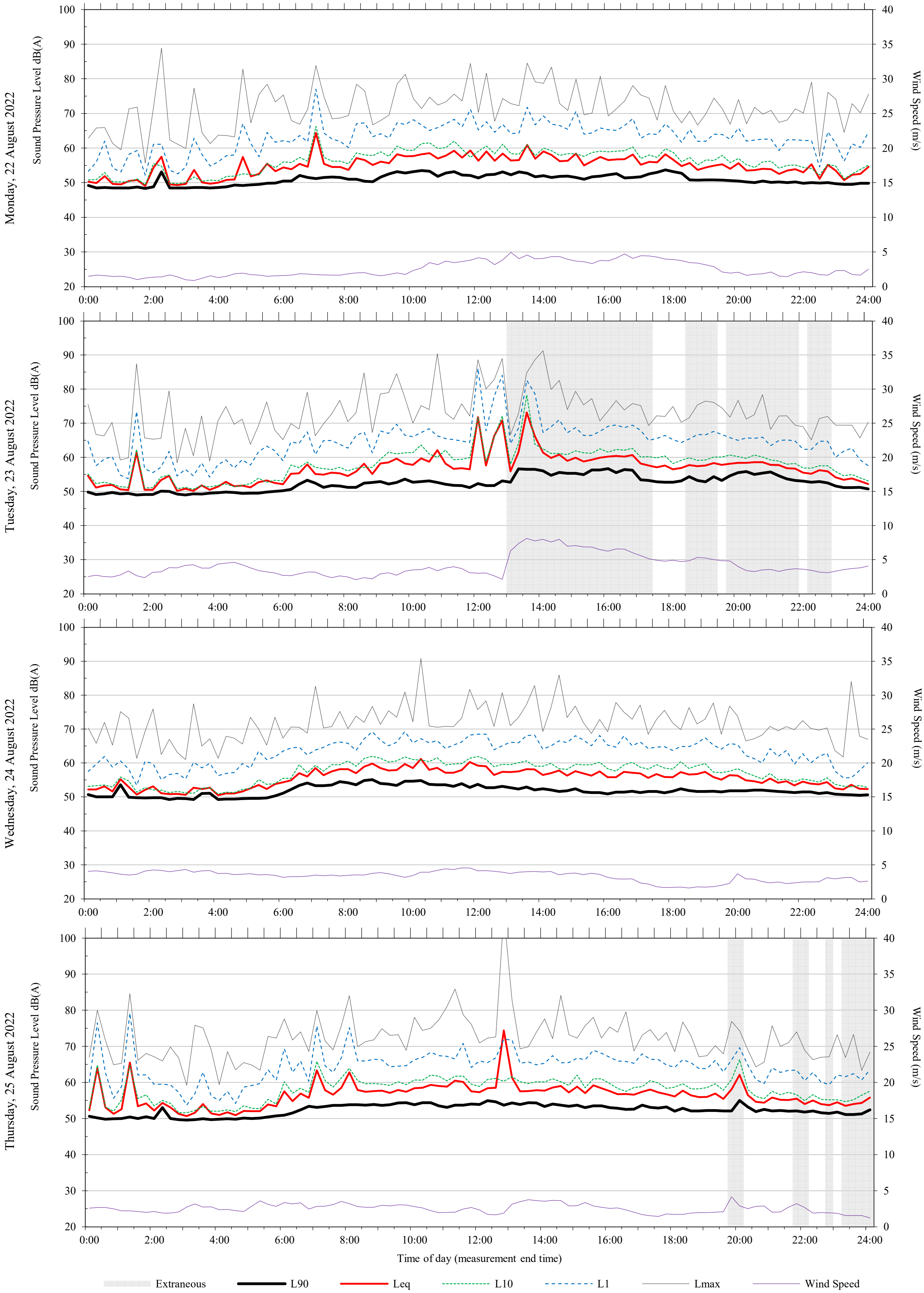
Unattended monitoring: St Johns (Free Field)

ARUP



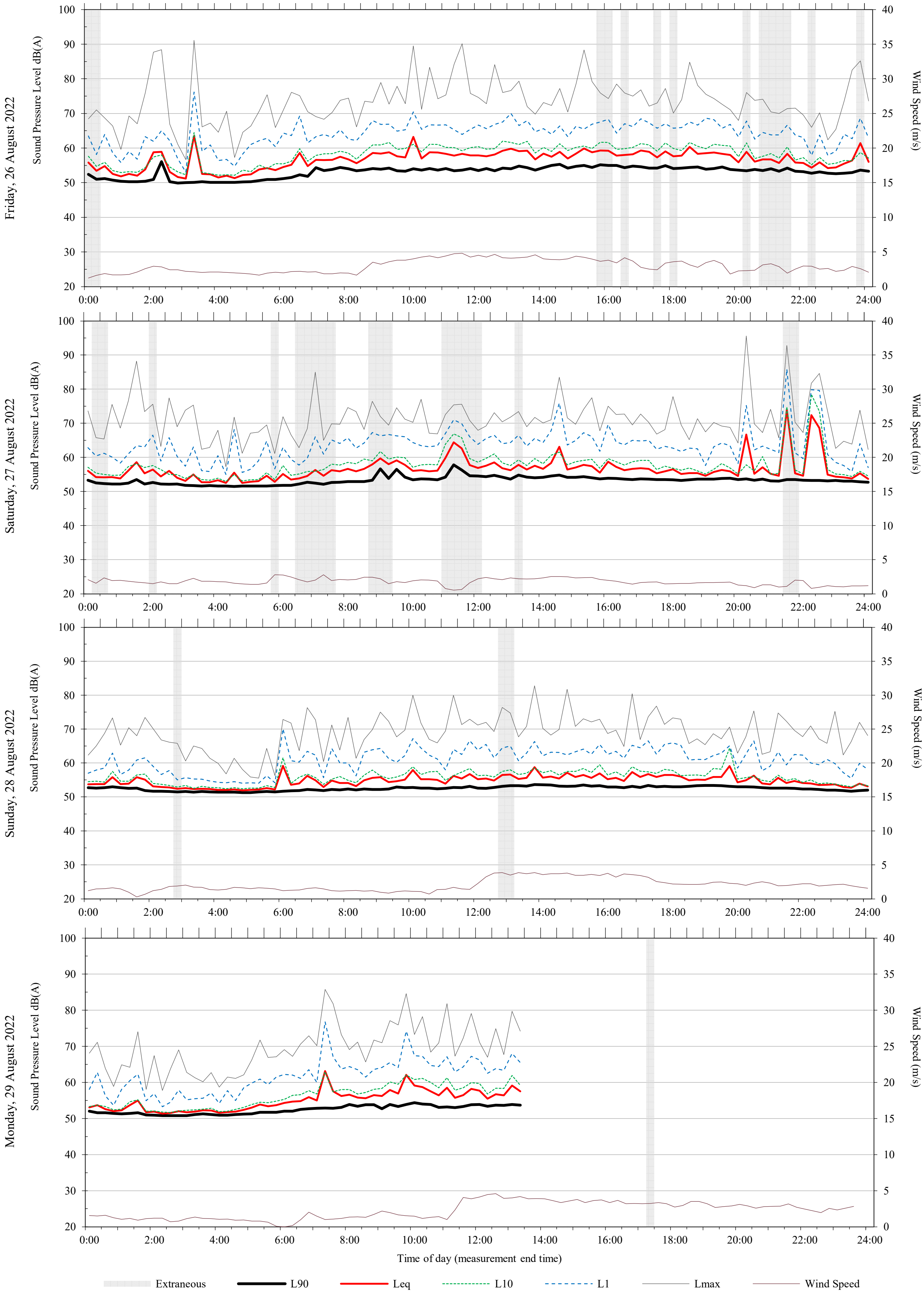
Unattended monitoring: St Johns (Free Field)

ARUP

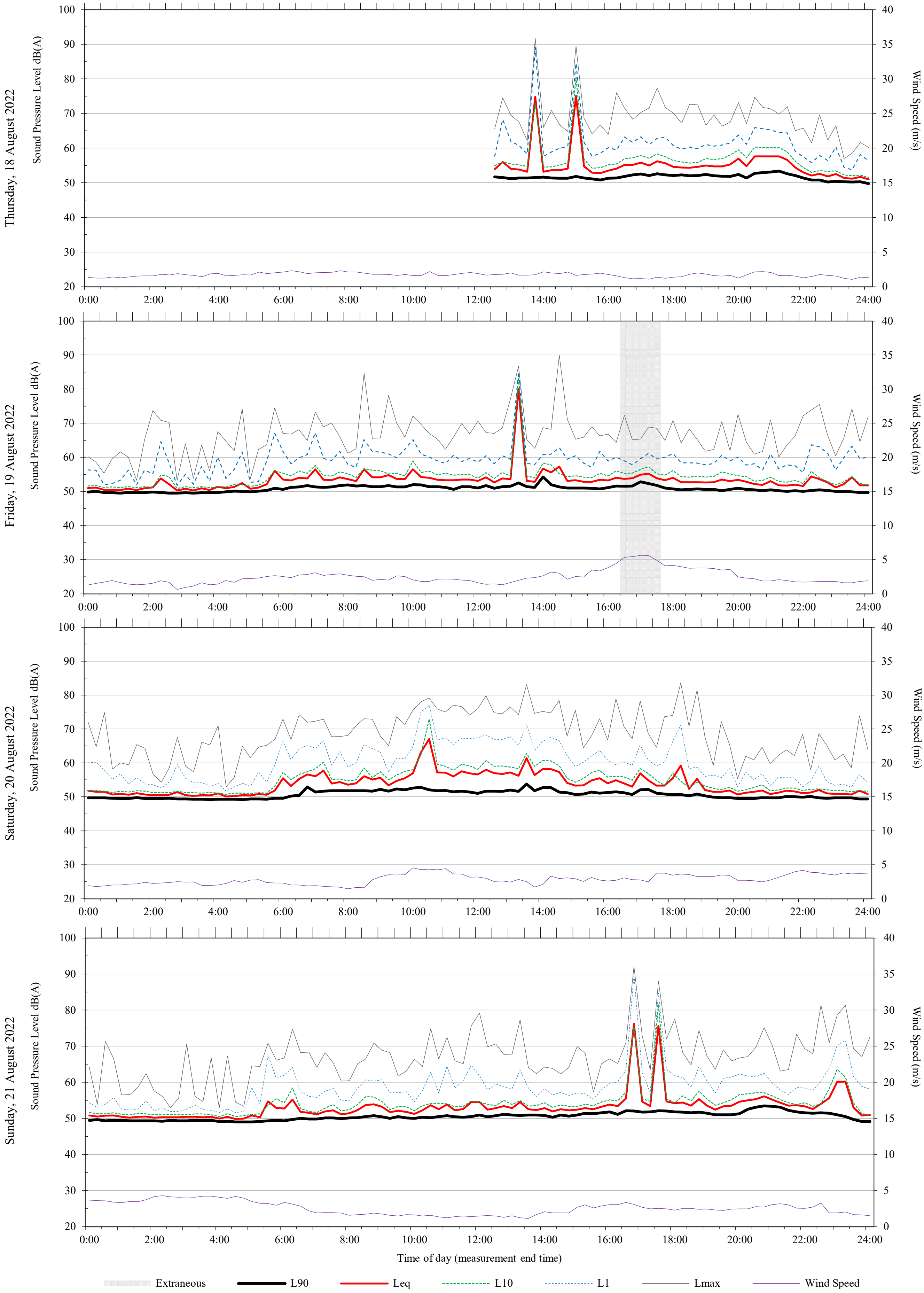


Unattended monitoring: St Johns (Free Field)

ARUP

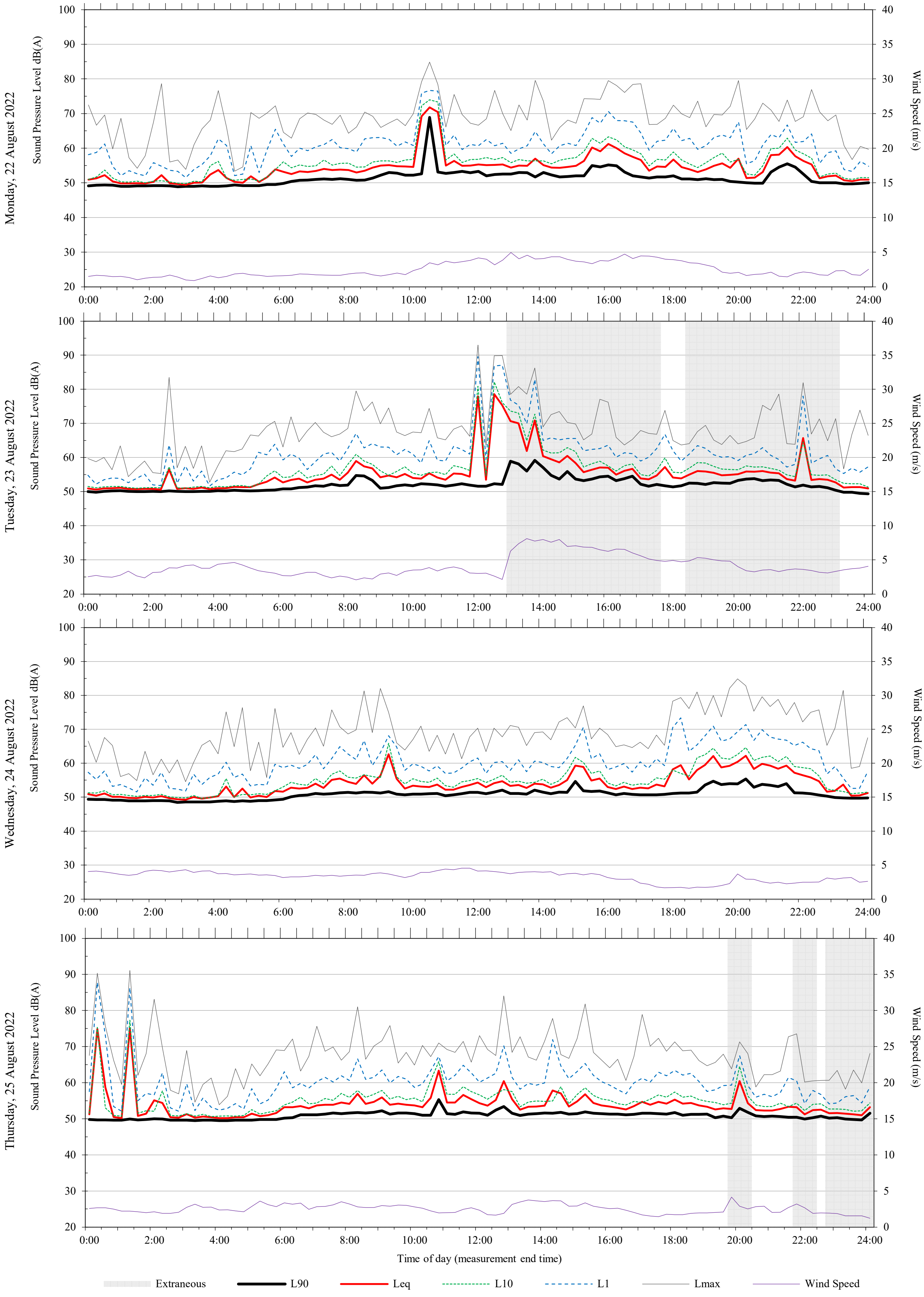


Unattended monitoring: St Andrews (Free Field)



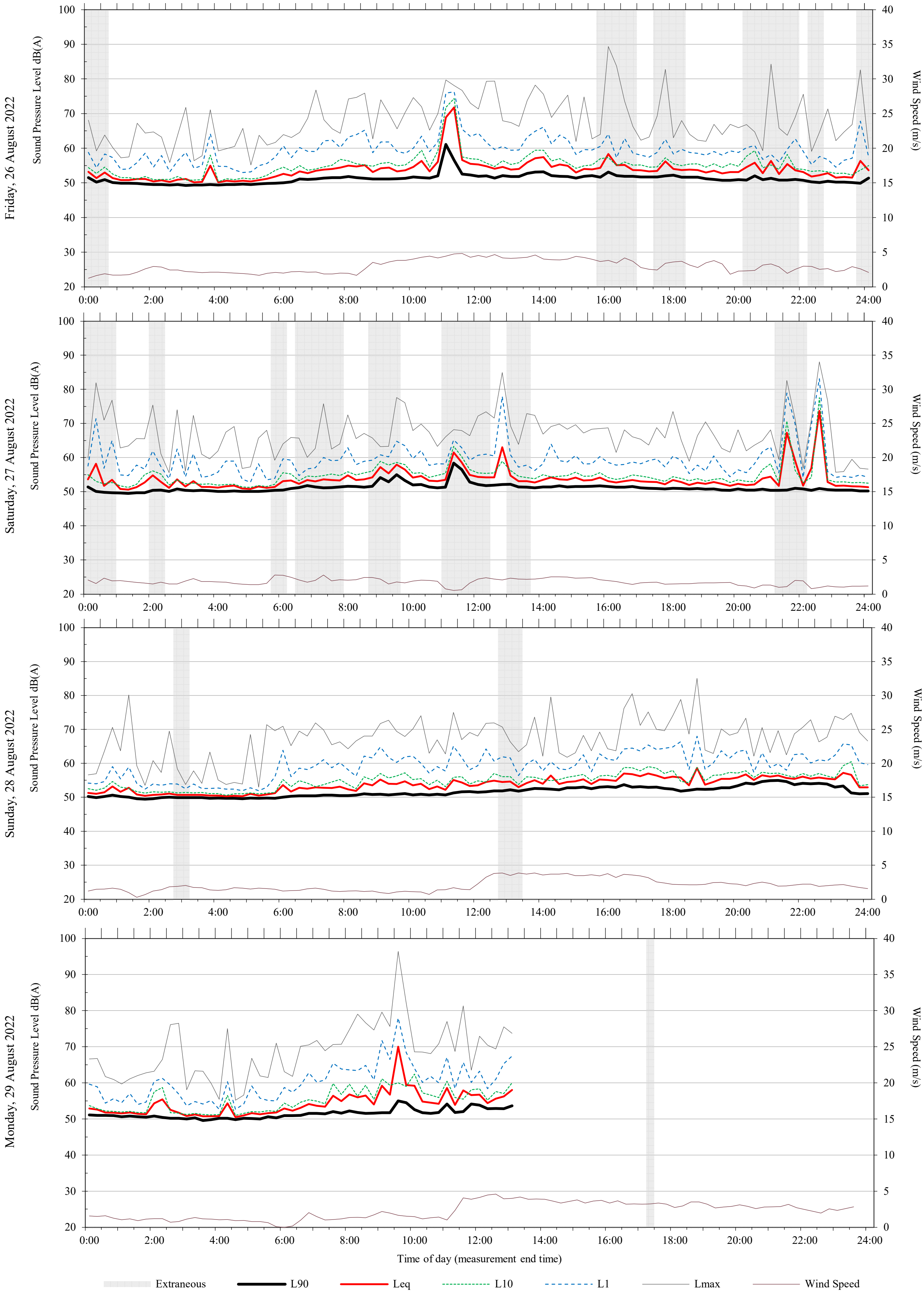
Unattended monitoring: St Andrews (Free Field)

ARUP



Unattended monitoring: St Andrews (Free Field)

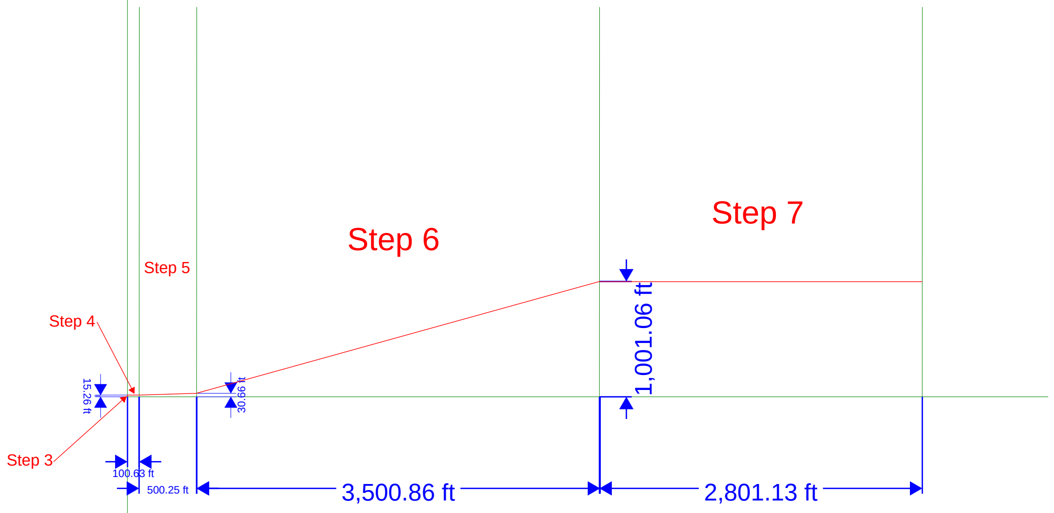
ARUP



Appendix E

Helicopter ascent and descent diagram

Departure Steps

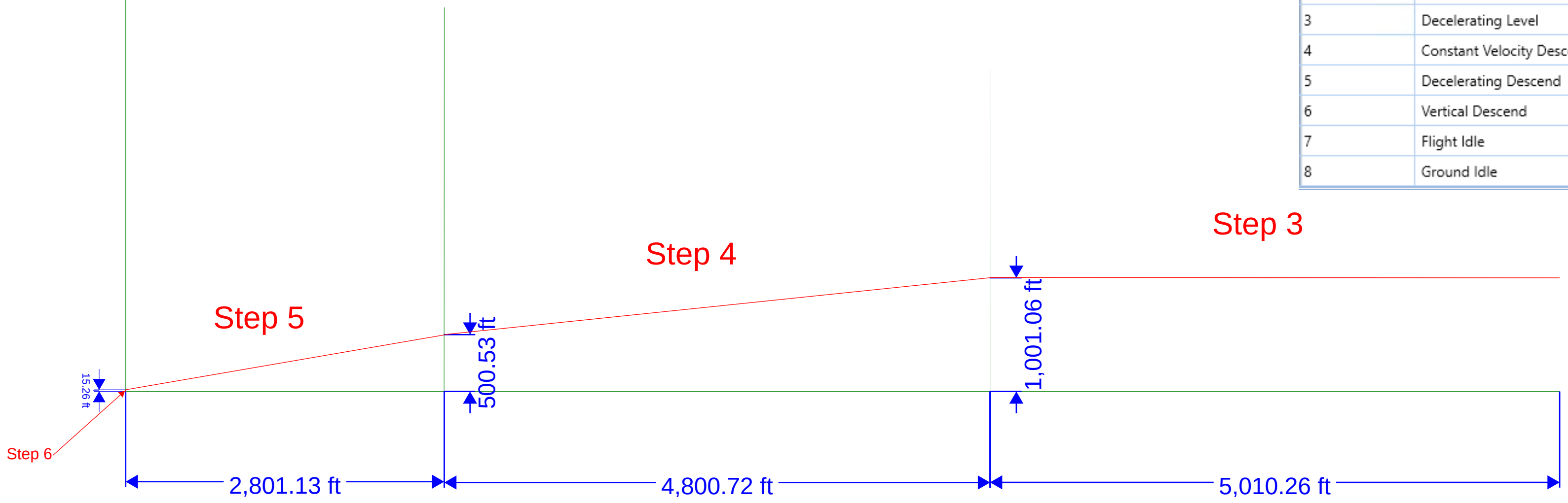


	Name	Operation Type	Weight (lb)	Takeoff Ground Heading	Takeoff Hover Heading	Land Ground Heading
⊞	STANDARD	Approach	15432	0	0	0
⊟	STANDARD	Departure	15432	0	0	0

Step Number	Step Type	Duration (hh:mm:ss)	Distance (ft)	Altitude AFE (ft)	Speed (KTAS)
1	Ground Idle	00:00:30			
2	Flight Idle	00:00:30			
3	Vertical Ascend	00:00:03		15	
4	Accelerating Level		100		30
5	Accelerating Climb		500	30	69.4
6	Constant Velocity Climb		3500	1000	
7	Accelerating Level		2800		126
8	Constant Velocity Level		93100		

- Vertical Climb: This step is used to maintain horizontal position while ascending to a final altitude over a given duration. The duration of the step and the final altitude are inputs. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.
- Level Acceleration: This step is used to accelerate to a final speed over a given distance. The track distance covered by the step and the final speed are inputs. The altitude and initial speed are defined by the previous step.
- Ascending Acceleration: This step is used to climb and accelerate to a final altitude and speed over a given distance. The track distance covered by the step, the final altitude, and the final speed are inputs. The initial altitude and speed are defined by the previous step.
- Constant-Velocity Climb: This step is used to climb at constant speed to a given altitude over a given distance. The track distance covered by the step and the final altitude are inputs. The initial altitude and speed are defined by the previous step.

Approach Steps



	Name	Operation Type	Weight (lb)	Takeoff Ground Heading	Takeoff Hover Heading	Land Ground Heading
	STANDARD	Approach	15432	0	0	0

Step Number	Step Type	Duration (hh:mm:ss)	Distance (ft)	Altitude AFE (ft)	Speed (KTAS)
1	Start			1000	126
2	Constant Velocity Level		87250		
3	Decelerating Level		5000		69.6
4	Constant Velocity Descend		4800	500	
5	Decelerating Descend		2850	15	0
6	Vertical Descend	00:00:03		0	
7	Flight Idle	00:00:30			
8	Ground Idle	00:00:30			

- Start Altitude: This step is used to start a profile at a given altitude and speed. The starting altitude and speed are inputs.
- Constant-Velocity Level: This step is used to maintain altitude and speed for a given distance. The track distance covered by the step is the only input. Altitude and speed are defined by the previous step.
- Constant-Velocity Descent: This step is used tc descend at constant speed to a given altitude over a given distance. The track distance covered by the step and the final altitude are inputs. The initial altitude and speed are defined by the previous step.
- Descending Deceleration: This step is used to descend and decelerate to a final altitude and speed over a given distance. The track distance covered by the step, the final altitude, and the final speed are inputs. The initial altitude and speed are defined by the previous step.
- Level Deceleration: This step is used to decelerate to a final speed at constant altitude over a given distance. The track distance covered by the step and the final speed are inputs. The altitude and initial speed are defined by the previous step.
- Vertical Descent: This step is used to maintain horizontal position while descending to a final altitude over a given duration. The duration of the step and the final altitude are inputs. The horizontal position of the step is calculated from the previous step and the horizontal speed is zero.
- Hover: This step is used to maintain altitude and horizontal position for a given duration. The duration of the step is the only input. The altitude is defined by the previous step, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.
- Idle With Ground Support: This step is used to maintain ground idle for a given duration. The duration of the step is the only input. The altitude is zero, the horizontal position of the step is calculated from the previous step, and the horizontal speed is zero.