World Class End of Life Care – Tamworth Hospital

REF - Acoustic Assessment

NSW Health Infrastructure
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North Sydney NSW 2059

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1 INTRODUCTION

As part of the Review of Environmental Factors (REF) assessment, Pulse White Noise Acoustics (PWNA) has undertaken a noise and vibration impact assessment for the World Class End of Life Facility (WCEoLF) at Tamworth Hospital.

Therefore, this report discusses the operational and construction acoustic criteria required to conduct this assessment.

The report summarises the conceptual acoustic treatments required to achieve compliance with the operational criteria.

Additionally, this report also addresses the potential acoustic impacts that construction activities might have onto nearest impacted receivers which are within the Tamworth Hospital campus. The assessment of these impacts is indicative at this stage.

A list of acoustic terminology used in this report is included in Appendix A of this report.

1.1 Project Description

The WCEoLF will be constructed as an extension to the Palliative Care Unit in the Acute Services Building (ASB). The WCEoLF will be located at Ground Level (i.e. Level 00).

This facility will comprise the following premises within a one-storey building:

- 6 palliative care bedrooms with ensuites
- 1 overnight stay bedroom with ensuite
- Lounge & dining rooms
- Private enclosed office
- Meeting rooms
- Office workstations
- Corridor (link) and circulation areas
- Storage and medication rooms
- Dirty utility, disposal, cleaner, laundry rooms
- Toilets
- Outdoor courtyard

1.2 Site Layout

As mentioned in Section 1.1, the WCEoLF will be situated in the north-western corner of the ASB, as an extension to the existing Palliative Care Unit at Ground Level.

We also note the WCEoLF will be located within the Tamworth Hospital Campus. As a result, the facility will be mostly surrounded by the following hospital premises (refer to Figure 1):

- Main Hospital Building: The ASB is situated immediately south of the WCEoLF. At Ground Level, the nearest impacted hospital facilities are bedrooms and ward areas corresponding to the Palliative Care Unit and Medical Inpatient Unit.

  Overlooking the WCEoLF from Levels 1, 2 and 3; the nearest impacted facilities mostly comprise additional bedrooms and ward areas which form part of the Surgical Inpatient Unit, ICU/HDU, and Paediatric Inpatient Unit.

  The WCEoLF is also in direct line of sight to a plant room which is located at the west end of Level 1, ASB.

- Main Hospital Building: The Emergency Department and Maternity Wards are located west of the WCEoLF; where we found the following hospital premises as nearest impacted receivers:

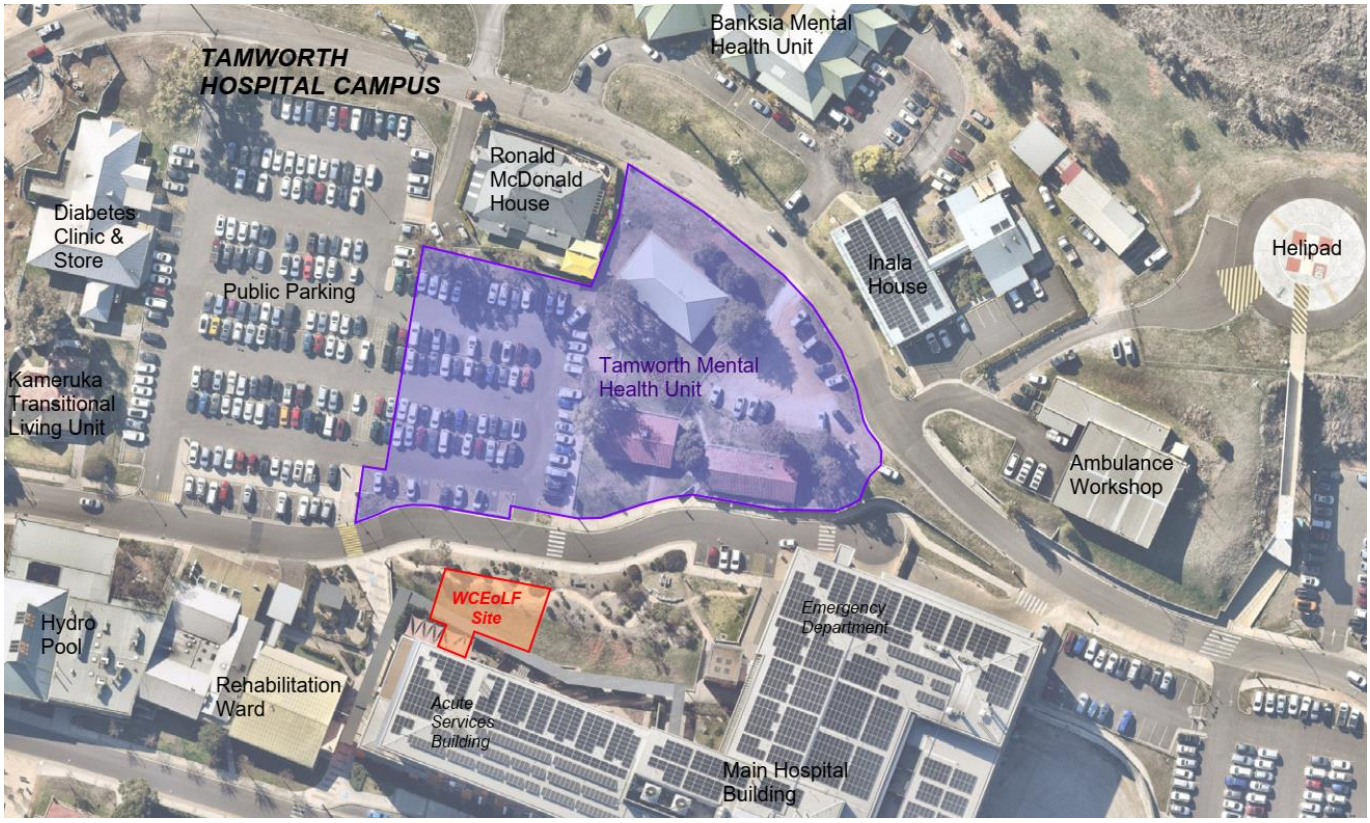
    - Ground Level: Central Sterile Services Department (CSSD).
    - Level 1: Emergency Department comprising corridors, consultations rooms, ward areas.
    - Level 2: Operating Suites comprising corridors and operating theatres.
    - Level 3: Maternity Inpatient Unit comprising corridors, bedrooms, birthing rooms.

- Existing Rehabilitation Ward and Hydrotherapy Pool, which are located west of the WCEoLF (at approximately 14m from the project site).

- Tamworth Mental Health Unit (TMHU), which is under construction, will be located north of the WCEoLF (at approximately 15m from the project site). The nearest impacted facilities within the TMHU mostly comprise bedrooms, corridors, lounges, courtyards and outdoor gardens, meeting rooms and workspaces.

Figure 1 also indicates that the hospital helipad is located at approximately 180m north-east from the project site.

Figure 1 Site layout



2 OPERATIONAL ACOUSTIC CRITERIA

2.1 External Noise Emission Criteria

2.1.1 Operational Criteria

Since most of the nearest impacted receivers are considered non-residential (i.e. hospital premises as discussed in Section 1.2), then we consider that a long-term noise survey is not required to determine the external noise level criteria. Instead, these criteria are established based on the amenity noise level criteria discussed in the NSW Noise Policy for Industry (NSW NPI).

These criteria are nominated for the purpose of determining the operational noise limits for mechanical plant associated with the development which can potentially affect noise sensitive receivers. These are shown in bold text in Table 1.

Table 1 External noise level criteria

Location	Time of Day	Project Amenity Noise Level, $L_{Aeq, period}$ (dBA)	Measured $L_{A90, 15\ min}$ (RBL) [1] (dBA)	Measured $L_{Aeq, period}$ Noise Level (dBA)	Intrusive $L_{Aeq, 15\ min}$ Criterion for New Sources (dBA)	Amenity $L_{Aeq, 15\ min}$ Criterion for New Sources (dBA) [3,4]
Hospital Ward (External)	Noisiest 1 hour	45	-	-	-	**48**

Note 1: L_{A90} Background Noise or Rating Background Level
Note 2: Project Noise Trigger Levels are shown in bold
Note 3: This is based on the assumption that the existing noise levels are unlikely to decrease in the future
Note 4: According to Section 2.2 of the NSW NPI, the $L_{Aeq, 15\ minutes}$ is equal to the $L_{Aeq, period}$ + 3 dB

2.1.2 Emergency Plant

For emergency plant, such as stand-by generators, which only operate occasionally (such as emergencies and maintenance operations), the NSW NPI allows for modifying factors that can be subtracted from the predicted noise levels. These modifying factors should be applied prior to assessing against the external noise level criteria. These duration modifying factors are summarised in Table 2 below.

Table 2 Modifying factors for duration

Allowable Duration of Noise (one event in any 24 hour period)	Allowable Exceedance at Receiver for the Period of Noise Event	
	Daytime and Evening (7am – 10pm)	Night time (10pm – 7am)
1 to 2.5 hours	2	Nil
15 minutes to 1 hour	5	Nil
6 minutes to 15 minutes	7	2
1.5 minutes to 6 minutes	15	5
Less than 1.5 minutes	20	10

Note: Where the duration of the noise event is smaller than the duration of the project trigger noise level (PNTL), that is, less than 15 minutes, the allowable adjusted project noise trigger level (APNTL) is derived as follows:

$$APNTL = 10\log((10^{\frac{PNTL}{10}}\ x\ (\frac{900 - duration}{900})) + (10^{\frac{PNTL+allowable\ exceedance\ in\ table\ above}{10}}\ x\ duration))$$

2.2 Internal Noise Level Criteria

2.2.1 The State Environmental Planning Policy (Transport & Infrastructure) 2021

The State Environmental Planning Policy (Infrastructure) 2007 (Infrastructure SEPP) provides conditions for noise intrusion generated by road and rail traffic noise. The guidelines for the assessment of noise intrusion are discussed in the document prepared by the Department of Planning of the NSW Government and which is titled *"Developments Near Rail Corridors and Busy Roads – Interim Guideline"* (DNRC & BR-IG).

The DNRC & BR-IG applies to development adjacent to rail corridors and busy roads. It can also provide a useful guide for all development that may be impacted by, or may impact on, rail corridors or busy roads.

Sections 2.119 and 2.120 of the SEPP 2021, state the following regarding traffic noise or vehicle noise emissions:

2.119 Development with frontage to classified road

(2) The consent authority must not grant consent to development on land that has a frontage to a classified road unless it is satisfied that -

(c) The development is of a type that is not sensitive to traffic noise or vehicle emissions, or is appropriately located and designed, or includes measures, to ameliorate potential traffic noise or vehicle emissions within the site of the development arising from the adjacent classified road.

2.120 Impact of road noise or vibration on non-road development

(1) This section applies to development for any of the following purposes that is on land in or adjacent to the road corridor for a freeway, a tollway or a transitway or any other road with an annual average daily traffic volume of more than 20,000 vehicles (based on the traffic volume data published on the website of TfNSW) and that the consent authority considers is likely to be adversely affected by road noise or vibration:

(a) residential accommodation,

(b) a place of public worship,

(c) a hospital,

(d) an educational establishment or centre-based child care facility

(3) If the development is for the purposes of residential accommodation, the consent authority must not grant consent to the development unless it is satisfied that appropriate measures will be taken to ensure that the following L_{Aeq} levels are not exceeded:

(a) In any bedroom in the residential accommodation—35 dBA at any time between 10 pm and 7 am,

(b) Anywhere else in the residential accommodation (other than a garage, kitchen, bathroom or hallway)—40 dBA at any time.

In accordance with Clause 2.120 of the Transport & Infrastructure SEPP, for the purpose of residential accommodation, the consent authority must be satisfied that appropriate measures will be taken to ensure that the following L_{Aeq} levels are not exceeded (with windows and doors closed):

- In any bedroom in the building – 35 dB $L_{Aeq\ (9hour)}$ between 10:00 pm and 7:00 am
- Anywhere else in the building (other than a garage, kitchen, bathroom or hallway) – 40 dB L_{Aeq} at any time (i.e. $L_{Aeq\ (15hour)}$ and $L_{Aeq\ (9hour)}$).

However, we understand that the WCEoLF at Tamworth Hospital, is not considered as residential accommodation, therefore the requirements discussed in the Transport & Infrastructure SEPP do not apply.

2.2.2 Project Specific Requirements

However, as part of the project specific requirements (i.e. ESD evaluation tool), it will be required for the WCEoLF to achieve compliance with internal noise level criteria in accordance with the Engineering Services Guide (ESG), issued by NSW Health.

Hence, these criteria will require that the resulting overall internal noise level should satisfy the maximum noise levels in Column A of Table 15 in the ESG. The overall noise level is the aggregate of the external noise intrusion and the noise emissions from mechanical services. In this instance, external noise intrusion excludes intermittent noise events and those generated by helicopter flight events.

2.3 National Construction Code 2022

Based on report titled *"BCA Access Assessment Report, Schematic Design Report, World Class End of Life Program, Tamworth Hospital"* (revision 2, dated 28 November 2024, issued by BMG), we understand that the proposed facility is classified as follows:

- Class 3: overnight bedroom.
- Class 9a: hospital, patient care.

Since the existing ASB already includes overnight rooms, then the proposed overnight room within the WCEoLF is classified as a Class 3 facility. As such, this overnight room is subject to the sound insulation requirements stated in the National Construction Code 2022 (NCC 2022) for class 3 accommodation. These requirements are summarised in Table 3.

Table 3 NCC 2022, sound insulation requirements (Class 2 and 3)

Construction	NCC 2022	
	Laboratory Performance Requirements	**Verification Method**
Walls between sole occupancy units	$R_w + C_{tr}$ not < 50	$D_{nT,w} + C_{tr}$ not < 45
Walls between a bathroom, sanitary compartment, laundry or kitchen in one sole occupancy unit and a habitable room (other than a kitchen) in an adjoining unit	$R_w + C_{tr}$ not < 50 and Must have a minimum 20 mm cavity between two separate leaves	$D_{nT,w} + C_{tr}$ not < 45 "Expert Judgment" Comparison to the "Deemed to satisfy" Provisions
Walls between sole occupancy units and a plant room or lift shaft	R_w not < 50 and Must have a minimum 20 mm cavity between two separate leaves[1]	$D_{nT,w}$ not < 45
Walls between sole occupancy units and a stairway, public corridor, public lobby or the like, or parts of a different classification	R_w not < 50	$D_{nT,w}$ not < 45
Door assemblies located in a wall between a sole-occupancy unit and a stairway, public corridor, public lobby or the like	R_w not < 30	$D_{nT,w}$ not < 25
Floors between sole-occupancy units or between a sole-occupancy unit and a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification	$R_w + C_{tr}$ not < 50 $L_{n,w}$ not > 62	$D_{nT,w} + C_{tr}$ not < 45 $L'_{nT,w}$ not > 62
Soil, waste, water supply and stormwater pipes and ductwork to habitable rooms	$R_w + C_{tr}$ not < 40	N/A
Soil, waste, water supply and stormwater pipes and ductwork to kitchens and other rooms	$R_w + C_{tr}$ not < 25	N/A
Intra-tenancy Walls	There is no statutory requirement for airborne isolation via intra-tenancy walls.	

Note 1 In this table, the overnight room in the WCEoLF is equivalent to a sole occupancy unit

2.4 Vibration Criteria – Human Comfort

Vibration effects relating specifically to the human comfort aspects of the project are taken from the guideline titled *"Assessing Vibration – A Technical Guideline"* (AVTG) This type of impact can be further categorised and assessed using the appropriate criterion as follows:

- Continuous vibration - from uninterrupted sources (refer to Table 4).
- Impulsive vibration - up to three instances of sudden impact e.g. dropping heavy items, per monitoring period (refer to Table 5).
- Intermittent vibration - such as from drilling, compacting or activities that would result in continuous vibration if operated continuously (refer to Table 6).

Table 4 Continuous vibration acceleration criteria (m/s^2) 1 Hz-80 Hz

Location	Assessment period	Preferred Values		Maximum Values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
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
		0.04	0.029	0.080	0.058
Workshops	Day or night-time	0.04	0.029	0.080	0.058

Table 5 Impulsive vibration acceleration criteria (m/s^2) 1 Hz-80 Hz

Location	Assessment period	Preferred Values		Maximum Values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
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

Table 6 Intermittent vibration impacts criteria (m/s$^{1.75}$) 1 Hz-80 Hz

Location	Daytime		Night-time	
	Preferred Values	Maximum Values	Preferred Values	Maximum Values
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

3 CONSTRUCTION ACOUSTIC CRITERIA

3.1 Construction Noise Criteria

3.1.1 Interim Construction Noise Guideline

Noise criteria for construction and demolition activities are discussed in the *Interim Construction Noise Guideline* (ICNG). The ICNG also recommends procedures to address potential impacts of construction noise on residences and other sensitive land uses. The main objectives of the ICNG are summarised as follows:

- Promote a clear understanding of ways to identify and minimise noise from construction works
- Focus on applying all "feasible" and "reasonable" work practices to minimise construction noise impacts
- Encourage construction to be undertaken only during the recommended standard hours unless approval is given for works that cannot be undertaken during these hours
- Streamline the assessment and approval stages and reduce time spent dealing with complaints at the project implementation stage
- Provide flexibility in selecting site-specific feasible and reasonable work practices to minimise noise impacts

The ICNG contains a quantitative assessment method which is applicable to this project. Guidance levels are given for airborne noise at residences and other sensitive land uses.

The quantitative assessment method involves predicting noise levels at sensitive receivers and comparing them with the Noise Management Levels (NMLs). The NML affectation categories for residential receivers have been reproduced from the guideline and are listed in Table 7 below.

Specific non-residential receivers in the vicinity of the proposed construction site, and their recommended 'management levels', are presented in Table 8.

Based on the measured background noise levels summarised in Section 2.1.1, the NMLs to be used in this assessment are listed in Table 9.

It is our understanding that construction works will be conducted under typical standard construction hours.

Finally, we exclude the Tamworth Mental Health Unit (TMHU) from this assessment. The reason for this exclusion is because the construction of the TMHU will be undertaken concurrently with the construction of the WCEoLF.

Table 7 NMLs for quantitative assessment at residences (from ICNG)

Time of Day	Noise Management Level $L_{Aeq(15minute)}$[1,2]	How to Apply
Recommended standard hours: Monday to Friday 7:00 am to 6:00 pm Saturday 8:00 am to 1:00 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq(15minute)}$ 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 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences. 2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• 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 5 dB above the noise affected level, the proponent should negotiate with the community.

Note 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.*

Note 2 *The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours). The term RBL is described in detail in the NSW Industrial Noise Policy (EPA 2000).*

Table 8 NMLs for quantitative assessment at non-residential receivers

Land Use	$L_{Aeq(15minute)}$ Construction NML
Hospital wards, external: [1] Main Hospital Building, including: • Acute Services Building (ASB) • Emergency Department • Maternity Wards Rehabilitation Ward & Hydrotherapy Pool	45 dBA (internal) 70 dBA (external)

Note 1: External noise level criterion estimated from internal noise level criterion assuming a 25 dB noise level difference for non-openable facade windows

Note 2: External noise level criterion estimated from internal noise management level of 45 dB $L_{Aeq,\ 15\ minutes}$ for construction activities within private enclosed offices

Table 9 NMLs as basis for the acoustic assessment

Receiver Types	NML, dB $L_{Aeq(15minute)}$	
	Standard Hours **Monday to Friday: 7 am to 6 pm** **Saturday: 8 am to 1 pm**	**Outside Standard Hours**
Hospital wards, external: [1] Main Hospital Building, including: • Acute Services Building (ASB) • Emergency Department • Maternity Wards Rehabilitation Ward & Hydrotherapy Pool	70 (external)	N/A

Note 1: External noise level criterion estimated from internal noise level criterion assuming a 25 dB noise level difference for non-openable facade windows

Note 2: External noise level criterion estimated from internal noise management level of 45 dB $L_{Aeq,\ 15\ minutes}$ for construction activities within private enclosed offices

3.1.2 Sleep Disturbance

At this stage it is noted that construction works will be undertaken during standard construction hours. These standard hours are only part of the daytime period. Therefore, a sleep disturbance assessment is not required.

3.2 Vibration Criteria

Effects of ground borne vibration on buildings may be segregated into the following three categories:

- Human comfort – vibration in which the occupants or users of the building are inconvenienced or possibly disturbed. Refer to further discussion in Section 2.4.
- Effects on building contents – where vibration can cause damage to fixtures, fittings and other non-building related objects. Refer to further discussion in Section 3.2.1.
- Effects on building structures – where vibration can compromise the integrity of the building or structure itself. Refer to further discussion in Section 3.2.1.
- Effects on scientific and medical equipment – where vibration can have an impact on the functionality of scientific and medical equipment. Refer to discussion in Section 3.2.2.

3.2.1 Vibration Criteria – Building Contents & Structure

The vibration effects on the building itself are assessed against international standards as follows:

- For transient vibration: British Standard BS 7385: Part 2-1993 *"Evaluation and measurement for vibration in buildings Part 2: Guide to damage levels from ground borne vibration"* (BSI 1993); and
- For continuous or repetitive vibration: German DIN 4150: Part 3 – 1999 *"Effects of Vibration on Structure"* (DIN 1999).

3.2.1.1 Standard BS 7385 Part 2 – 1993

For transient vibration, as discussed in standard BS 7385 Part 2-1993, the criteria are based on peak particle velocity (mm/s) which is to be measured at the base of the building. These are summarised in Table 10 and illustrated in Figure 2.

Table 10 Transient vibration criteria as per standard BS 7385 Part 2 - 1993

Line in Figure 2	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Standard BS 7385 Part 2 – 1993 states that the values in Table 10 relate to transient vibration which does not cause resonant responses in buildings.

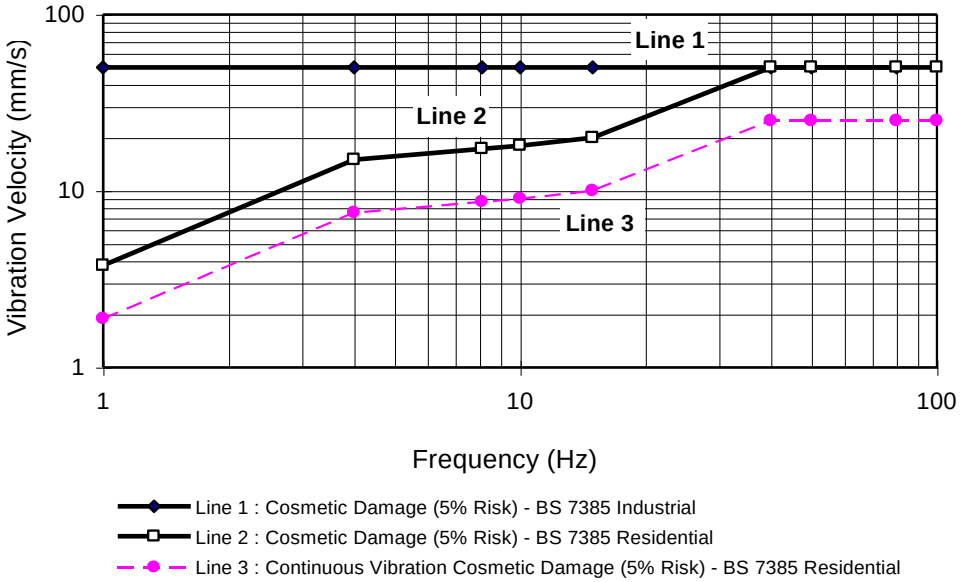
Where the dynamic loading caused by continuous vibration events is such as that results in dynamic magnification due to resonance (especially at the lower frequencies where lower guide values apply), then the values in Table 10 may need to be reduced by up to 50% (refer to Line 3 in Figure 2).

In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the recommended values corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The standard also states that minor damage is possible at vibration magnitudes which are greater than twice those given in Table 10, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the values in Table 10 should not be reduced for fatigue considerations.

Figure 2 BS 7385 Part 2 – 1993, graph of transient vibration values for cosmetic damage



3.2.1.2 Standard DIN 4150 Part 3 – 1999

For continuous or repetitive vibration, standard DIN 4150 Part 3-1999 provides criteria based on values for peak particle velocity (mm/s) measured at the foundation of the building; these are summarised in Table 11. The criteria are frequency dependent and specific to particular categories of structures.

Table 11 Structural damage criteria as per standard DIN 4150 Part 3 - 1999

Type of Structure	Peak Component Particle Velocity, mm/s Vibration at the foundation at a frequency of			
	1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz[1]	Vibration of horizontal plane of highest floor at all frequencies
Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
Structures that, because of their sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 8	8 to 10	8

Note 1: For frequencies above 100Hz, at least the values specified in this column shall be applied.

3.2.2 Scientific & Medical Equipment

Some scientific equipment (e.g. electron microscopes and microelectronics manufacturing equipment) can require more stringent objectives than those applicable to human comfort.

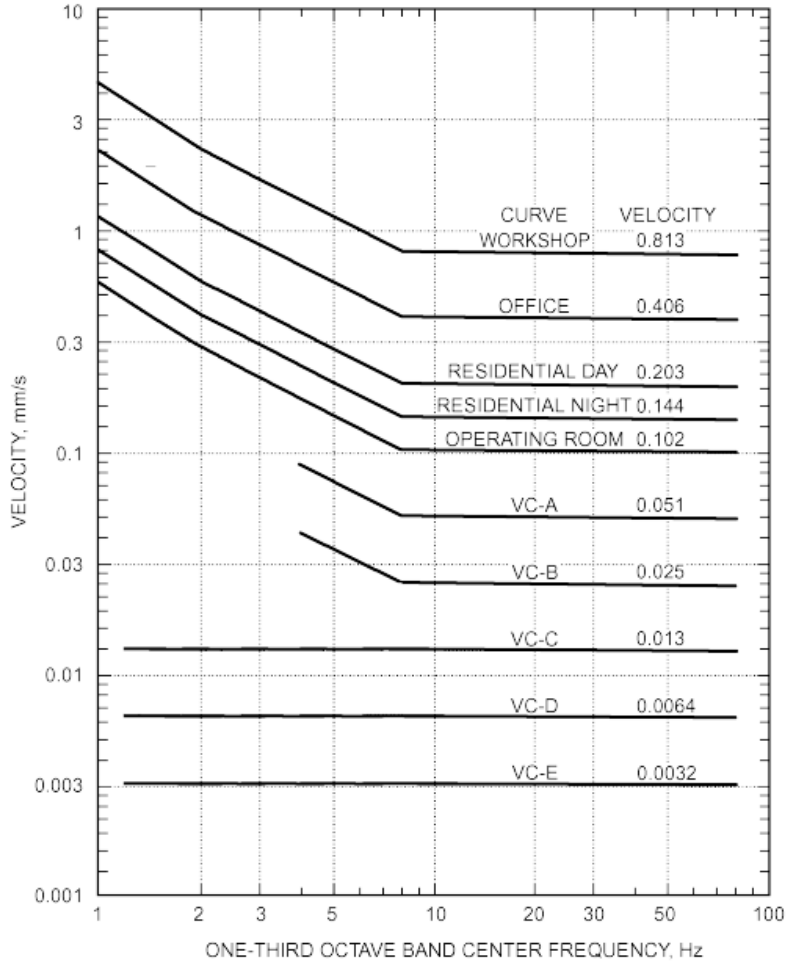
Where it has been identified that vibration sensitive scientific and/or medical instruments are likely to be in use at the nearest existing hospital buildings, objectives for the satisfactory operation of the instrument should be sourced from manufacturer's data.

Where manufacturer's data is not available, generic vibration criterion (VC) curves may be adopted as vibration goals. These generic VC curves are presented below in Table 12 and Figure 3.

Table 12 Criteria for vibration sensitive equipment

Equipment	Curve
Bench microscopes up to 100× magnification; laboratory robots	0.102 mm/s
Bench microscopes up to 400× magnification; optical and other precision balances; coordinate measuring machines; metrology laboratories; optical comparators; microelectronics manufacturing equipment; proximity and projection aligners, etc.	0.051 mm/s VC-A
Microsurgery, eye surgery, neurosurgery; bench microscopes at magnification greater than 400×; optical equipment on isolation tables; microelectronic manufacturing equipment, such as inspection and lithography equipment (including steppers) to 3 mm line widths	0.025 mm/s VC-B
Electron microscopes up to 30 000× magnification; microtomes; magnetic resonance imagers; microelectronics manufacturing equipment, such as lithography and inspection equipment to 1 mm detail size	0.013 mm/s VC-C
Electron microscopes at magnification greater than 30 000×; mass spectrometers; cell implant equipment; microelectronics manufacturing equipment, such as aligners, steppers, and other critical equipment for photolithography with line widths of 1/2 µm; includes electron beam systems	0.0054 mm/s VC-D
Non-isolated laser and optical research systems; microelectronics manufacturing equipment, such as aligners, steppers, and other critical equipment for photolithography with line widths of 1/4 µm; includes electron beam systems	0.0032 mm/s VC-E

Figure 3 Criteria for vibration sensitive equipment (ASHRAE 2007, HVAC Applications, Chapter 47 "Sound and Vibration Control")



3.3 Structure-Borne Noise Criteria

Ground-borne noise is noise generated by vibration transmitted through the ground into a structure. The following ground-borne limits for residences are only applicable when ground-borne or structure-borne noise levels are higher than airborne noise levels. The ground-borne noise levels are for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home.

- Evening (6:00 pm to 10:00 pm) - Internal: 40 dB $L_{Aeq\ (15\ min)}$
- Night-time (10:00 pm to 7:00 am) - Internal: 35 dB $L_{Aeq\ (15\ min)}$

Mitigation options to deal with ground-borne or structure-borne noise may include extensive community consultation to determine the acceptable level of disruption and the provision of respite accommodation in some circumstances, not just restriction of work hours.

4 OPERATIONAL ACOUSTIC ASSESSMENT

4.1 External Noise Emissions – Building Services

We advise the mechanical plant design and equipment selection should be made so that the aggregate noise level from all external emissions, comply with the external noise level criteria discussed in Section 2.1.

This has been conducted as part of the detailed design. The treatments that have been recommended to achieve compliance, include the following:

- Down-duct acoustic treatments for fans and FCUs. These treatments generally comprise the following: internally lined ductwork, internally lined return air / outside air plenums behind FCUs.
- Variable speed drives to be implemented whenever possible.
- Reduce the number of operational plant items between 6:00 pm and 7:00 am (and during the night-time period generally).
- Outdoor units and other plant items to be screened from direct line of sight to the affected residences (depending on their locations).

4.2 Internal Noise Levels – Building Services

The mechanical ventilation design should be designed to achieve the internal noise level criteria discussed in Section 2.2.

The assessment of internal noise levels should account for noise emission by building services, as well as noise intrusion from external noise sources such as local road traffic. Therefore, external building constructions should be designed to address noise intrusion from external noise sources (such as local road traffic).

Therefore, the following has been recommended as part of detailed design:

- Down-duct acoustic treatments for fans and FCUs. These treatments mostly comprise internally lined rigid ductwork, internally lined flexible ductwork, internally lined plenums behind return air / supply air registers.
- Internally lined ductwork components for relief air / return air transfer ducts.

We also advised that mechanical plant should be resiliently mounted. Vibration isolation mounts and supports should be designed to achieve compliance with vibration criteria discussed in Section 2.4.

4.3 Internal Architectural Elements

Internal spaces which are subject to the sound insulation requirements as per NCC 2022, should be designed to achieve these requirements (as discussed in Section 2.3). These spaces comprise the overnight stay room for visitors and staff (this is considered since there is more than one overnight stay room in the ASB and WCEoLF combined).

As part of the detailed design, sound insulation requirements have been nominated for inter-tenancy partitions (i.e. overnight room's perimeter walls) and door accessing overnight room from corridor. Hence, partition and door constructions are advised to achieve compliance with these requirements.

4.4 Building Envelope

As part of the detailed design, sound insulation requirements are recommended for building envelope constructions. These requirements are advised so the overall design noise levels comply with the internal noise level criteria discussed in Section 2.2 (refer to discussion in Section 4.2).

Consequently, constructions are recommended for façade walls, doors and windows to achieve compliance with these sound insulation requirements.

5 CONSTRUCTION NOISE & VIBRATION ASSESSMENT

5.1 Construction Noise Assessment

At this stage, no construction program is available for the project. Therefore, based on previous project experience, construction and demolition tasks have been assumed for our acoustic assessment. These are summarised in Table 13 below, along with the equipment likely to be used in each task and their sound power levels.

Table 13 Summary of sound power levels, construction activities

Tasks	Equipment	Max. Sound Power Levels (dBA re 1pW)	Aggregate Sound Power Level per Task (dBA re 1pW)
Site establishment	Elevator platform	90	105
	Road truck	100	
	Power hand tools	93	
	Mobile crane	102	
External works	Welder	100	112
	Elevator platform	90	
	Dump truck	109	
	Circular saw	105	
	Power hand tools	98	
	Mobile crane	102	
Internal works	Power hand tools	98	110
	Welder	105	
	Circular saw	105	
	Hand-held nail gun	84	

For this assessment, the nearest affected receivers on which our assessment is conducted, are listed in Table 14 below. Based on the equipment sound power levels given in Table 13, noise levels have been predicted at these nearest affected properties for each construction scenario (where each construction scenario comprises two or more construction tasks). These predicted levels are summarised in Table 15.

These predicted noise levels have been assessed against the construction noise criteria discussed in Section 3. The outcomes of this assessment are summarised in Table 16.

Table 14 Receiver IDs for assessment purposes

Receiver ID	Noise Sensitive Locations	Type
HS01	Main Hospital Building	Hospital
HS02	Rehabilitation Ward & Hydrotherapy Pool	Hospital

Table 15 Predicted external $L_{Aeq\ (15\ minutes)}$ noise levels at nearest impacted receivers

Predicted Scenario	Tasks	Aggregate Sound Power Level per Scenario (dBA re 1pW)	Predicted $L_{Aeq,\ 15\ min}$ Noise Levels, dB	
			HS01	HS02
1	Site establishment	105	63 - >75	60 - 70
2	External works	112	70 - >75	65 - >75
3	Internal works	110	70 - >75	65 - >75

Table 16 Summary of assessment outcomes and exceedances based on the ICNG criteria

Scenario	Parameter	Assessment Outcomes	
		HS01	HS02
1	*Predicted Noise Levels, dBA*	*63 - >75*	*60 - 70*
	Within standard construction hours		
	Exceedance over NML, dB	>20	0
2	*Predicted Noise Levels, dBA*	*70 - >75*	*65 - >75*
	Within standard construction hours		
	Exceedance over NML, dB	>20	>10
3	*Predicted Noise Levels, dBA*	*70 - >75*	*65 - >75*
	Within standard construction hours		
	Exceedance over NML, dB	>20	>8

*Note 1: Nil exceedances (i.e. 0 dB shown with **green** font) indicate compliance. Exceedances shown with **orange** font indicate noise affected receivers. Exceedances shown with **red** font indicate highly noise affected receivers*

Consequently, from the assessment outcomes summarised in Table 16, the following is noted:

- Hospital building adjacent to WCEoLF (i.e. ASB) will be highly noise impacted by construction activities.
- Existing Rehabilitation Ward & Hydrotherapy Pool is likely to be noise affected by construction activities.

Therefore, based on these findings, the conceptual management procedures discussed in Section 5.3 are recommended. It is recommended these procedures should be further developed and compiled into a construction noise and vibration management plan (CNVMP). This CNVMP should be prepared in coordination with building contractors.

5.2 Construction Vibration Assessment

To retain compliance with the human comfort vibration criteria discussed in Section 3.2, it is recommended that the indicative safe distances listed in Table 17 should be maintained. These indicative safe distances should be validated prior to the start of construction works by undertaking measurements of vibration levels generated by construction and demolition equipment to be used on site.

Since the criteria for scientific or medical equipment can be more stringent than those required for human comfort, vibration validating measurements should be conducted to determine the vibration level and potential impact onto this sensitive equipment. Likewise, structure-borne noise can be generated at lower vibration levels required from human comfort.

As general reference, refer to generic vibration criteria for scientific equipment which is provided in Section 3.2.2. Confirmation should be sought from HNELHD to confirm these criteria are acceptable for the assessment; or otherwise, user group should provide suitable criteria from manufacturers of scientific instrumentation.

Therefore, for spaces within the Tamworth Hospital ASB, we recommend that these validating measurements should be conducted prior to undertaking vibration intensive activities (such as demolition of existing floor slab components and façade constructions, etc.). Furthermore, we advise that construction and demolition activities within hospital premises should be conducted in coordination with HNELHD. Refer to further discussion in Section 5.3.3.

Additionally, any vibration levels should be assessed in accordance with the criteria discussed in Section 3.2. This information should also be included as part of the construction noise and vibration management plan (CNVMP).

Table 17 Recommended indicative safe working distances for vibration intensive plant

Plant	Rating / Description	Safe Working Distances (m)	
		Cosmetic Damage (BS 7385: Part 2 DIN 4150: Part 3)	Human Comfort (AVTG)
Vibratory roller	< 50 kN (Typically 1 – 2 tonnes)	5	15 – 20
	< 100 kN (Typically 2 – 4 tonnes)	6	20
	< 200 kN (Typically 4 – 6 tonnes)	12	40
	< 300 kN (Typically 7 – 13 tonnes)	15	100
	> 300 kN (Typically more than 13 tonnes)	20	100
Small hydraulic hammer	300 kg, typically 5 – 12 tonnes excavator	2	7
Medium hydraulic hammer	900 kg, typically 12 – 18 tonnes excavator	7	23
Large hydraulic hammer	1600 kg, typically 18 – 34 tonnes excavator	22	73
Vibratory pile driver	Sheet piles	2 – 20	20
Jackhammer	Hand held	1	Avoid contact with structure and steel reinforcements

5.3 Typical Noise & Vibration Management Procedures

The contractor should develop a construction noise and vibration management plan (CNVMP) to implement mitigation measures to manage the noise and vibration impact onto the potentially affected receivers within and the Tamworth Hospital campus.

The following sub-sections discuss the issues and measures that can be considered as part of this CNVMP.

5.3.1 Noise Mitigation Measures

A detailed construction program should be provided which should include the following:

- Schedule of construction activities (classified into scenarios if applicable)
- List of construction equipment per activity
- Location of construction equipment
- Duration of construction activities, as well as proposed construction hours

This construction program should be issued to assist on the prediction of the noise impact and to develop mitigation measures that can ameliorate this impact.

The contractor should, where reasonable and feasible, apply best practice noise mitigation measures. These measures include the following:

- Maximising the offset distance between plant items and nearby noise sensitive receivers.
- Preventing noisy plant working simultaneously and adjacent to sensitive receivers.
- Minimising consecutive works in the same site area.
- Orienting equipment away from noise sensitive areas.
- Carrying out loading and unloading away from noise sensitive areas.

To minimise noise impacts during the works, the contractor should take all reasonable and feasible measures to attenuate the noise impact. Hence it is advised that on-site monitoring be conducted to attest this impact and propose mitigation measures as construction activities develop.

The contractor should also take reasonable steps to control noise from all plant and equipment. Examples of appropriate noise control include efficient silencers and low noise mufflers.

The contractor should apply all feasible and reasonable work practices to meet the NMLs and inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels, duration of noise generating construction works, and the contact details for the proposal.

A potential approach would be to schedule a respite period after continuous construction activity, or undertaking high noise generating works to less sensitive times.

5.3.2 Vibration Mitigation Measures

The following vibration mitigation measures are recommended to be considered as part of a CNVMP:

- Any vibration generating plant and equipment is to be located in areas within the site in order to lower the vibration impacts.
- Investigate the feasibility of rescheduling the hours of operation of major vibration generating plant and equipment.
- Identify of other vibration sensitive structures such as tunnels, gas pipelines, fibre optic cables, Sydney Water retention basins. Specific vibration goals should be determined on a case-by-case basis by an acoustic consultant which is to be engaged by the construction contractor.
- Identify heritage structures as well as vibration sensitive premises (such as those containing scientific and surgery equipment). Safe working distances from vibration generating equipment should be established in order to achieve compliance with the criteria discussed in Section 3.2.

  Hence, it is advised to conduct attended measurements of vibration generating plant at commencement of works to confirm compliance with vibration criteria discussed in Section 3.2. Measurements should be conducted within Tamworth Hospital ASB. If possible, measurements will also be used to validate the safe working distances advised in Table 17 and to establish safe working distances suitable to the project.
- Use lower vibration generating items of construction plant and equipment, that is, smaller capacity plant.
- Minimise conducting vibration generating works consecutively in the same area (if applicable).
- Schedule a minimum respite period prior to long continuous activities.

5.3.3 Impact Onto Existing Hospital Premises

Noise and vibration levels from the proposed works will mostly affect the existing Tamworth Hospital ASB. As such, internal management of the potential impacts should be managed between the managing building contractor and NSW Health Infrastructure (Hunter New England Local Health District).

Due to the difficulty in predicting the operation parameters of the hospital during the forecasted works (i.e. number of staff, number of patients, location of patients, etc), the noise and vibration mitigation measures will need to be adopted on a case-by-case basis. However, to assist in preventing calculated exceedances, some of the mitigation measures outlined below are to be adopted:

- Ongoing communication between the managing contractor and NSW Health Infrastructure during the works.
- Consultation with the end users of the affected spaces.
- Temporary relocation of patients and or staff during high levels of noise and vibration.
- Noise and vibration monitoring to be undertaken at the nearest most affected areas within the building with real-time feedback capabilities to ensure for a quick response to any exceedances.
- Alternate selection of equipment and or methodologies.

5.3.4 Miscellaneous Measures

Deliveries should be undertaken, where possible, during standard construction hours.

Maximise hammer penetration (and reduce blows) by using sharp hammer tips. Keep stocks of sharp profiles on site; and monitor the profiles in use.

It is advised that mobile plant and trucks operating on site for a significant portion of the project are to have reversing alarm noise emissions minimised. Broadband "quacker" reversing alarms should be used in preference to tonal alarms. This is to be implemented subject to recognising the need to maintain occupational safety standards.

No public address system should be used on site.

A complaint response procedure should be implemented. Information to be gathered as part of this process should include location of complainant, time/s of occurrence of alleged noise or vibration impacts (including nature of impact particularly with respect to vibration), perceived source, prevailing weather conditions and similar details that could be utilised to assist in the investigation of the complaint. All resident complaints will be responded to in the required timeframe and action taken recorded.

6 CONCLUSIONS

Pulse White Noise Acoustics (PWNA) has conducted a noise and vibration impact assessment for the World Class End of Life Facility (WCEoLF) at Tamworth Hospital.

From this assessment, conceptual treatments are recommended for mechanical services to achieve compliance with the operational acoustic criteria discussed in Section 2. We advise that these treatments should be further developed during detailed design stages. Additionally, building envelope constructions should be designed to mitigate external noise intrusion and maintain compliance with internal noise level criteria. All mechanical plant should be resiliently mounted.

Based on the construction acoustic assessment discussed in Section 5, we find that areas within the hospital campus are likely to be impacted by airborne noise emissions, vibration levels and structure-borne noise emissions generated by these construction activities.

Therefore, we recommend that a construction noise & vibration management plan (CNVMP) should be developed to mitigate and manage the acoustic impact from construction activities. Management procedures that can be considered and further elaborated as part of the CNVMP, are discussed in Section 5.3. These procedures should be developed in consultation with NSW Health Infrastructure (Hunter New England Local Health District).

Provided the recommendations above are fully implemented and further developed, we are of the opinion the World Class End of Life Facility (WCEoLF) at Tamworth Hospital will satisfy the typical acoustic requirements of the REF.

APPENDIX A: ACOUSTIC TERMINOLOGY

The following is a brief description of the acoustic terminology used in this report.

Sound power level	The total sound emitted by a source
Sound pressure level	The amount of sound at a specified point
Decibel [dB]	The measurement unit of sound
A Weighted decibels [dB(A])	The A weighting is a frequency filter applied to measured noise levels to represent how humans hear sounds. The A-weighting filter emphasises frequencies in the speech range (between 1kHz and 4 kHz) which the human ear is most sensitive to, and places less emphasis on low frequencies at which the human ear is not so sensitive. When an overall sound level is A-weighted it is expressed in units of dB(A).
Decibel scale	The decibel scale is logarithmic in order to produce a better representation of the response of the human ear. A 3 dB increase in the sound pressure level corresponds to a doubling in the sound energy. A 10 dB increase in the sound pressure level corresponds to a perceived doubling in volume. Examples of decibel levels of common sounds are as follows:

0dB(A)	Threshold of human hearing
30dB(A)	A quiet country park
40dB(A)	Whisper in a library
50dB(A)	Open office space
70dB(A)	Inside a car on a freeway
80dB(A)	Outboard motor
90dB(A)	Heavy truck pass-by
100dB(A)	Jackhammer/Subway train
110 dB(A)	Rock Concert
115dB(A)	Limit of sound permitted in industry
120dB(A)	747 take off at 250 metres

Frequency [f]	The repetition rate of the cycle measured in Hertz (Hz). The frequency corresponds to the pitch of the sound. A high frequency corresponds to a high pitched sound and a low frequency to a low pitched sound.
Ambient sound	The all-encompassing sound at a point composed of sound from all sources near and far.
Equivalent continuous sound level [L_{eq}]	The constant sound level which, when occurring over the same period of time, would result in the receiver experiencing the same amount of sound energy.
Reverberation	The persistence of sound in a space after the source of that sound has been stopped (the reverberation time is the time taken for a reverberant sound field to decrease by 60 dB)
Air-borne sound	The sound emitted directly from a source into the surrounding air, such as speech, television or music
Impact sound	The sound emitted from force of one object hitting another such as footfalls and slamming cupboards.
Air-borne sound isolation	The reduction of airborne sound between two rooms.
Sound Reduction Index [R] (Sound Transmission Loss)	The ratio the sound incident on a partition to the sound transmitted by the partition.
Weighted sound reduction index [R_w]	A single figure representation of the air-borne sound insulation of a partition based upon the R values for each frequency measured in a laboratory environment.
Level difference [D]	The difference in sound pressure level between two rooms.

Normalised level difference [D_n]	The difference in sound pressure level between two rooms normalised for the absorption area of the receiving room.
Standardised level difference [D_{nT}]	The difference in sound pressure level between two rooms normalised for the reverberation time of the receiving room.
Weighted standardised level difference [$D_{nT,w}$]	A single figure representation of the air-borne sound insulation of a partition based upon the level difference. Generally used to present the performance of a partition when measured in situ on site.
C_{tr}	A value added to an R_w or $D_{nT,w}$ value to account for variations in the spectrum.
Impact sound isolation	The resistance of a floor or wall to transmit impact sound.
Impact sound pressure level [L_i]	The sound pressure level in the receiving room produced by impacts subjected to the adjacent floor or wall by a tapping machine.
Normalised impact sound pressure level [L_n]	The impact sound pressure level normalised for the absorption area of the receiving room.
Weighted normalised impact sound pressure level [$L_{n,w}$]	A single figure representation of the impact sound insulation of a floor or wall based upon the impact sound pressure level measured in a laboratory.
Weighted standardised impact sound pressure level [$L'_{nT,w}$]	A single figure representation of the impact sound insulation of a floor or wall based upon the impact sound pressure level measured in situ on site.
C_I	A value added to an L_{nW} or $L'_{nT,w}$ value to account for variations in the spectrum.
Energy Equivalent Sound Pressure Level [$L_{A,eq,T}$]	'A' weighted, energy averaged sound pressure level over the measurement period T.
Percentile Sound Pressure Level [$L_{Ax,T}$]	'A' weighted, sound pressure that is exceeded for percentile x of the measurement period T.

*Definitions of a number of terms have been adapted from Australian Standard AS1633:1985 *"Acoustics – Glossary of terms and related symbols"*