Health Infrastructure

Royal Prince Alfred Hospital

Molecular Imaging Extension and B63/64 lift
Acoustic Assessment Report

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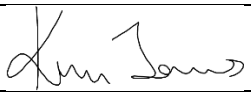
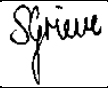
		Signature			

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Contents

Appendices

1 Introduction

Arup has been engaged by Health Infrastructure NSW to undertake an acoustic assessment to support Review of Environmental Factors (REF) for the Enabling / Early Works related to the proposed Molecular Imaging Extension and B63/64 lift at the Royal Prince Alfred Hospital (RPAH).

The works are being carried out under State Environmental Planning Policy (Infrastructure) 2007 [1] as 'Development without Consent' by Health Infrastructure NSW 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 required if demolition is proposed outside of standard construction hours (i.e. 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]

2 Scope

The scope of these early / enabling works includes the following:

Molecular Imaging (MI)

Relocation of the MI department within the RPAH main building. 2 level extension to B89, attaching to the rear of B63.

Scope of works includes:

- Level 6: various laboratory spaces, plant room, cold shell for future laboratories
- Level 7: PET CT and MR rooms, patient uptake rooms, plant room
- External glass lift between B63 and B64, servicing Levels 5-7
- New lift lobby and access to Building 63
- Installation of Photovoltaic panels on Level 8 Roof

Locations of works are shown in Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5.

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

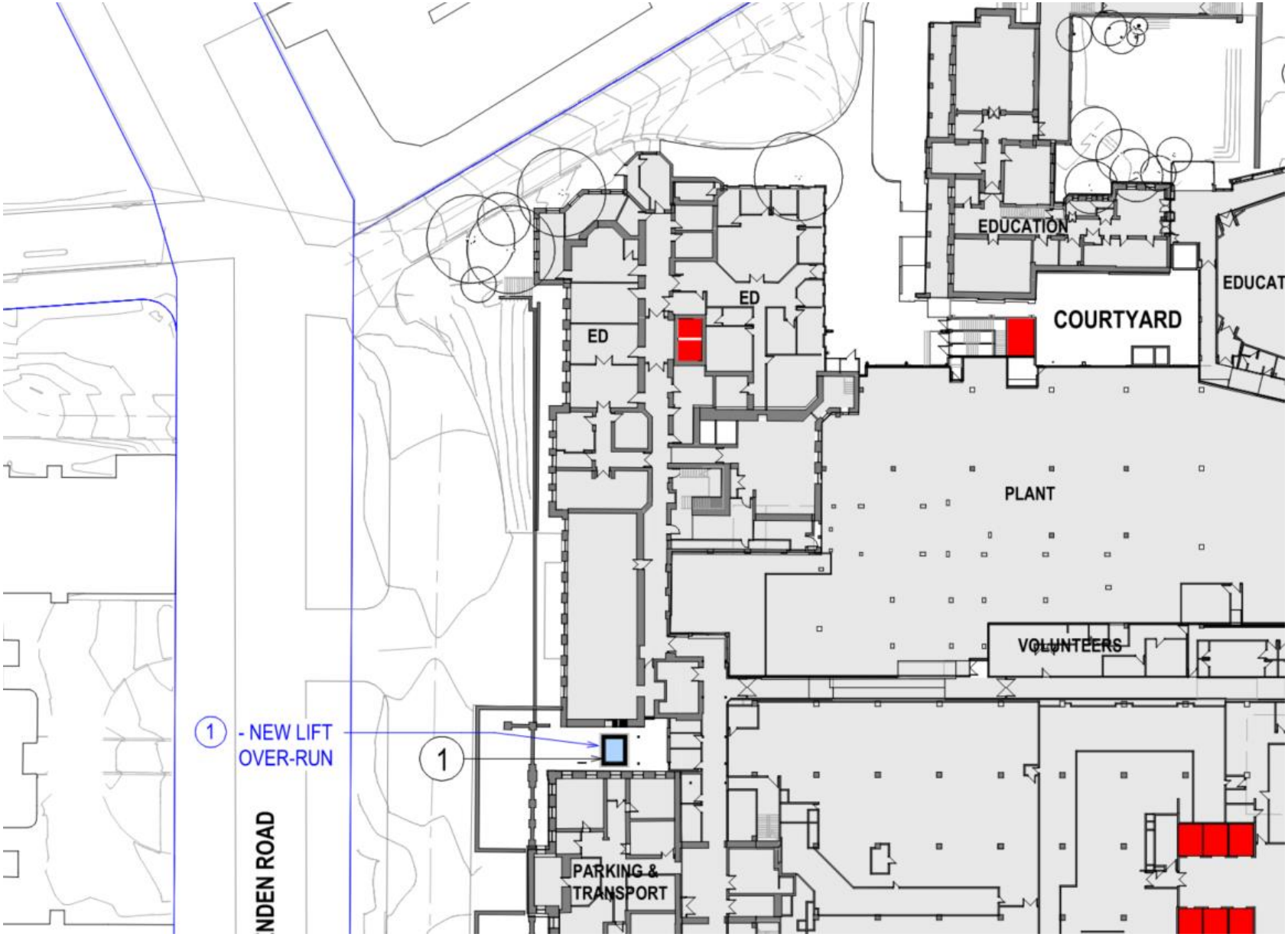

Figure 1: General arrangement plan of Level 4 of RPAH Main Building. Location of works for this package are shown in blue and green; other areas are out-of-scope.

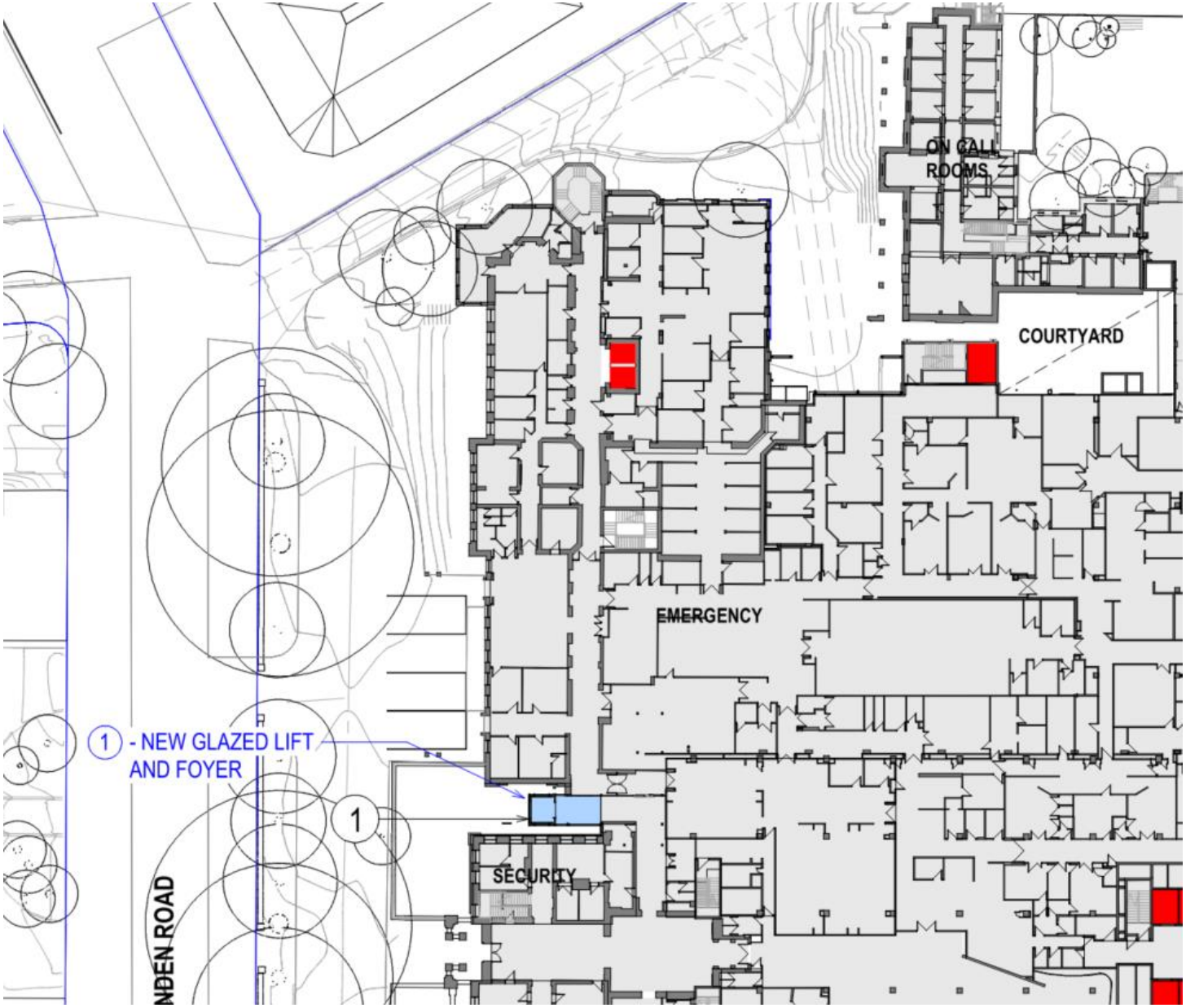

Figure 2: General arrangement plan of Level 5 of RPAH Main Building. Location of works for this package are shown in blue and green; other areas are out-of-scope.

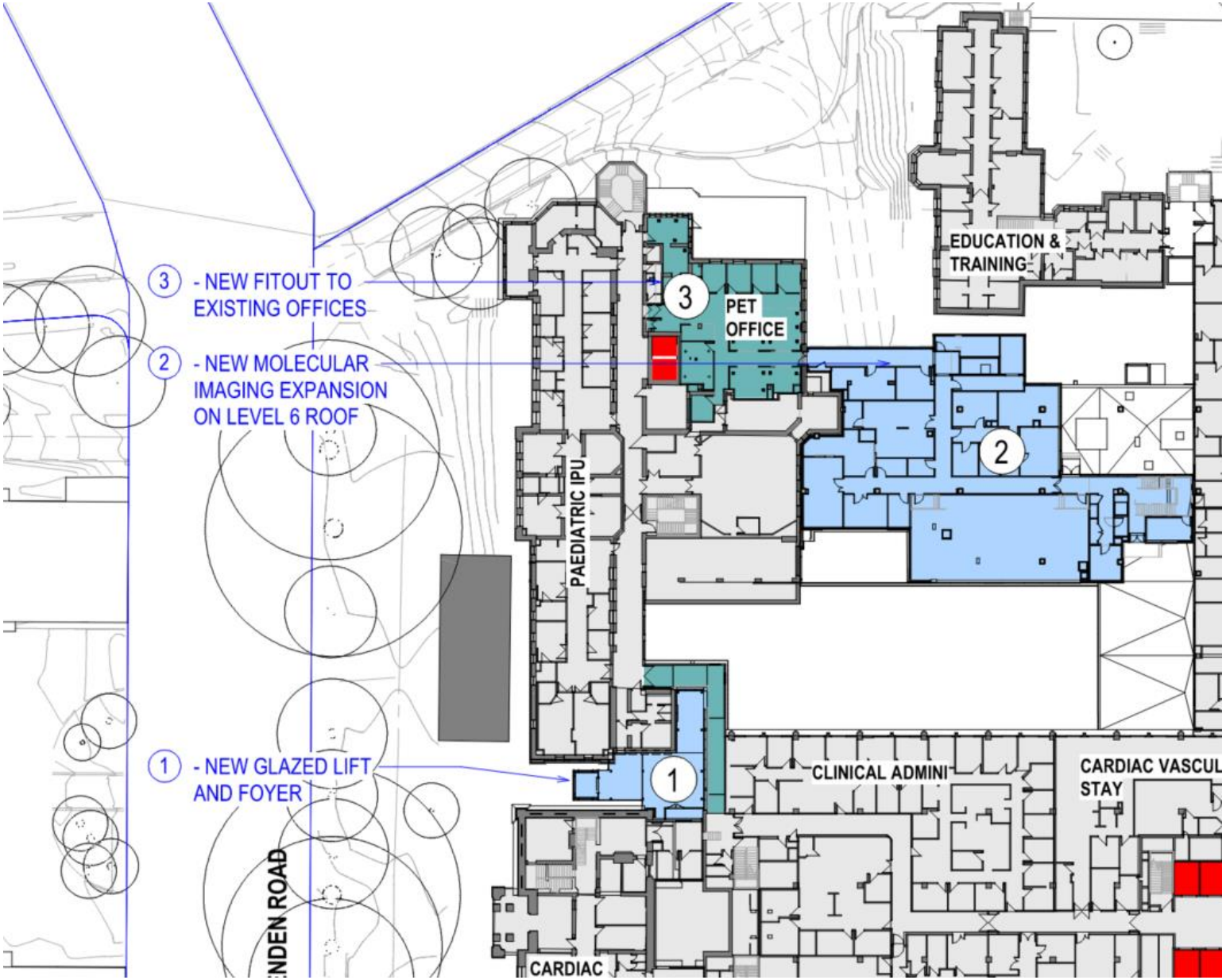

Figure 3: General arrangement plan of Level 6 of RPAH Main Building. Location of works for this package are shown in blue and green; other areas are out-of-scope.

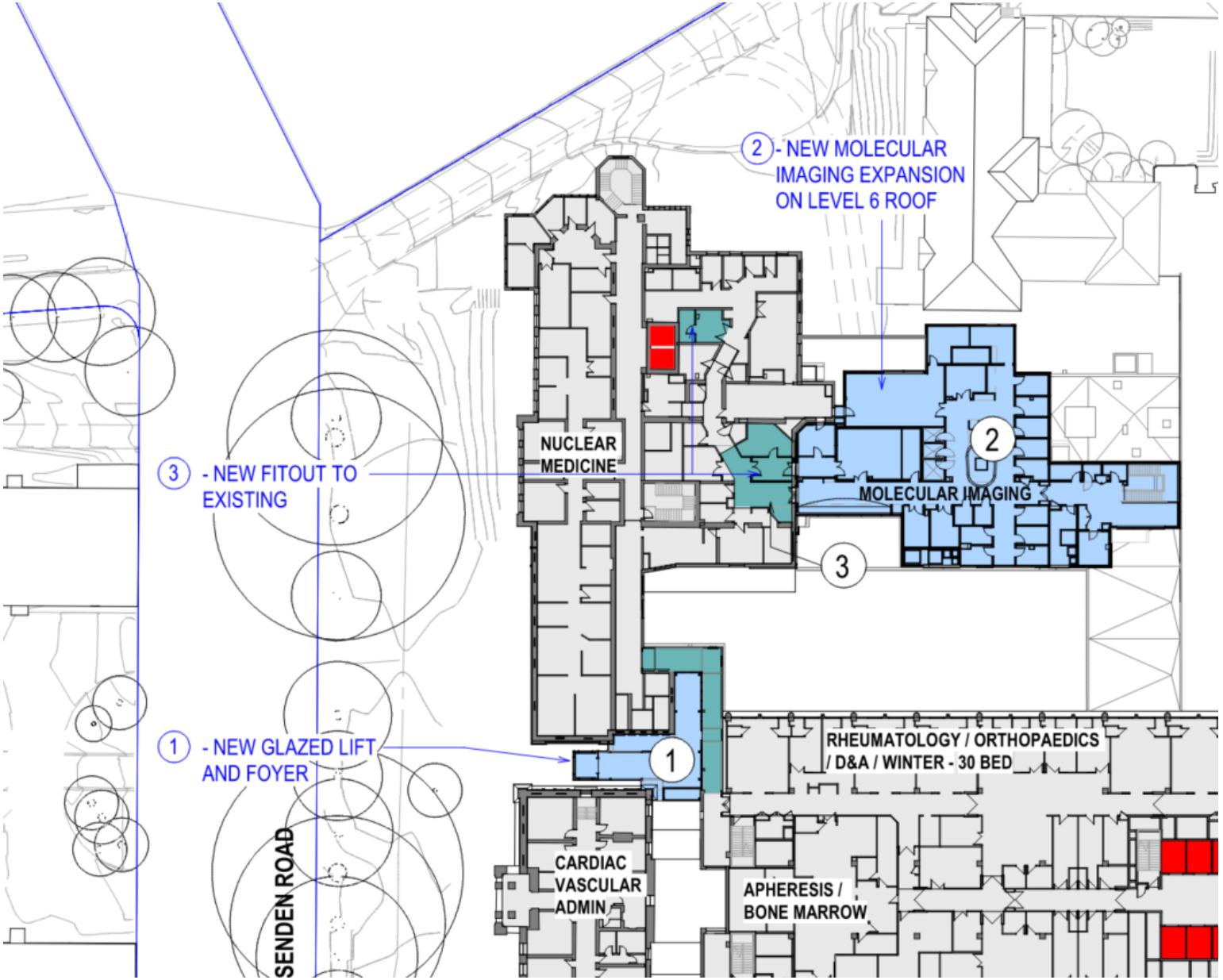

Figure 4: General arrangement plan of Level 7 of RPAH Main Building. Location of works for this package are shown in blue and green; other areas are out-of-scope.

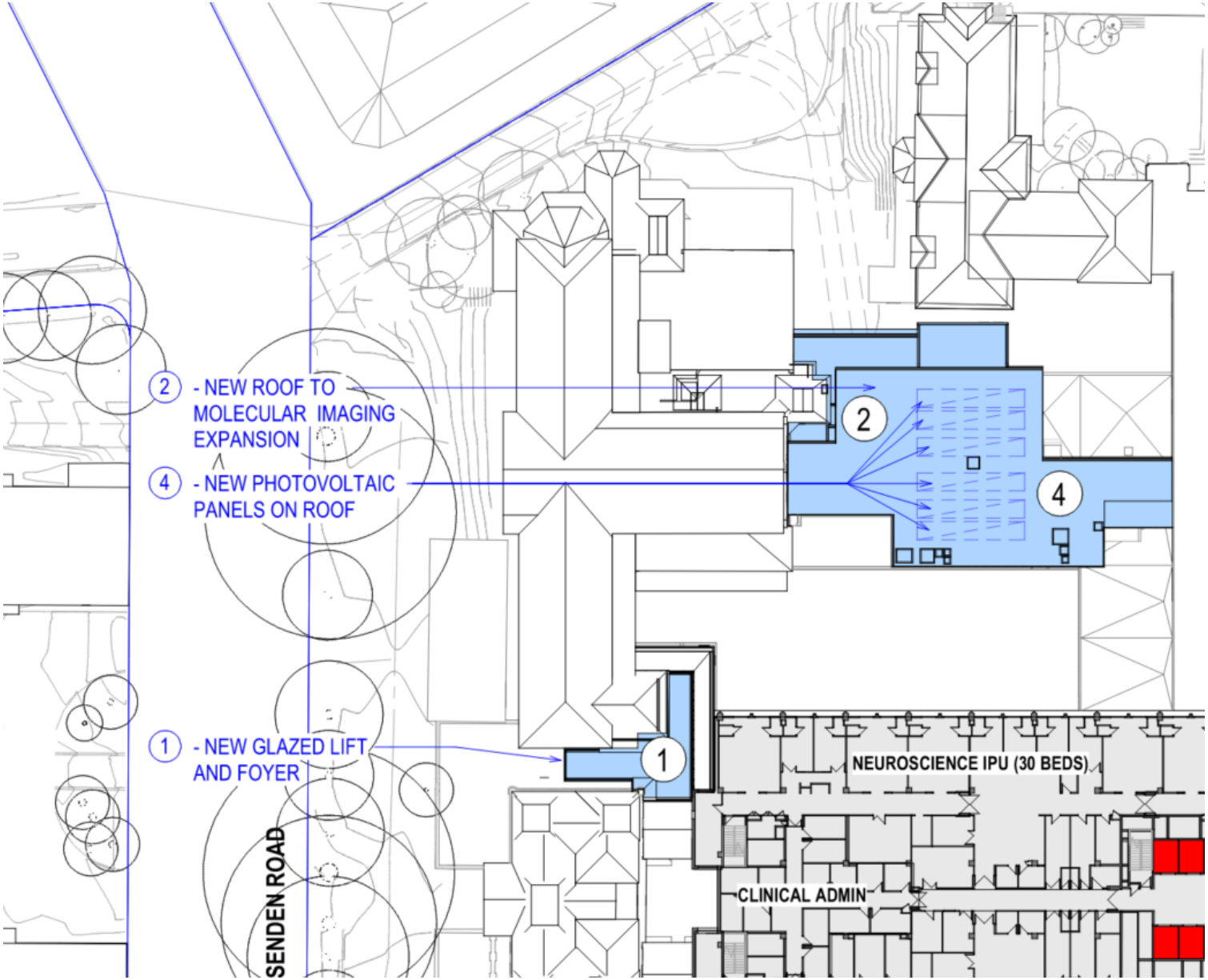

Figure 5: General arrangement plan of Level 8 of RPAH Main Building. Location of works for this package are shown in blue and green; other areas are out-of-scope.

2.1 Site description

This section of the report references the Camperdown Health Education & Research Precinct (CHERP) RPAH Campus Plan [9].

The RPA campus is located within Camperdown, Sydney, between the Leichhardt, Inner West and City of Sydney Local Government Areas. It sits between Sydney University to the east and the residential area of Camperdown to the West. The campus is bisected by Missenden Road, which runs north - south, dividing the East Campus from the West Campus. The northern boundary of the campus is defined by the Queen Elizabeth II Rehabilitation Centre located on the corner of Missenden Road and Lucas Street. The southern extent of the campus is defined by Carillon Avenue. Church Street forms the western boundary.

The subject site for this REF is The RPAH main building. This subject 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, including those noted in Table 1.

Table 1: Heritage buildings in the RPA campus

Building	Heritage Status
Admission Block	Exceptional significance
Albert and Victoria Pavilion	High significance
King George V Memorial Hospital	High significance
Morgue and Chapel	Chapel of Low significance
Immunology building	Exceptional significance
Gloucester House	High significance
Resident Medical Officer's Quarters (Nurses Home)	Significance not rated
Boiler House	Moderate significance

3 Surrounding land uses

The nearest most potentially affected off-site land uses surrounding the development have been identified in Figure 6, 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 2 summarises the location of the nearest most potentially affected receivers.

Table 2: Receiver locations

ID	Receiver	Description
SS	Hospital wards within the subject site, i.e. RPA Main Building, Centenary Institute, 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
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
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

Figure 6: Site, receiver and noise monitoring locations

4 Existing noise environment

Unattended noise monitoring was undertaken at St. Andrew's College by Resonate in 2018 for the SEARS Noise and Vibration Assessment for the Susan Wakil AO Health Building ("the Resonate report") [10].

The background noise levels presented in the Resonate report were assessed against attended noise measurements that were obtained during the daytime period at Building 12 and St John's College by Acoustic Studio in 2012 and presented in the report *Royal Prince Alfred Hospital North West Precinct Redevelopment Main Works Contract - Excavation & Construction Noise And Vibration Management* [11].

The attended daytime noise levels at Building 12 and St. John's College from the between 1 and 6 dB higher than the unattended daytime noise levels presented in The Resonate Report. Therefore, the background noise levels measured at St. Andrew's College are more conservative and expected to be representative of the current environment and have been adopted in this report.

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.

The long-term measurement locations are outlined in Table 3 and shown in Figure 6.

Table 3: Noise monitoring locations

ID	Address
L1[1]	St. Andrew's College

Notes:
1. Long-term noise monitoring results obtained from the Resonate report

4.2 Long-term noise measurement results

Long-term noise monitoring was carried out from Wednesday, 10 January 2018 to Wednesday, 17 January 2018.

Table 4 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 [3].

Table 4: Long-term noise monitoring results, dB(A)

Location	**Time period**	**Rating background noise levels, dBL_{A90}**	**Ambient dBL_{Aeq} noise levels**
L1	Day	50	58
	Evening	50	54
	Night	47	52

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)

5 Operational noise criteria

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.

The operational noise impact on the subject site (SS) is not required to be assessed, but a discussion of potential impacts on the SS is provided for information only in Section 5.2.1.

5.1 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.

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 5.

Table 5: NPfI Recommended Amenity Noise Levels (RANLs)

Receiver	**Noise amenity area**	**Time of Day**	**Recommended amenity noise levels (RANLs) L_{Aeq}, dB(A)**
Residential	Rural	Day	50
		Evening	45
		Night	40
	Suburban	Day	55

Receiver	Noise amenity area	Time of Day	Recommended amenity noise levels (RANLs) L_{Aeq}, dB(A)
		Evening	45
		Night	40
	Urban	Day	60
		Evening	50
		Night	45
Hotels, motels, caretakers' quarters, holiday accommodation, permanent resident caravan parks	See column 4	See column 4	5 dB(A) above the recommended amenity noise level for a residence for the relevant noise amenity area and time of day
School classroom - internal	All	Noisiest 1-hour period when in use	35 (see notes for table)
Hospital ward Internal External	 All All	 Noisiest 1-hour Noisiest 1-hour	 35 50
Place of worship – internal	All	When in use	40
Area specifically reserved for passive recreation (e.g. national park)	All	When in use	50
Active recreation area (e.g. school playground, gold course)	All	When in use	55
Commercial premises	All	When in use	65
Industrial premises	All	When in use	70
Industrial interface (applicable only to residential noise amenity areas)	All	All	Add 5 dB(A) to recommended noise amenity area

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 recommended amenity noise levels (RANLs) represent the objective for **total** industrial noise at a receiver location, whereas the **project amenity noise level (PANL)** represents the objective for noise from a **single** industrial development at a receiver location.

To ensure that any new industrial source of noise is within the RANLs for an area, the PANL applies for each new source of industrial noise as follows:

- *Project Amenity Noise Level (PANL) = Recommended Amenity Noise Level (RANL) minus 5 dB(A)*

The NPfI also provides the following exceptions to the above method for deriving the project amenity noise level:

1. *In areas with high traffic noise levels.*
2. *In proposed developments in major industrial clusters.*
3. *Where the resultant project amenity noise level is 10 dB or more lower than the existing industrial noise level. In this case the project amenity noise levels can be set at 10 dB below existing industrial noise levels if it can be demonstrated that existing industrial noise levels are unlikely to reduce over time.*
4. *Where cumulative industrial noise is not a necessary consideration because no other industries are present in the area, or likely to be introduced into the area in the future. In such cases the relevant amenity noise level is assigned as the project amenity noise level for the development.*

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 6 summarises the RANLs and the PANLs applicable for the project.

Table 6: 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	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

Receiver	Indicative Noise Amenity Area	Time of day[1]	Recommended Amenity Noise Level (RANL) $L_{Aeq(period)}$	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$
C1, C2, C3	N/A[2]	When in use	65	60
SS, H1, H2, H3, H4, H5	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 5.

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 receiver.

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 7.

Table 7: 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 Noise Trigger Level (PNTL) $L_{Aeq(15min)}$	Sleep Disturbance $L_{Amax(night)}$
R1, R2	Day	55	55	55	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 Noise Trigger Level (PNTL) $L_{Aeq(15min)}$	Sleep Disturbance $L_{Amax(night)}$
	Evening	55	45	48	N/A[2]
	Night	52	40	43	62
E1, E2, E3	Classroom – noisiest 1 hour, when in use	N/A[2]	35 (internal) 45 (external)	38 (internal) 48 (external)	N/A[2]
A1, A2, A3	When in use	N/A[2]	50	53	N/A[2]
C1, C2, C3	When in use	N/A[2]	60	63	N/A[2]
SS, H1, H2, H3, H4, H5	Hospital ward – noisiest 1 hour	N/A[2]	30 (internal) 45 (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

5.2 Operational noise review

5.2.1 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 (e.g. REF).

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 7).
- Building services noise emission 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.

Risers and louvres

There will be some diversion of ventilation risers. The air intake and discharge locations on the roof of the existing RPAH building will therefore need to be relocated.

It is not anticipated that the relocation of ventilation systems will result in any significant increase in noise levels at the nearest sensitive external receivers but an increase in noise level may be experienced by internal receivers within the subject site. It is expected that noise mitigation measures can readily be incorporated into the design if required.

Plant equipment

New plant serving the MI department include:

- Five (5) Air Handling Units within the plantroom on Level 6
- A new heat pump on the Level 6 roof
- New Condenser Units on the Level 6 roof
- New Air-Cooled Process Cooling Chillers on the roof (Level 8)
- New Smoke Exhaust Fans and Ventilation Fans on the roof (Level 8)

Building services equipment has not been selected at this early stage of design.

It is expected that any necessary noise control measures required for plant (as listed above) can be readily integrated into the design to control noise levels at nearby external receivers and for receivers within the RPAH main building.

Vehicular movements on site

As these works involve the relocation of an existing hospital department to another location within the same building, it is expected that vehicular movements and traffic noise levels will not significantly increase as a result of the proposed works.

6 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.

6.1 Construction noise criteria – external receivers

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 early / enabling 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.

6.1.1 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 8 and in Table 9 respectively.

Table 8: 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 9: 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]
Places of worship	Internal noise level	45 dB(A)
Active recreation areas	External noise level	65 dB(A)
Passive recreation areas	External noise level	60 dB(A)
Community centres	Depends on the intended use of the centre.	Refer to the 'maximum' internal levels in AS2107 for specific uses.
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

Notes:

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.

6.1.2 Project construction noise targets

Based on the measured background noise levels presented in Table 4 and the criteria methodology presented above, Table 10 outlines the construction noise management levels applicable to demolition, excavation and construction.

Table 10: 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	External	60	75	52	57
E1, E2, E3	Internal External[3]	45 55	-	45 55	-
A1, A2, A3	External	65	-	65	-
C1, C2, C3	External	70	-	70	-
SS, H1, H2, H3, H4, H5	Internal External[3]	45 55	-	45 55	-

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

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

6.2 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 6.6.2 and 6.8.4.

6.3 Construction vibration criteria

6.3.1 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 11.

Table 11: 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 12 reproduces the 'Preferred' and 'Maximum' values for continuous and impulsive vibration from Table 2.2 of the Guideline.

Table 12: 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

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

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

Table 13: 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

6.3.2 Structural damage

6.3.2.1 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.

6.3.2.2 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 14 sets out the BS7385 criteria for cosmetic, minor and major damage.

Table 14: 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		

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
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.

6.3.2.3 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 15, 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 15: 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]

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

6.3.3 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.

Regarding existing hospital buildings/facilities on site at RPA, an investigation of all vibration sensitive equipment should take place during development of the detailed Construction Noise and Vibration Management Plan.

6.3.4 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 16).

Table 16: 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 [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.

6.4 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 17 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.

The works involve:

- the construction of an extension on the existing roof of the RPAH main building and related works such as the diversion of ventilation systems, installation of new plant, etc. (affecting external and internal receivers)
- the construction of a new glass lift on the western side of the building between Levels 4 – 7 (affecting external and internal receivers)
- the fit-out of the new extension (affecting internal receivers)

As the fit-out works affect internal receivers only, a quantitative assessment is not provided. Discussion of impacts on internal receivers is covered in Section 6.6.2.

It is emphasised that all the equipment listed in Table 17 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 17.

Table 17: 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$_{Aeq}$**
Construction of extension, glass lift and related works	Demolition works, construction works, removal of waste	Concrete pump truck	113	112
		Concrete saw	122	121
		Crane (Franna)	98	97
		Crane (Mobile)	113	112
		Generator (diesel)	113	112
		Handheld tools – electric	110	109
		Jack Hammer	121	120
Removal of waste	Removal of waste	Dump truck	117	116

6.5 Construction hours

In addition to the ICNG [3] recommended standard construction hours, approval is being sought to extend construction hours on Saturdays to commence at 7 am.

In addition to this slight extension, it is understood that out-of-hours works (OOHW) will be required, because the extension is above the emergency department (ED) and access will be required at times to minimise impact on ED operations. Proposed hours of works are presented in Table 18.

Table 18: Proposed construction hours

Day	Standard construction hours	Proposed construction hours
Monday to Friday	7 am to 6 pm	7 am to 6 pm + OOHW as required for access
Saturday	8 am to 1 pm	7 am to 1 pm + OOHW as required for access
Sunday and public holiday	No work	No work other than OOHW as required for access

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 and given that slightly longer hours shorten the construction duration for an essential service site, Arup recommends that approval be granted for the extension to operating hours on Saturday mornings, on the condition that the works being undertaken are low noise activities only (such as site preparation works). In particular, the following activities are excluded:

- Demolition works

Justification for other ad hoc OOHW

On the basis of point 5 and the need to minimise impact on staff and patients in the ED and other areas of the hospital, Arup recommends that approval be granted

for OOHW which cannot take place during standard hours, including demolition works where deemed necessary.

6.6 Construction noise predictions

6.6.1 Noise assessment – external receivers

Predicted construction noise levels, considering standard construction hours and outside standard construction hours, are tabulated in Table 19. 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 the waste removal assessment, it has been conservatively assumed that the dump truck is located adjacent to the subject site, on the street, nearest to each receiver. This results in a very conservative noise level prediction.

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

Table 19: 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**	Construction of extension, glass lift and related works	Waste removal
During standard hours				
R1	60	75	82	90
R2	60	75	74	90
E1	45[1]	-	68[2]	76[2]
E2	45[1]	-	67[2]	84[2]
E3	45[1]	-	48[2,3]	46[2,3]
A1	65	-	75	75
A2	65	-	73	71
A3	65	-	76	71
C1	70	-	83	90
C2	70	-	80	94

Receiver	NML, dBL$_{Aeq(15\ min)}$		Predicted sound level at receiver, dBL$_{Aeq(15\ min)}$	
	Noise affected	Highly noise affected	Construction of extension, glass lift and related works	Waste removal
C3	70	-	74	70
H1	45[1]	-	65[2]	84[2]
H2	45[1]	-	68[2]	72[2]
H3	45[1]	-	65[2]	61[2]
H4	45[1]	-	59[2]	39[2,3]
H5	45[1]	-	63[2]	61[2]
Outside standard hours[4]				
R1	52	57	82	90
R2	52	57	74	90
E1	45[1]	-	68[2]	76[2]
E2	45[1]	-	67[2]	84[2]
E3	45[1]	-	48[2,3]	46[2,3]
A1	65	-	75	75
A2	65	-	73	71
A3	65	-	76	71
C1	70	-	83	90
C2	70	-	80	94
C3	70	-	74	70
H1	45[1]	-	65[2]	84[2]
H2	45[1]	-	68[2]	72[2]
H3	45[1]	-	65[2]	61[2]
H4	45[1]	-	59[2]	39[2,3]
H5	45[1]	-	63[2]	61[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. Assessment assumes full construction and demolition works being undertaken out of hours

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 and outside standard hours for most receivers, with residential receiver R1 and R2 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 (in particular for the waste removal scenario) and that noise mitigation measures could be undertaken to further mitigate the impact on nearby receivers.

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.

6.6.2 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 17, it is expected that occupants of the RPAH main building (especially the occupants of the spaces surrounding the existing Level 4 rooftop) 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 6.2, 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 6.8.4), are implemented. The CNVMP should outline steps to minimise the impact on staff and patients as far as practicable.

6.7 Construction vibration

The nearest off-site vibration sensitive receiver locations are presented in Table 20. Distances are based on the “Construction of extension, glass lift and related works” scenario, as vibration levels from waste removal are expected to be minimal.

Table 20: Nearest off-site vibration receivers

ID	Description	Type of receiver	Approx. distance from structure to location of works, m
SS	Subject site, i.e. Building 12	Healthcare	0
R1	St. John’s College	Residential	54

ID	Description	Type of receiver	Approx. distance from structure to location of works, m
E1	CreateSpace and Susan Wakil Health Building, University of Sydney	Classroom	86
H2	Building 12	Healthcare	84
C1	7-11 Camperdown	Commercial	50
C2	King George V Building (hospital administration)	Commercial	74

6.7.1 Vibration – minimum working distances

Recommended minimum working distances for vibration intensive plant, which are based on international standards and guidance, are provided in Table 21. 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 21: 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 2)	Residential and light commercial buildings BS 7385 Line 2 - 7.5 mm/s (See note 2)	Unsound structures DIN 4150 Line 3 - 3 mm/s	
Jackhammer	Hand-held	1 (nominal)	1 (nominal)	3	5
Truck movements	-	-	-	-	10

Notes:

1. Based on TRL document [13] using Godio et al formula, equation 24
2. Where vibration might give rise to resonant responses in structures

6.7.2 Vibration assessment

Based on the working distances for the vibration-intensive plant listed in Table 20, nearby off-site sensitive receivers are not expected to be impacted from a structural or human comfort perspective.

It is expected that the subject site may be affected by vibration-intensive works. The subject site contains vibration-sensitive equipment, such as MRI machines.

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.

6.8 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.

6.8.1 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.

6.8.2 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.

6.8.3 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

6.8.4 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.

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 at Building 12, and with the head contractor and their subcontractors.

6.8.5 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 6.7.1.

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.

7 Conclusion

Arup has completed an acoustic and vibration assessment for REF submission for the proposed Early / Enabling Works for the Molecular Imaging Extension and B63/64 lift as part of the RPA Hospital Redevelopment.

Regarding operations, the assessment concludes that the proposed development is capable of satisfying the standard NSW EPA noise policy requirements. Notwithstanding, further detailed acoustic assessment is warranted during the design development, particularly concerning building services noise control.

Regarding construction, the proposed works are predicted to result in exceedance of the relevant noise management levels at most off-site assessment locations and accordingly mitigation and management procedures will need to be considered for the works. However, 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.

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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 22.

Table 22: Assumed distances from location of works to nearby sensitive receivers

Receiver	Distance (m)	
	Construction of extension, glass lift and related works	Waste removal
R1	54	8
R2	137	8
E1	86	12
E2	103	5
E3	152	68
A1	120	45
A2	161	68
A3	116	70
C1	50	8
C2	74	5
C3	137	80
H1	130	5
H2	84	20
H3	126	67
H4	261	148
H5	163	66