Health Infrastructure

Royal Prince Alfred Hospital

Review of Environmental Factors (REF#05) for Medical Gas Compound
Acoustic Assessment Report

AC10

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Contents

Appendices

1 Introduction

Arup has been engaged by Health Infrastructure to undertake an acoustic assessment to support Review of Environmental Factors (REF) for the Campus Infrastructure Works related to the proposed gas compound at the Royal Prince Alfred (RPA) Hospital west campus.

The works are being carried out under State Environmental Planning Policy (Transport & Infrastructure) 2021 [1] as 'Development without Consent' by Health Infrastructure as a public authority. This acoustic and vibration assessment considers the polices, guidelines and standards outlined in Section 1.1.

This document provides noise and vibration advice on the following:

- Impact on adjacent sensitive receivers and mitigation measures (during construction and operation) – i.e. including existing hospital uses, child care centres etc
- Consideration of noise and vibration impacts with the proposed construction hours for REF works.
- Further assessment/justification for works outside of standard construction hours (standard hours are Monday – Friday: 7am to 6pm; Saturday: 8am to 1pm; Sunday and public holidays: no work)
- Identification of work equipment and machinery for construction and assessment of impact on surrounding receivers.

1.1 Relevant documentation

The assessment of construction noise impacts has been carried out in accordance with the NSW Interim Construction Noise Guidelines [2]. 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) [3].

Potential impacts from vibration during construction and/or operation has been quantified as per Assessing Vibration: a technical guideline [4].

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) [5]
- DIN 4150-3: 1999 Structural vibration – Effects of vibration on structures, (1999) [6]
- ASHRAE Handbook, Chapter 49 – Noise and vibration control (2019) [7]
- DIN 4150-2: 1999 Structural vibration – Human exposure to vibration in buildings [8].

1.2 Site description and Scope of Works

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 proposed activity comprises alterations and additions to the Capital Infrastructure and Engineering (CI & E) building loading dock located off Rochester Street in the RPA Hospital West Campus (refer to Figure 1, Figure 2 and Figure 3). Specifically, the works are to establish a reconfigured and expanded Medical Gas Compound (MGC) comprising the following works:

- Demolish three (3) existing oxygen tanks;
- Demolish existing shed structure (roof, walls and slab to 300mm below existing ground level);
- Removal of redundant services;
- Existing road surface to be saw cut;
- New MGC enclosure comprising fire rated walls and sliding door to house new main primary and secondary oxygen tanks (60kL), emergency oxygen tank (20kL) and new vaporisers;
- Install new hard stand on road for filling point;
- Install new bollards;
- Install new roof mounted fans;
- New oxygen pipe distribution system infrastructure within confines of MGC area.
- Removal of adjacent trees

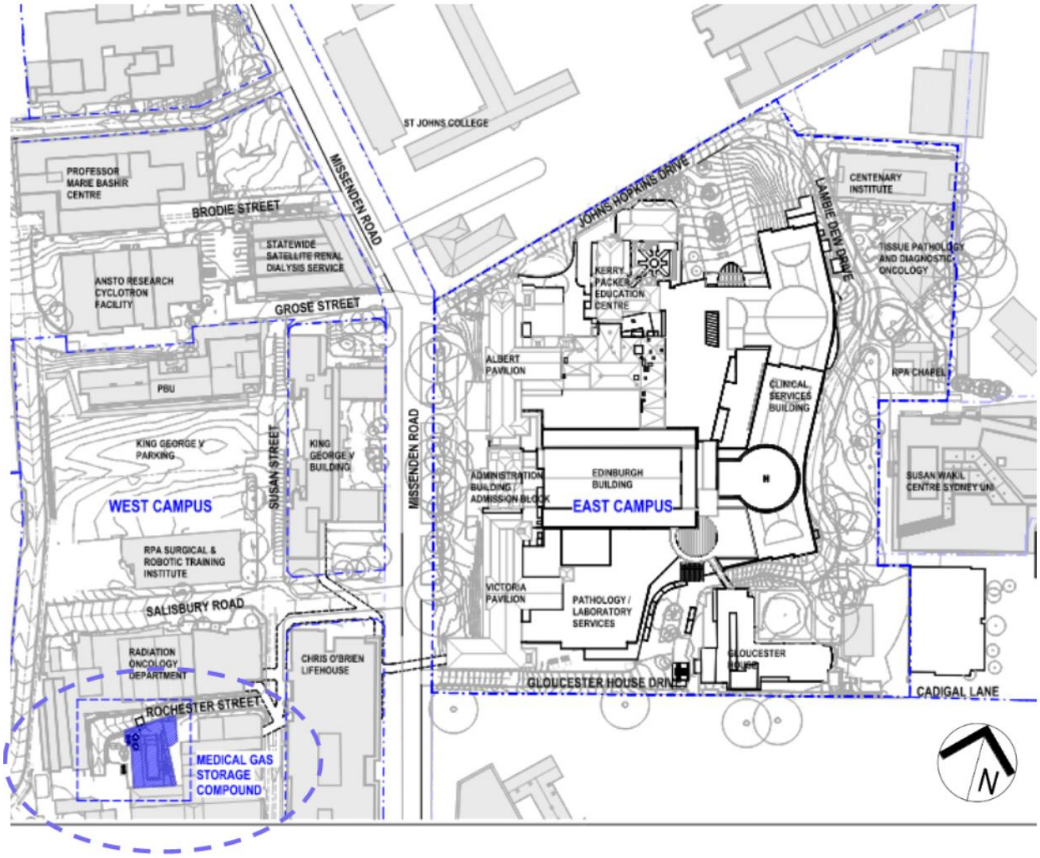

Figure 1: Site Boundary

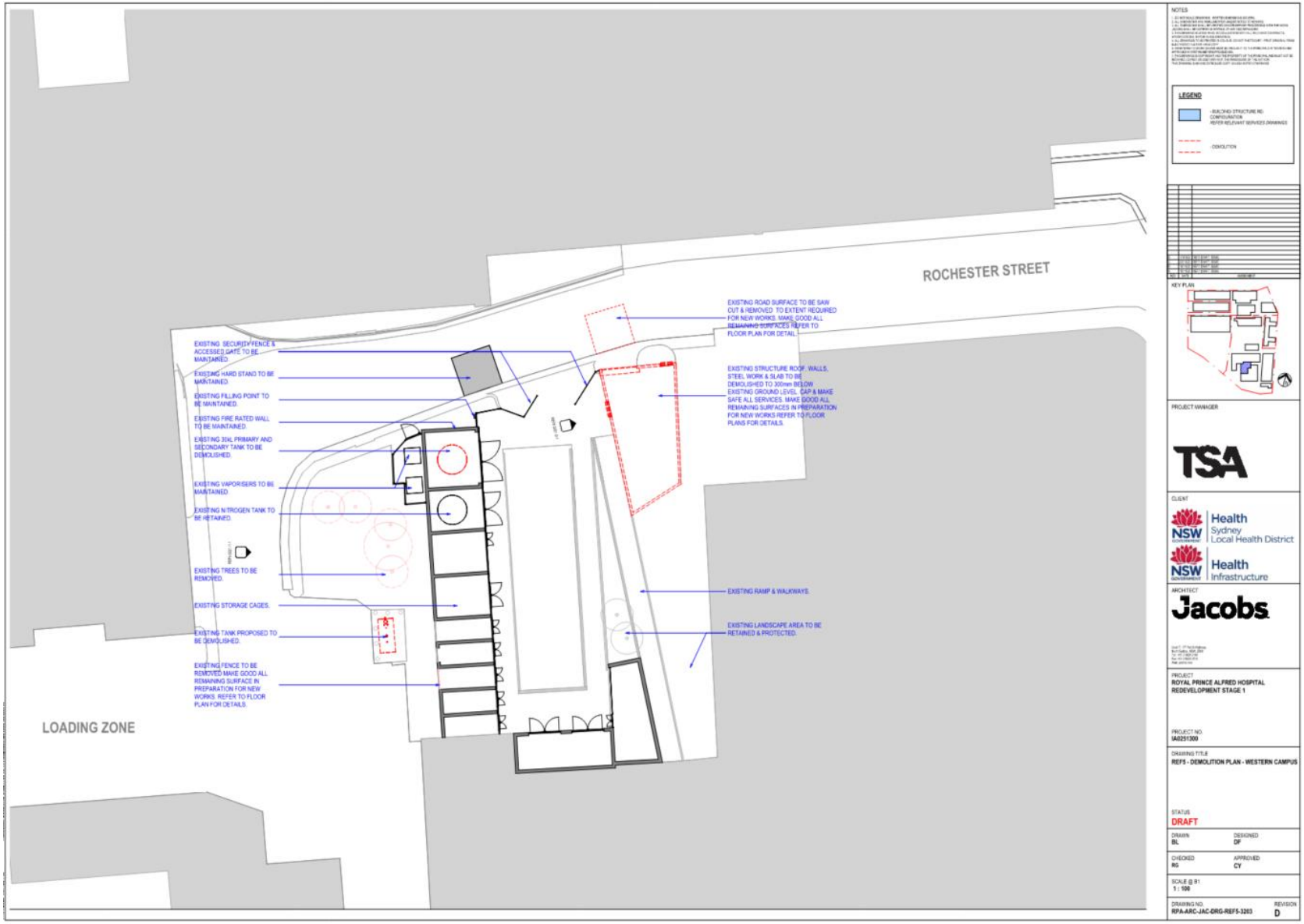

Figure 2: Proposed demolition works

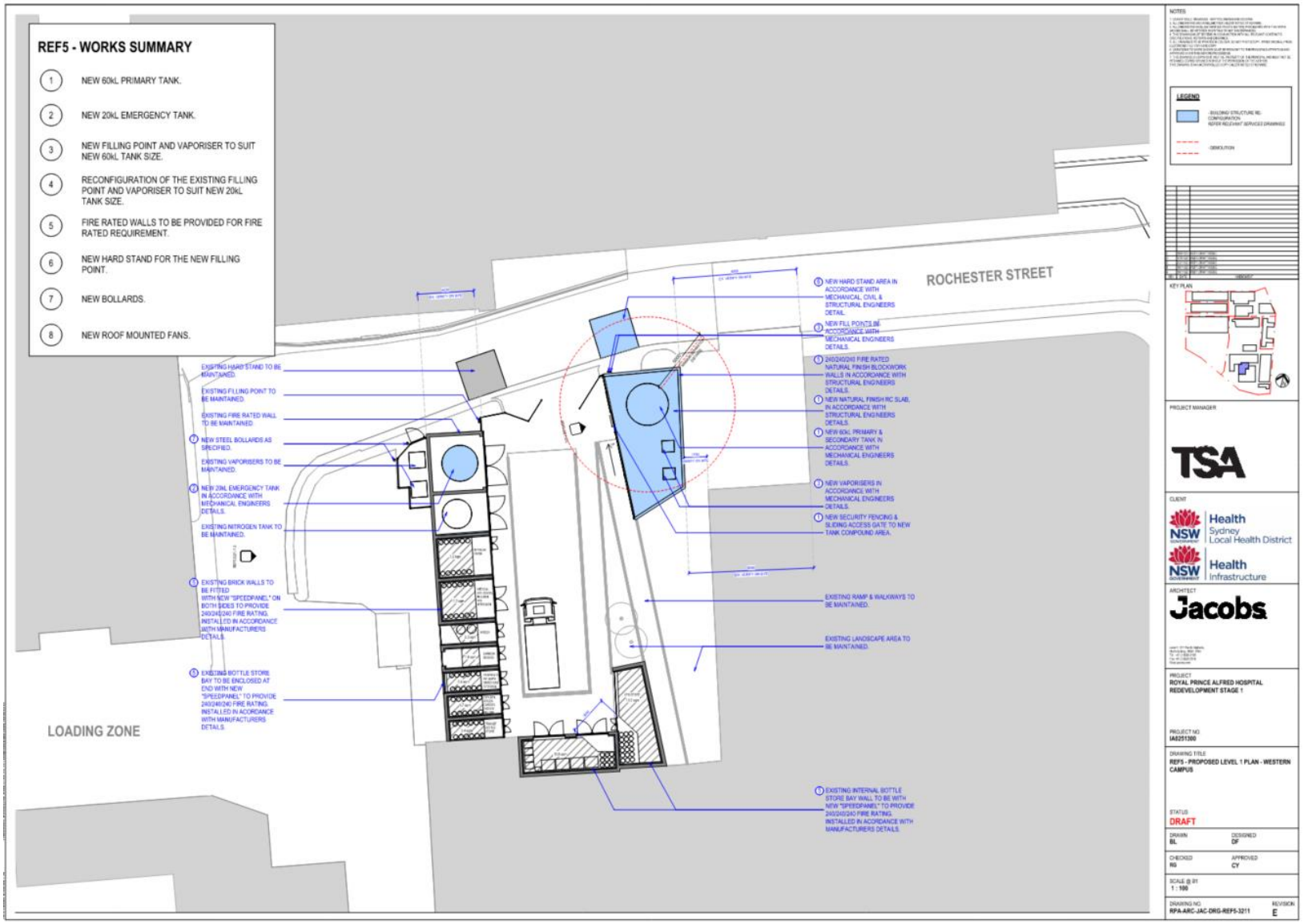

Figure 3: Proposed construction works

2 Surrounding land uses

The nearest most potentially affected off-site land uses surrounding the development have been identified in Figure 4.

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

Table 1: Receiver locations

ID	Receiver	Description
R1	St Andrew's College	Residential
R2	138 Carillon Avenue	Residential
R3	130 Carillon Avenue	Residential
E1	Surgical and Robotic Training Institute	Classroom
C1	Capital Infrastructure and Engineering	Commercial
H1	Chris O'Brien Lifehouse	Hospital Ward
H2	Radiation Oncology Department	Hospital Ward

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Figure 4: Site, sensitive receiver and noise monitoring locations

3 Existing noise environment

3.1 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. The college contains student dormitories and so is classified as a residential receiver.

The long-term measurement locations are outlined in Table 2 and shown in Figure 4.

Table 2: Noise monitoring locations

ID	Address
L1	St. Andrew's College

3.2 Long-term noise measurement results

Long-term noise monitoring was carried out at L1 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	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)

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 C.

4 Operational noise criteria

4.1 NSW Noise Policy for Industry

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.

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 4.

Table 4: NPfI Project specific noise levels

Receiver	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) $L_{Aeq(15min)}$[3]**	**Project Noise Trigger Level (PNTL) $L_{Aeq(15min)}$**	**Sleep Disturbance $L_{Amax(night)}$**
R1, R2, R3	Day	56	55	58	56	N/A[2]
	Evening	56	45	48	48	N/A[2]
	Night	55	40	43	43	65
E1	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]
C1	When in use	N/A[2]	60	63	63	N/A[2]
H1, H2	Hospital ward – noisiest 1 hour	N/A[2]	30 (internal) 45 (external)	33 (internal) 48 (external)	33 (internal) 48 (external)	N/A[2]

Receiver	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) $L_{Aeq(15min)}$[3]	Project Noise Trigger Level (PNTL) $L_{Aeq(15min)}$	Sleep Disturbance $L_{Amax(night)}$

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. 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 receiver.

4.1.1 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.

4.2 Operational noise review

Building services

Building services equipment has not been selected at this early stage of design. 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 (e.g. REF).

Preliminary guidance concerning building services noise control is provided below.

- 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 4).
- Building services noise emission can be controlled by appropriate system design and implementation of common engineering methods, which may include:

- Procurement of 'quiet' plant.
- 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.

It is understood that there are three (3) fans mounted on the roof of the gas compound and that the fans will be operational 24 hours a day, 7 days a week.

A preliminary acoustic assessment has been undertaken, as detailed in Table 5. The assessment is based on an assumed maximum sound power level of **68 dB(A) per fan**. If final fan selections are louder than this, noise emissions can otherwise be controlled using the acoustic mitigation measures outlined above. Therefore, it is expected that the operational criteria can readily be complied with.

Table 5: Preliminary operational noise assessment

Receiver	**Time of day**	**Approx. distance to fans, m**	**Predicted level at receiver, dBL$_{Aeq,\ 15min}$**	***External noise criteria, dBL$_{Aeq,\ 15min}$***
R1	Day	100	25	*56*
	Evening			*48*
	Night			*43*
R2	Day	65	29	*56*
	Evening			*48*
	Night			*43*
R3	Day	67	29	*56*
	Evening			*48*
	Night			*43*
E1	Noisiest 1-hour	58	30	*48*
C1	When in use	1	63	*63*
H1	Noisiest 1-hour	62	29	*48*
H2	Noisiest 1-hour	18	40	*48*

Notes:
Values in RED indicate an exceedance of the criteria.

Vehicular movements on site

It is expected that vehicular movements and traffic noise levels will not increase as a result of the proposed works.

5 Construction

This assessment should be used to inform the proposed work practices and management measures contained in the preliminary Construction Management Plan (CMP). The preliminary CMP will be further developed as the construction methodologies and processes are confirmed during the design development process.

5.1 Construction noise criteria

5.1.1 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 of the Campus Infrastructure 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.

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 6 and in Table 7 respectively.

Table 6: 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.
	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 7: 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)

Land use	Where objective applies	Management level $L_{Aeq(15\ min)}$[1]
Commercial premises	External noise level	70 dB(A)

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.

5.1.2 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 8. 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 8: CoS Construction Code Criteria

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

5.1.3 Project construction noise targets

Based on the measured background noise levels presented in Table 3 and the criteria methodology presented above, Table 9 outlines the construction noise management levels applicable to demolition, excavation and construction.

Table 9: Construction noise management levels (NMLs)

Receiver	Where objective applies	Noise management level, $dBL_{Aeq(15\ min)}$			
		Standard hours[1]		Outside standard hours[2]	
		Noise affected	Highly noise affected	Noise affected	Highly noise affected
R1, R2, R3	External	61	75	55	60
E1	Internal External[3]	45 55	-	45 55	-
C1	External	70	-	70	-
H1, H2	Internal External[3]	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. External noise level based on an assumed 10dB reduction through open window

5.2 Construction vibration criteria

5.2.1 Disturbance to building occupants

Potential vibration disturbance to human occupants of buildings is made in accordance with the NSW DEC Guideline [4]. The criteria outlined in the guideline is based on BS 6472-1992 [12]. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent', as described in Table 10.

Table 10: 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.

Type of vibration	Definition	Examples
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 11 reproduces the 'Preferred' and 'Maximum' values for continuous and impulsive vibration from Table 2.2 of the Guideline.

Table 11: 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
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 12 reproduces the 'Preferred' and 'Maximum' values for intermittent vibration from Table 2.4 of the Guideline.

Table 12: 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

5.2.2 Structural damage

5.2.2.1 Definition

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard 7385 Part 2 [5] and/or German Standard DIN4150-3 [6]. 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.

5.2.2.2 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 13 sets out the BS7385 criteria for cosmetic, minor and major damage.

Table 13: 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.

5.2.2.3 German standard DIN 4150

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure'* [6] 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 14, 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 14: 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

5.2.3 Vibration sensitive equipment or receivers

Some high technology manufacturing facilities, hospitals and laboratories use equipment and processes that are highly sensitive to vibration, such as high magnification microscopy (including optical and electron microscopes) and high-resolution imaging equipment (e.g. MRI). Buildings housing sensitive computer or telecommunications equipment may also require assessment against stricter criteria than those nominated for building damage or human comfort.

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. Baseline vibration levels could also be measured to inform the establishment of appropriate criteria.

An investigation of all vibration sensitive equipment in buildings surrounding the location of works should take place during development of the detailed Construction Noise and Vibration Management Plan.

5.2.4 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 15).

Table 15: 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

	Pipe material	Guideline values for vibration velocity measured on the pipe, mm/s

Notes:

For gas and water supply pipes within 2m of buildings, the levels given in DIN4150-3 [6] 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.

5.3 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.

Table 16 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.

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.

It is emphasised that all the equipment listed in Table 16 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 16.

Table 16: 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}
Gas compound	Construction works, removal of waste, demolition of old oxygen tank, tree removal	Angle grinder	108	107
		Handheld tools – electric x 2	110 (each)	109 (each)
		Dump truck	117	116
		Concrete pump truck	113	112
		Concrete saw	122	121
		Jackhammer	126[1]	125[1]
		Chainsaw	114	113
		Mulcher	116	115

Notes:

1. Includes 5 dB penalty for impulsive noise characteristic

5.4 Construction hours

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 7), approval is being sought to extend Saturday construction hours as outlined in Table 17.

In addition, some works, such as connecting and disconnecting services and works that are considered disruptive, may need to be completed during certain hours, beyond the limitations noted in Table 17, to ensure minimal impact on hospital operations.

Table 17: Proposed construction hours

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

Notes:

1. OOHW are proposed only if required to prevent undue impacts on RPA Hospital operations

For projects undergoing a typical approvals process, permission for extended operating hours is granted for:

1. the delivery of oversized plant or structures that police or other authorities determine require special arrangements to transport along public roads

2. emergency work to avoid the loss of life or damage to property, or to prevent environmental harm
3. maintenance and repair of public infrastructure where disruption to essential services and/or considerations of worker safety do not allow work within standard hours
4. public infrastructure works that shorten the length of the project and are supported by the affected community
5. works where a proponent demonstrates and justifies a need to operate outside the recommended standard hours

Justification for extension to Saturday morning operating hours

On the basis of point 5 above, and 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 Table 17. 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 17.

Justification for extension to Saturday morning operating hours

On the basis of point 5 above, it is proposed that OOHW could be conducted as required to prevent undue disruption on RPA Hospital operations.

These works are to be planned in consultation with stakeholders and subject to Disruption Notice applications to ensure all aspects of the works are clearly understood by all parties to minimise disruption.

Arup recommends that approval be granted for these OOHW.

The following high noise impact activities should be avoided outside of standard ICNG construction hours wherever possible:

- Demolition works
- Excavation works
- Piling

5.5 Construction noise predictions

5.5.1 Noise assessment

Predicted construction noise levels, considering standard construction hours and outside standard construction hours, are tabulated in Table 18. 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.

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

Table 18: Predicted noise levels at nearest affected off-site receivers

Receiver	**NML, dBL$_{Aeq(15\ min)}$**		**Predicted sound level at receiver, dBL$_{Aeq(15\ min)}$**
	Noise affected	Highly noise affected	
During standard hours			
R1	61	75	64[3]
R2	61	75	83
R3	61	75	68[3]
E1	45[1]	-	59[2,3]
C1	70	-	119
H1	45[1]	-	73[2]
H2	45[1]	-	97[2]
Outside standard hours[4]			
R1	55	60	64[3]
R2	55	60	83
R3	55	60	68[3]
E1	45[1]	-	59[2,3]
C1	70	-	119
H1	45[1]	-	73[2]
H2	45[1]	-	97[2]

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. Assumes that any and all construction plant may be used during OOHW in a worst-case scenario to prevent undue impacts on RPA Hospital operations

Predicted sound pressure level ≤ noise affected level

Noise affected level < predicted sound pressure level ≤ highly noise affected

Highly noise affected < predicted sound pressure level

Results show that construction noise is predicted to exceed 'noise affected' levels during standard hours, with R2 predicted to be "highly noise affected". Outside standard hours, residential receivers are predicted to the 'highly noise affected', with other receivers predicted to be "noise affected".

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. It is also noted that the OOHW noise predictions conservatively assume that high impact activities (such as demolition) may need to occur out of hours.

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.

5.6 Construction vibration

Recommended minimum working distances for vibration intensive plant, which are based on international standards and guidance, are provided in Table 19. Minimum working distances are quoted for:

- Cosmetic damage (based on the British Standard 7385 [5])
- Human comfort (based on the DECCs 'Assessing Vibration; a technical guideline' [4])
- Unsound structures (based on German Standard DIN 4150 [6])

Table 19: Recommended minimum working distances for vibration intensive equipment

Plant item	**Rating / description**	**Minimum working distance (m)**			
		Cosmetic damage – screening criteria			**Human response** DECC Guideline
		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)	**Unsound structures** DIN 4150 Line 3 - 3 mm/s	
Jackhammer	Hand-held	1 (nominal)	1 (nominal)	3	5
Truck movements	-	-	-	-	10

Notes:

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

5.6.1 Vibration assessment

Based on the minimum working distances quoted in Table 19 and the distances from the works to each receiver in Table 20, off-site sensitive receivers are not expected to be impacted from a structural perspective. There is a possibility of some minor human comfort impacts during the works at C1 and H2.

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. Where vibration generating equipment is proposed to be used within the minimum distance in Table 19, a review of equipment selection and/or method of construction should be conducted. Vibration monitoring might also be required.

It is expected that some nearby receivers will contain vibration-sensitive equipment. While beyond the scope of this assessment, an investigation of vibration sensitive equipment located in proximity to the proposed works should occur. If vibration sensitive equipment is identified, a review of the equipment and manufacturer data should be conducted to establish acceptable vibration levels. Subsequently, a review of construction equipment selection and/or method of construction should be completed.

5.7 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.

5.7.1 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.

5.7.2 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.

5.7.3 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

5.7.4 Vibration – minimum working distances

Recommended minimum working distances for vibration intensive are provided in the standards and guidance listed in Section 5.6.

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

6 Conclusion

Arup has completed an acoustic and vibration assessment for REF submission for the proposed Campus Infrastructure Works for the gas compound on the RPA Hospital West Campus.

Regarding operations, the assessment concludes that the proposed development is capable of satisfying the standard NSW EPA noise policy requirements.

Regarding construction, the proposed works are predicted to result in exceedance of the relevant noise management levels at most off-site assessment locations. Accordingly mitigation and management procedures will need to be considered for the works, to ameliorate the construction noise impacts. The predicted exceedances are only expected during periods of intense activity subject to the type of equipment used.

During development of the detailed Construction Noise and Vibration Management Plan an investigation of vibration impact upon the following should take place:

- the subject site
- nearby sensitive receivers
- 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 and the occupants within the buildings on the subject site. It is expected that the detailed CNVMP would be prepared by the contractor prior to the commencement of works.

References

[1] NSW Government, "State Environmental Planning Policy (Infrastructure) 2007," 2007.

[2] Department of Environment and Climate Change NSW, "Interim Construction Noise Guideline," Department of Environment and Climate Change NSW, Sydney, 2009.

[3] NSW Environment Protection Authority, "NSW Noise Policy for Industry," NSW Environment Protection Authority, Sydney, 2017.

[4] Department of Environment and Conservation (NSW), "Assessing Vibration: A technical guideline," Department of Environment and Conservation (NSW), Sydney, 2006.

[5] Bristish Standard Institution, "BS 7385-2: 1993 Evaluation and measurement for vibration in buildings - Pt 2: Guide to damage levels from groundborne vibration," Bristish Standard Institution, London, 1993.

[6] Deutsches Institut fur Normung, "DIN 4150-3 (1999) Structural vibration - Effects of vibration on structures," Deutsches Institut fur Normung, Berlin, 1999.

[7] American Society of Heating, Refrigerating and Air-Conditioning Engineers, "Applications Handbook (SI), Chapter 49 Noise and Vibration Control," ASHRAE, Atlanta, 2019.

[8] D. I. f. Normung, "DIN 4150-2:1999 Structural vibration - Human exposure to vibration in buildings," Deutsches Institut fur Normung, Berlin, 1999.

[9] City of Sydney, "Construction Hours/ Noise within the Central Business District Code of Practice," Sydney, 1992.

[10] British Standards Institute, "BS 6472:1992 Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)," BSI, London, 1992.

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 construction works and the nearest sensitive receivers are presented in Table 20.

Table 20: Assumed distances from location of works to nearby sensitive receivers

Receiver	Distance (m)
R1	100
R2	65
R3	67
E1	58
C1	1
H1	62
H2	4

Appendix C

Noise monitoring

C1 Noise monitoring equipment

Unattended monitoring was carried out using the following equipment:

Measurement location	Equipment/model	Serial No.	SLM Type
L1 (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.

C2 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*'.

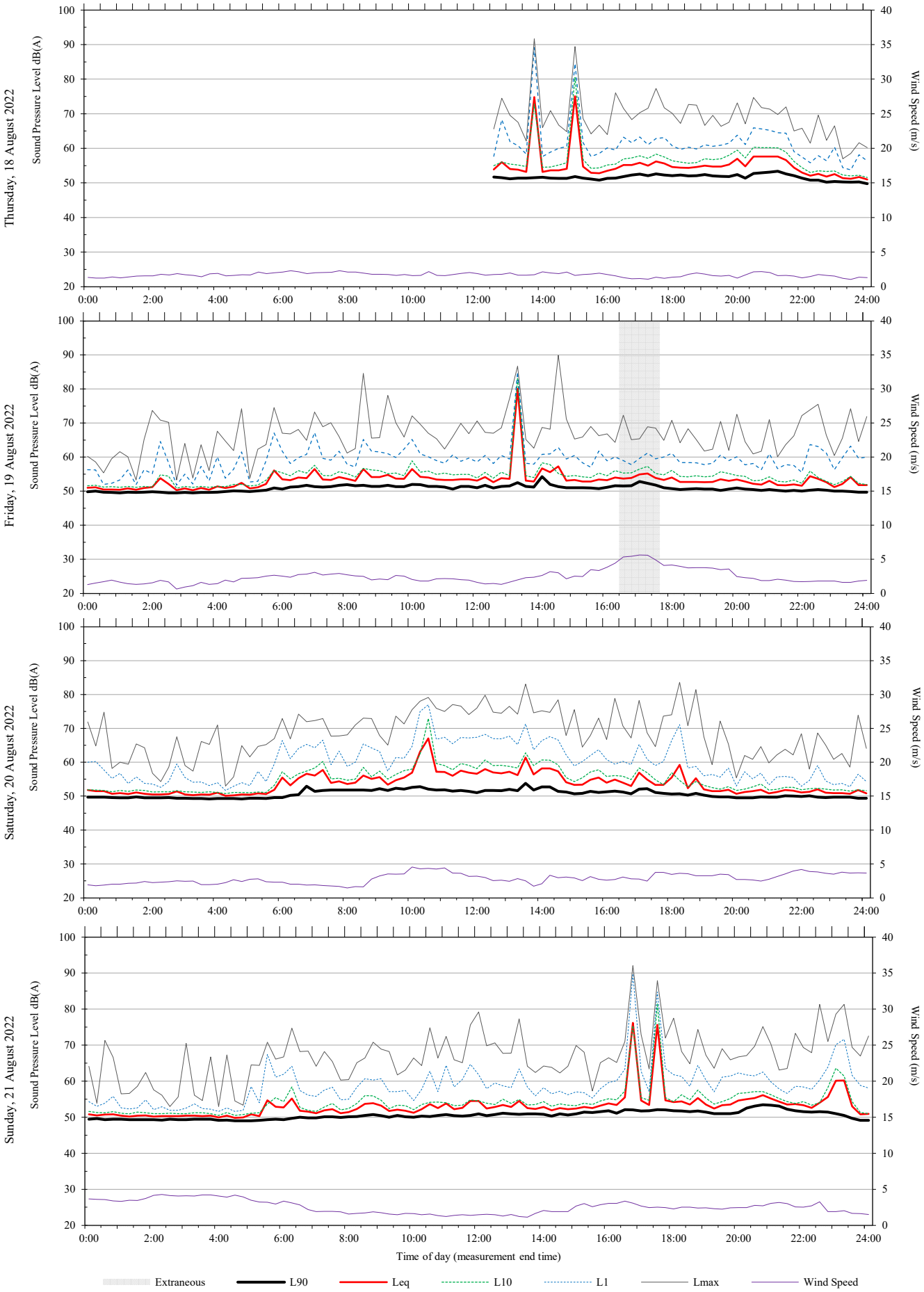
C3 Logger graphs

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.

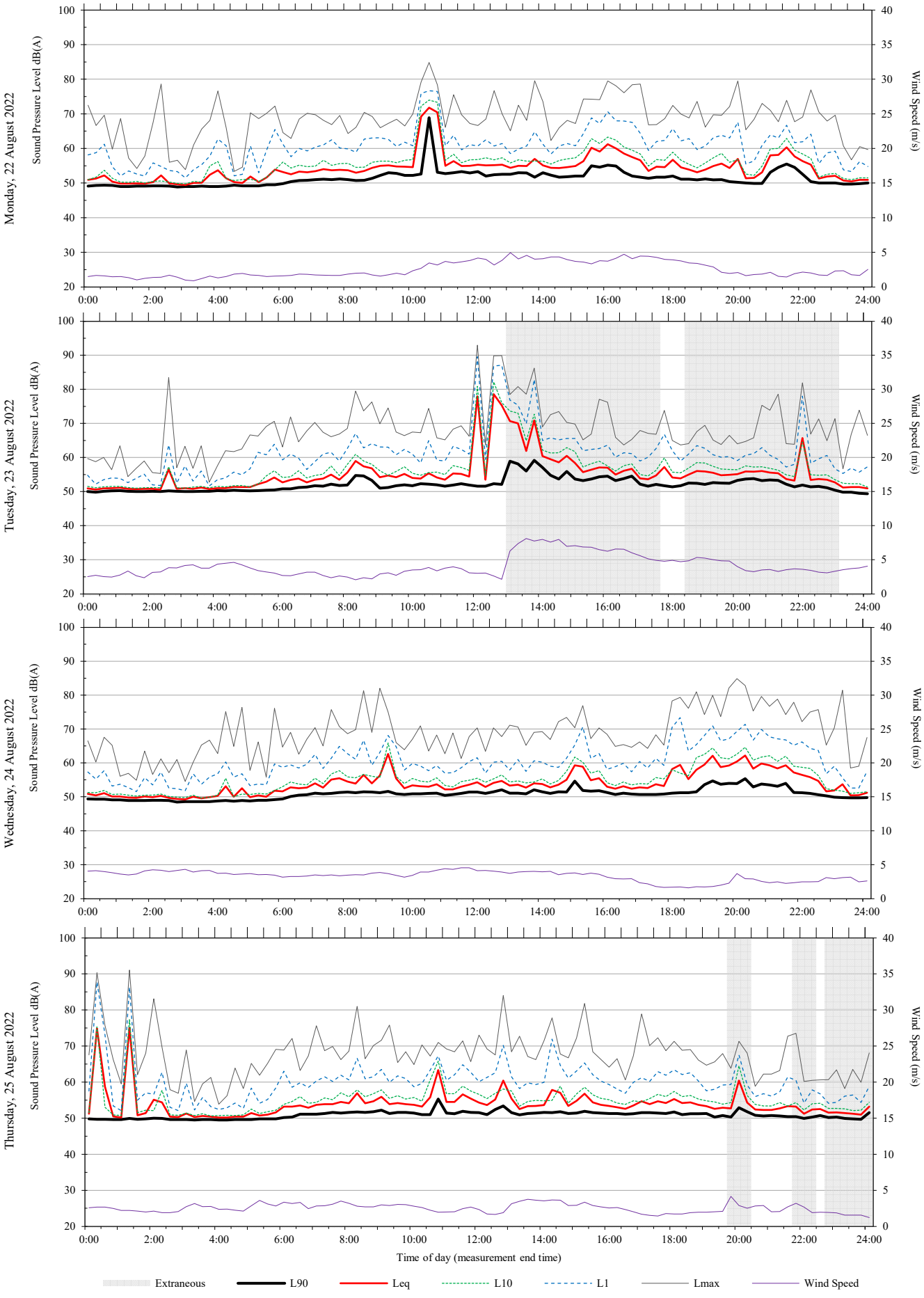
Unattended monitoring: St Andrews (Free Field)

ARUP



Unattended monitoring: St Andrews (Free Field)

ARUP



Unattended monitoring: St Andrews (Free Field)

ARUP