Hayball Pty Ltd

Bills Street Estate, Hawthorn

Acoustic Detailed Design Report

AC3

2 | 27 August 2021

PLANNING and ENVIRONMENT ACT
BAROONDARA PLANNING SCHEME

CONSENT UNDER CLAUSE 52.20
VPP2101334
ENDORSED PLAN
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Signed: for
MINISTER FOR ENERGY, ENVIRONMENT AND CLIMATE CHANGE
Date: 5 Nov 2021

Job number 277560

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1 Introduction

The Department of Health and Human Services Victoria (DHHS) propose to develop the parcel of land at 1-12 Bills Street, Hawthorn (the Subject Site) for residential use.

Arup has been engaged by Hayball Pty Ltd (Hayball) to undertake an assessment to inform the acoustic design for the Subject Site.

This report provides detail of the noise assessment and provides an acoustic design and noise mitigation requirements to comply with relevant legislation and guidelines.

A glossary of acoustic terminology used in this report is provided in Appendix A.

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2 Site Description

2.1 General

The Subject Site is a General Residential Zone (GRZ) in Hawthorn, approximately 6 km south-east of the Melbourne central business district. The site currently consists of public housing.

The Subject Site is bounded by:

- To the north: The University of Melbourne Hawthorn Campus.
- To the east: Residential property at 9 Bills Street and commercial properties at 14-20 Bills Street, with the University of Melbourne Hawthorn Campus farther to the east.
- To the south: Patterson Reserve, which includes a Velodrome, hockey fields and park area. Residential properties are located on Burgess Street.
- To the west: Additional Patterson Reserve Parkland, approximately 160m to the west is the Monash Freeway Toll Road (M1).

The nearest sensitive receivers are residential properties located on Bills Street to the east and Burgess Street to the south.

The Monash Freeway City-Link Toll Road is a significant road traffic noise source that may impact on the proposed development.

The subject site is a General Residential Zone (GRZ) with a Road Zone (RDZ1), Public Use Zone 2 (PUZ2), Commercial 1 Zone(C1Z), and Public Park and Recreation Zones (PPRZ) nearby.

2.2 Proposed Development

The proposed development includes six (6) new multi-storey residential buildings. The buildings vary in heights and consist of both social housing and affordable housing. The site plan is shown in Figure 1.

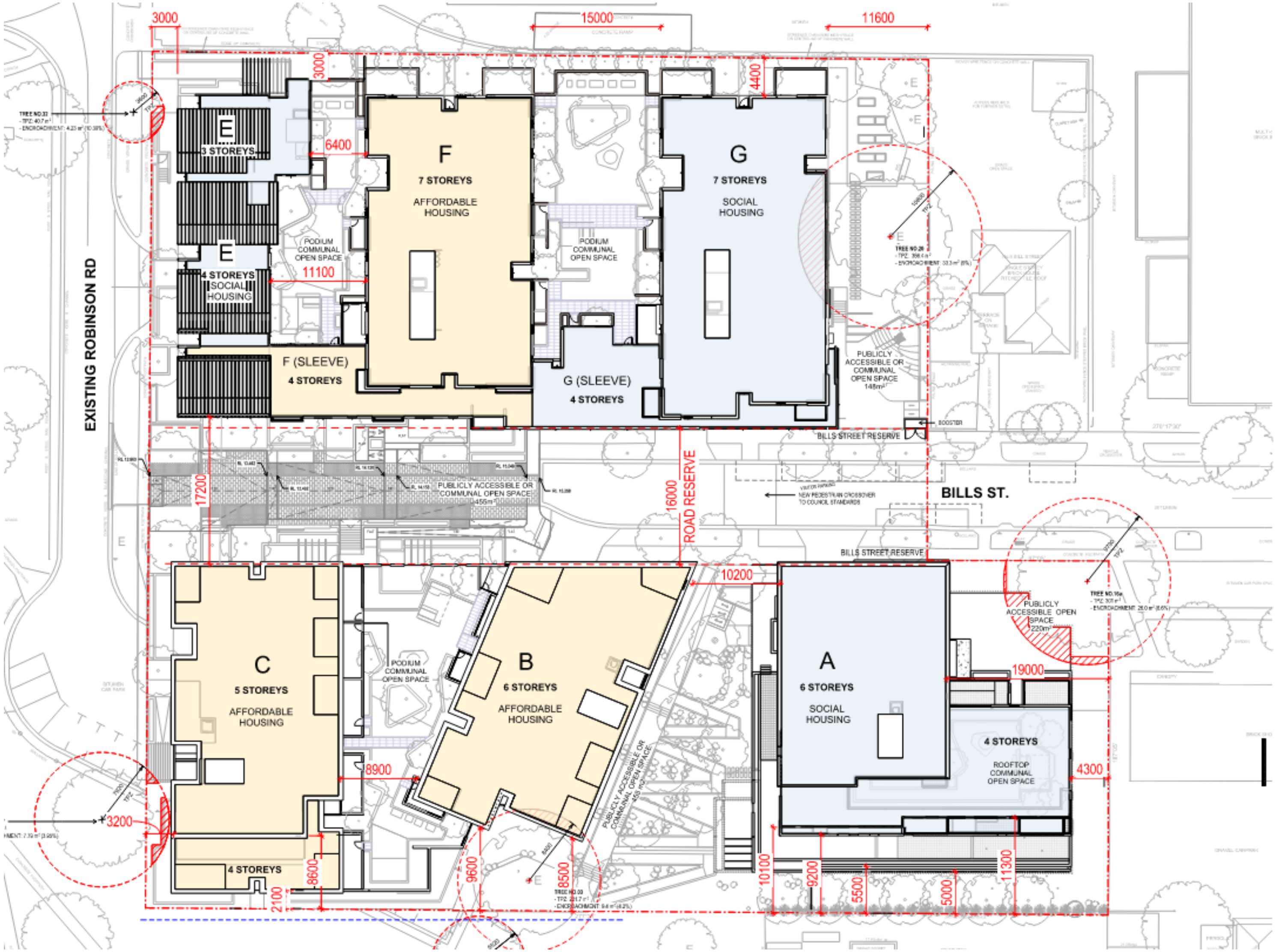

Figure 1: Site plan.

3 Noise and Vibration Environment

3.1 Background Noise

Background noise level measurements at the site were not undertaken and the base noise limits from *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade* N-1 (SEPP N-1) have been used to determine any significant project limitations. This is a conservative approach and is checked with nearby Pre-COVID-19 noise monitoring data where relevant.

3.2 Road Traffic Noise

Road traffic noise data measured pre-COVID-19 at 111 Reserve Road, adjacent to the site has been used for this assessment. The data has been corrected to account for differences in distance from the Monash Freeway.

The average measured and corrected noise levels used for this assessment are provided in Table 1 below.

Table 1: Measured Noise Levels

Location	Correction applied, dB	Daytime $dBL_{Aeq(16hr)}$	Night-time $dBL_{Aeq(8hr)}$	Peak $dBL_{Aeq(2hr)}$
111 Reserve Road	4.3	59	51	59

The traffic peak is measured to occur between 7 and 8am and 5 and 6pm and so are considered to occur during the 'daytime' period.

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4 Assessment Criteria

Guidelines, standards and legislation are used in Victoria to assess and control noise and vibration for developments. The relevant source of the assessment criteria is provided in Table 2, Table 3, and Table 4 for noise ingress, noise egress and internal noise respectively. Further details are provided in the following sections where required.

This building is targeting Greenstar requirements associated with the acoustic design.

Table 2 Noise and Vibration Ingress Assessment Criteria

Potential Impact	Source of Assessment Criteria	Status
Internal Services Noise	AS 2107:2016 *Acoustics-* *Recommended design sound levels and reverberation times for building interior*	Standard
Road Traffic Noise	*Victoria Planning Provisions –* Clause 55.07-6 AS 3671:1989 Acoustics - *Road traffic noise intrusion – Building siting and construction.* AS 2107:2016 *Acoustics- Recommended design sound levels and reverberation times for building interior*	Standard

Table 3 Noise and Vibration Egress Assessment Criteria

Potential Impact	Source of Assessment Criteria	Status
Mechanical Services Noise Delivery movements Waste collection	SEPP N-1 EPA Noise Control Guidelines	Legislation
Delivery movements Waste collection	EPA Noise Control Guidelines	Guideline

Table 4: Noise Transfer within development

Potential Impact	Source of Assessment Criteria	Status
Noise between apartments	NCC BCA	Legislation
Noise between apartments	Greenstar part 10.3	Guideline

4.1 Noise Ingress

4.1.1 Industrial and Commercial Noise

The SEPP N-1 legislation for commercial noise do not apply to noise ingress to this development because they are for control of a noise source. In this case, SEPP N-1 will be used for context to understand the impact of existing noise sources on the proposed development.

4.1.2 Road Traffic Noise

VicRoads Requirements of Developers (2004) does not apply to this development because it is not adjacent to a freeway or VicRoads controlled roads.

Clause 55.07-6 Standard B40 applies because the development is within 300 m of a freeway and/or tollway and must meet the criteria provided in Table 5 below.

Table 5: Clause 55.07-6 Standard B40 Criteria

Noise Source	Noise Influence Area	Indoor Noise Criteria
Monash Freeway (M1) CityLink Tollway section	300 metres from industrial freeway / tollway	Not greater than 35 dB(A) for bedrooms, assessed as an dBLAeq(8hr) from 10:00pm to 6:00am, Not greater than 40 dB(A) for living areas, assessed as an dBLAeq(16hr) from 6:00am to 10:00pm,

Clause 55.07-6 Standard B40 criteria are long term day (16-hour) and night-time (8-hour) noise parameters.

In addition to the above the following standards are considered:

- AS 2107 – 2000 Acoustics – Recommended design sound levels and reverberation times for building interiors
- AS 3671 – 1989 Acoustics – Road traffic noise intrusion – Building siting and construction.

AS 3671[1] recommends that satisfactory indoor sound levels should be determined from AS 2107[2]. AS 2107 provides guideline design criteria for conditions affecting the acoustic environment within occupied spaces. The ambient sound levels recommended consider the function of the area(s) and apply to the sound level measured with the space unoccupied but ready for occupancy. The Standard also provides methods of measuring the ambient sound level and reverberation time in occupied spaces in new and existing buildings.

The purpose of AS 3671 is to achieve compliance with AS 2107. Demonstrating compliance with AS 2107 is therefore equivalent to conformance with AS 3671.

An extract of some of the recommended levels that are applicable to the proposed development is provided in Table 6 below.

Table 6: Recommended design sound levels for different areas of occupancy in buildings

Type of occupancy/activity	**Recommended design sound level, LAeq, dB(A)**	
	Satisfactory	**Maximum**
Living areas	30	40

[1] *AS3671-1989 Acoustics – Road traffic Noise Intrusion – Building Siting and Construction*.
[2] *AS2107-2016 Acoustics - Recommended design sound levels and reverberation times for building interiors*

Type of occupancy/activity	Recommended design sound level, LAeq, dB(A)	
	Satisfactory	**Maximum**
Sleeping areas	30	35
Work areas	35	40
Apartment common areas (e.g. foyer, lift lobby)	45	55

4.1.3 Community Noise

The site is located near the Patterson Reserve Hockey fields and velodrome. It is expected there will be periods of consistent noise such as: umpire whistles, conversation, and other noises associated with sport.

Victoria has no relevant noise policy for noise from sporting activities. A suitable noise objective will be determined and used to provide guidance on the acoustic design of the façade to limit noise break-in to typical acceptable levels.

4.2 Noise Egress

4.2.1 Commercial Noise

Noise from industrial and commercial premises is governed by the State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1 (SEPP N-1) within the Melbourne metropolitan area and includes noise from waste collection, site delivery movements and mechanical services. SEPP N-1 uses the time periods provided in Table 7.

Table 7 SEPP N-1 Time Periods

Period	Day of week	Time period
Day	Monday – Friday	07:00-18:00hrs
	Saturday	07:00-13:00hrs
Evening	Monday – Friday	18:00-22:00hrs
	Saturday	13:00-22:00hrs
	Sunday, Public Holidays	07:00-22:00hrs
Night	Monday – Sunday	22:00-07:00hrs

The calculation of noise limits requires the calculation of a zoning level that is based on land use in the surrounding area. The zoning level is then adjusted appropriately, depending on the measured background noise level. For this assessment the base noise limits from SEPP N-1 are used.

The SEPP N-1 noise limits used for the three time periods at the identified noise sensitive receivers are provided in Table 8.

Table 8 SEPP N-1 Noise Criteria for Receivers on Bills Street.

Period	**Noise Limit, dBL_{Aeq}**
Day	45
Evening	40
Night	35

Where the air conditioning units are individually and independently controlled by occupants, the following guidance from *EPA Publication 1254*[3] applies:

EPA guidelines recommend:

- Daytime/evening (0700-2200 or 0900-2200 on weekends) background plus 5 dB; and
- Night-time (2200-0700 or 2200-0900 on weekends): inaudible inside a habitable room.

4.3 Internal Noise

Internal acoustic performance between occupants and internal building services requirements such as lifts, garbage chutes or air-conditioning is determined by the National Construction Code (NCC) and typically addressed in Section 4.4 of this report.

4.3.1 Background Noise

Background noise is not specifically part of the NCC and guidance is provided by AS/NZS 2107:2016 for design internal noise levels for various types of occupancy. Recommended internal noise levels are provided in Table 9\

These levels are the same as those recommended for road traffic noise intrusion and in this case apply to the combination of all sources, including internal sources such as lifts and air condition.

Table 9 – Recommended background noise criteria for apartments near major roads

Room Description	**AS/NZS 2107:2016, dBL_{Aeq}**
Corridor	45 to 50

4.4 Sound Insulation

4.4.1 Building Code of Australia

The National Construction Code (NCC) provides the minimum necessary requirements for safety, health, amenity and sustainability for the design and construction of buildings and other structures throughout Australia. The Building Code of Australia (BCA) is a uniform set of technical provisions for building

[3] EPA *Victoria Publication 1254 – Noise Control Guidelines* October 2008

work. The criteria for the apartments has been nominated to enable compliance with the requirements of BCA.

The BCA Section F (Health and Amenity) Part F5 (Sound transmission and insulation) outlines the following acoustic requirements for Class 2 and 3 Buildings. The accommodation building falls under Class 3. Clauses that form part of Section F but do not relate to Class 2 and 3 buildings are not provided in Table 10.

Sound insulation and impact isolation requirements are included in the NCC for Class 2 buildings with Sole Occupancy Units, which is applicable between apartments for this project. The requirements are provided in Table 10.

Table 10 – BCA Part F5: Sound Transmission and Insulation

F5.2 Determination of airborne sound insulation ratings
A form of construction *required* to have an airborne sound insulation rating must – a) have the *required* value for weighted sound reduction index (R_w) or weighted sound reduction index with spectrum adaptation term ($R_w + C_{tr}$) determined in accordance with AS/NZS 1276.1 or ISO 717.1 using results from laboratory measurements; or *b)* comply with Specification F5.2 (Note 1)
F5.3 Determination of impact sound insulation ratings
a) A floor in a building *required* to have an impact sound insulation rating must – i) have the *required* value for weighted normalised impact sound pressure level with spectrum adaptation term ($L_{n,w}$) determined in accordance with AS/ISO 717.2 using results from laboratory measurements; or ii) comply with Specification F5.2. b) A wall in a building required to have an impact sound insulation rating must – i) for a Class 2 or 3 building be of discontinuous construction c) For the purposes of this part, discontinuous construction means a wall having a minimum 20 mm cavity between 2 separate leaves, and i) for masonry, where wall ties are required to connect leaves, the ties are of the resilient type; and *ii)* for other than masonry, there is no mechanical linkage between leaves except at the periphery.
F5.4 Sound insulation rating of floors
a) A floor in a Class 2 or 3 building must have an $R_w + C_{tr}$ (airborne) not less than 50 and an $L_{n,w}$ (impact) not more than 62 if it separates – i) *sole-occupancy units*; or *ii)* a *sole-occupancy unit* from a plant room, lift *shaft*, stairway, *public corridor*, public lobby or the like, or parts of a different classification.

F5.5 Sound insulation rating of walls

a) A wall in a Class 2 or 3 building must –

i) have an $R_w + C_{tr}$ (airborne) not less than 50, if it separates *sole-occupancy units*; and

ii) have an R_w (airborne) not less than 50, if it separates a sole-occupancy unit from a plant room, lift *shaft*, stairway, *public corridor*, public lobby or the like, or parts of a different classification; and

iii) comply with F5.3(b) if it separates:

(A) a bathroom, *sanitary compartment*, laundry or kitchen in one *sole-occupancy unit* from a *habitable room* (other than a kitchen) in an adjoining unit; or

(B) a *sole-occupancy unit* from a plant room or lift shaft.

b) A door may be incorporated in a wall in a Class 2 or 3 building that separates a *sole-occupancy unit* from a stairway, *public corridor*, public lobby or the like, provided the door assembly has an R_w not less than 30.

e) Where a wall *required* to have sound insulation has a floor above, the wall must continue to –

i) the underside of the floor above; or

ii) a ceiling that provides the sound insulation required for the wall.

f) Where a wall *required* to have sound insulation has a roof above, the wall must continue to –

i) the underside of the roof above; or

ii) a ceiling that provides the sound insulation *required* for the wall.

F5.6 Sound insulation rating of services

a) If a duct, soil, waste or water supply pipe, including a duct or pipe that is located in a wall or floor cavity, serves or passes through more than one *sole-occupancy unit*, the duct or pipe must be separated from the rooms of any *sole-occupancy unit* by construction with an R_w+C_{tr} (airborne) not less than –

i) 40 if the adjacent room is a *habitable room* (other than a kitchen); or

ii) 25 if the adjacent room is a kitchen or non-*habitable room*.

b) If a storm water pipe passes through a *sole-occupancy unit* it must be separated in accordance with (a).

F5.7 Sound isolation of pumps

A flexible coupling must be used at the point of connection between the service pipes in a building and any circulating or other pump.

Notes

Note 1: Specification F5.2 lists the weighted sound reduction index R_w for some common forms of construction.

Table 11 and Table 12 below summarise the minimum acoustic design requirements for compliance with BCA for partitions in the apartment buildings.

Table 11– Sound Insulation Criteria – Walls between Occupancies

Room Type in Occupancy 1	Room Type in Occupancy 2	Acoustic Design Requirement	Additional Requirements
Habitable room	Habitable room	$R_w + C_{tr} \geq 50$	The wall must extend full height, from the slab to the floor / roof above, or an acoustically rated ceiling must be installed.
Habitable room	Non-Habitable room	$R_w + C_{tr} \geq 50$	The wall must be of discontinuous construction; and; The wall must extend the full height from the slab to the floor / roof above, or an acoustically rated ceiling must be installed.
Non-habitable room	Non-Habitable room	$R_w + C_{tr} \geq 50$	The wall must extend the full height from the slab to the floor / roof above, or an acoustically rated ceiling must be installed.

Table 12 – Sound Insulation Criteria – Walls between Occupancies and Other Areas

Room Type in Occupancy	Adjoining Area	Acoustic Design Requirement	Additional Requirements
Any room	Public Corridor, Lobby, Stairway	$R_w \geq 50$	The wall must extend the full height from the slab to the floor / roof above, or an acoustically rated ceiling must be installed.
Any room	Lift Shaft	$R_w \geq 50$	The wall must be of discontinuous construction; and The wall must extend the full height from the slab to the floor / roof above, or an acoustically rated ceiling must be installed.

A floor must have an $R_w + C_{tr}$ of no less than 50, and an $L_{n,w}$ of no more than 62 if it separates a sole-occupancy unit from another unit or a plant room, lift shaft, stairway or a public corridor and lobby.

A door may be incorporated into a wall that separates a sole-occupancy unit from a corridor, stairway, lobby or the like, provided that the door assembly achieves a minimum R_w rating of 30.

If a duct, soil, waste or water supply pipe passes through more than one sole-occupancy unit, the duct or pipe must be separated from the unit with a construction that achieves an Rw + Ctr of no less than 40 if the adjacent room is a habitable room, and an Rw + Ctr of no less than 25 if the adjacent room is a non-habitable room (e.g.. kitchen), as shown in Table 13 below.

Table 13 – Sound Insulation Criteria for Services

Area	Acoustic Criteria
Habitable	$R_w + C_{tr} \geq 40$
Non-habitable	$R_w + C_{tr} \geq 25$

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4.4.2 Green Star Accreditation

For this project we will target the 10.3 ‘Acoustic Separation’ Greenstar Star as part of the project accreditation. The requirements are as follows:

- The inter-tenancy apartment construction to habitable areas results in airborne noise isolation standard of R_w+C_{tr} > 55; and
- All inter-tenancy walls should include Discontinuous Construction as defined by the Building Code of Australia
- Walls between apartments and public corridors results in airborne noise isolation standard of R_w > 55; and
- The floor construction above habitable rooms and wet areas of adjacent dwellings (i.e. floor cover) results in an impact isolation standard of $L_{n,w}$ + CI < 55.
- Apartment entry doors include acoustic seals and achieve laboratory acoustic rating of R_w 30.

These requirements are typically more onerous than the NCC and meeting therefore meeting eth Green Star requirements will also meet the NCC requirements.

4.4.3 Summary of Criteria

A summary of the applicable airborne sound insulation criteria for the project is provided in Table 14.

The sound insulation criteria has been developed to capture the requirements for all relevant standards guidelines and policies. Where multiple policies apply to a particular area, the most stringent applicable criterion has been adopted, and the summary criteria supersedes the individual guidelines or policies. Where a standard guideline or policy does not apply to a particular partition type, Arup’s experience in the design of similar buildings has been drawn upon to nominate a suitable sound insulation criterion.

Design criteria for airborne noise insulation has been summarised using R_w and R_w + C_{tr} values. Where an alternative sound insulation metric is required by a standard guideline or policy, the generally equivalent R_w rating has been used in the summary. For instance:

Table 14 – Summary of Sound Insulation criteria

Acoustic Performance Rating	Applicable area
R_w + C_{tr} 25 (Note 1)	Services risers adjacent to non-habitable rooms in single occupancy units.
R_w +C_{tr} 40 (Note 1)	Services risers adjacent to habitable rooms in single occupancy units.

Acoustic Performance Rating	**Applicable area**
R_W 55	Partitions between units and corridors Partitions between units and lift shafts (Note 2)
$R_w + C_{tr}$ 55 (Note 1) (Note 2)	Partitions between units (habitable spaces adjacent to habitable spaces, or non-habitable spaces adjacent to non-habitable spaces) Partitions between units to other areas Partitions between units (habitable spaces adjacent to non-habitable spaces) (Note 2) Music rooms within Student Accommodation building adjacent to other occupied spaces

Notes

1. The C_{tr} is a spectral adjustment factor that is used to account for low frequency noise. See Glossary for full details of acoustic metrics.
2. These partitions will also require discontinuous construction in accordance with BCA requirements as outlined above.

In addition to the airborne noise insulation, criteria for impact noise isolation will also apply to the floors / ceiling constructions in the buildings.

Criteria for impact noise is determined as $L_{n,w}$ ratings. For $L_{n,w}$ ratings, a lower rating relates to a better performance for impact noise isolation.

The nominated impact noise criteria for the project is outlined in Table 15.

Table 15 – Summary of impact noise criteria

Impact Noise Rating	**Applicable area**
$L_{n,w} + CI < 55$	Floors / ceilings above Student Accommodation units

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5 Acoustics Recommendations

5.1 Noise Ingress

5.1.1 Industrial and Commercial Noise

Commercial noise form Melbourne University is expected to meet relevant targets based on typical constructions and no specific acoustic design is required.

5.1.2 Road Traffic Noise

All south facing façade requires 6mm laminate glazing or any typical IGU construction to meet the road traffic noise ingress criteria.

5.2 Noise Egress

Plant noise acoustic mitigation to rooftop plant will be required. There is to be a solid barrier to should break line of site between mechanical plant and the noise sensitive receiver in all cases.

5.3 Sound Insulation

Partitions

Partitions are detailed on Drawing AR P00.02 (rev 4) and have been designed to meet criteria outlined in this report. Any variation from these details are to be confirmed with the acoustic consultant and architect.

The partition constructions are required to extend from ‘slab to slab’, i.e., from floor to soffit above, and are required to be acoustically sealed to the floor and soffit above. Penetrations through these partitions will be required to be acoustically sealed.

Penetrations through these partitions will be required to be acoustically sealed to maintain the acoustic rating. Particular care is needed with the installation of GPUs and other panels set into partitions.

Discontinuous Construction

Discontinuous construction is incorporated into walls that separate apartment spaces to control impact noise and clearly identified on Drawing AR P00.02 (rev 4). Discontinuous construction is achieved with a 20mm gap between separate leaves, and is not satisfied by staggered studs or resilient connections.

No rigid connection is to bridge across discontinuous constructions and prior to closing, the 20mm gap should be checked for stray bolts or debris.

Doors

Doors to SOUs within the project are required to achieve R_w 30 by the BCA. Door types options to achieve the required criteria are presented in Table 16.

Table 16 – Door Types

Door Rating	Door Construction
R_w 30	• 35mm solid-core door with rebated frame; with • Perimeter seals installed to jambs and door bottom, such as Raven RP10 and RP8si (or equivalent door seals) OR Proprietary door system that achieves R_W 30.
R_w 40	• Proprietary door system with that achieves R_W 40. • Typically include: ○ ≥ 50mm Solid-core door with filled metal rebated frame ○ Acoustically rated drop seals and frame seals.

Floors/Ceilings

The floor / ceiling construction between individual SOUs is required to achieve acoustic ratings in accordance with the Green Star 10.3 target. As the apartments are proposed to comprise of a concrete slab and plasterboard ceiling, the floor system, concrete slab and plasterboard ceiling will need to achieve the airborne and impact-noise requirements.

The following acoustic treatment items are included in the design:

- Airborne noise requirements will be achieved with the concrete slab and plasterboard suspended ceiling.
- Impact-noise isolation will be achieved with the combination of concrete slab thickness, ceiling cavity size below the concrete slab, and ceiling types throughout the building. This includes areas of:
  - Carpet
  - Tiled areas such as in bathrooms.
  - Vinyl flooring with backing, for instance to kitchen areas of cluster rooms.

Any tiled areas includes acoustic underlay to meet impact noise requirements. Vinyl flooring products must contain a backing which can act as an underlay, avoiding the need for a traditional acoustic underlay.

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6 Summary

The Subject Site is adjacent to a significant road traffic noise source as well as noise sensitive receivers.

Specific noise mitigation requirements have been integrated into the design to meet the noise criteria and are identified in Section 5. Recommendations include:

- Façade construction;
- Internal partition and door details;
- Floor finish requirements; and
- Acoustic shielding of onsite noise sources.

These acoustic mitigation requirements are considered feasible and environmental noise can be managed to meet relevant acoustic criteria for the proposed development.

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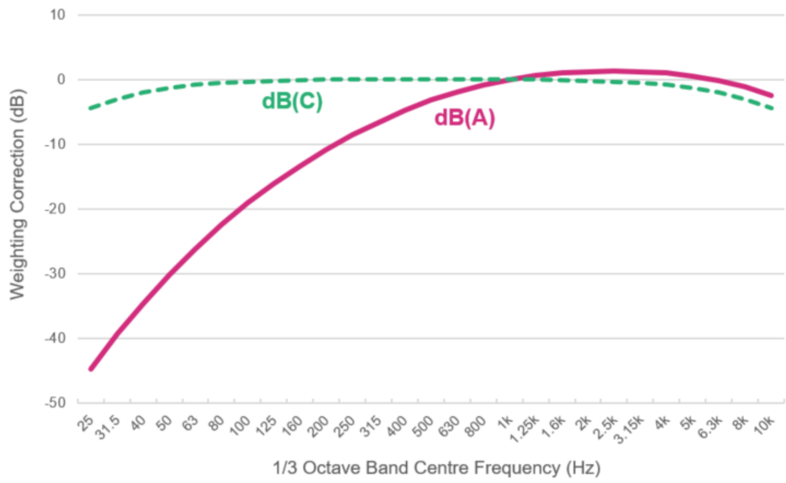
Appendix A

Acoustic Glossary

A1 Acoustic Glossary

Term	Definition
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 building is being investigated, the ambient noise level is the noise level from all other sources without the fan operating, such as traffic, birds, people talking and other noise from 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.
Decibel (dB)	The logarithmic scale used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressures, which would be difficult if presented on a linear scale. Use of a logarithmic scale allows all sound levels to be expressed based on how loud they are relative to a reference sound (typically 20 µPa, which is the approximate human threshold of hearing). For sound in other media (e.g. underwater noise) a different reference level (1 µPa) is used instead. 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 weighting curves	The frequency of a sound affects its perceived loudness and human hearing is less sensitive at low and very high frequencies. When seeking to represent the summation of sound pressure levels across the frequency range of human hearing into a single number, weighting is typically applied. Most commonly, A-weighting, denoted as dB(A), is used for environmental noise assessment. This is often supplemented by the linear or C-weighting curves, where there is the potential for excess low-frequency sound at higher sound pressure levels.



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.

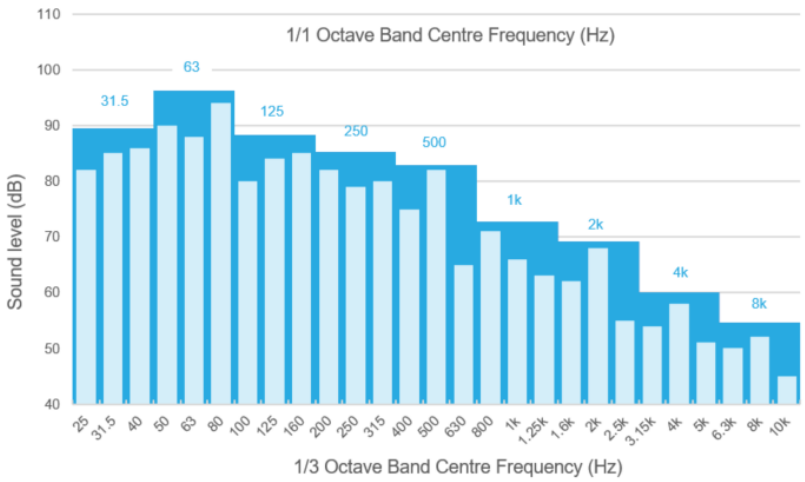
Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living 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

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’.

The unit of frequency is the hertz (Hz), which is identical to cycles per second. A thousand Hz is generally denoted as kHz. Human hearing ranges approximately from 20 Hz to 20 kHz.

While single weighted sound pressure levels simplify the assessment and evaluation of sound levels, frequency analysis is often undertaken. ‘Octave bands’, either 1/1 or 1/3 octave bands are most commonly utilised and are referred to by the nominal centre frequency of the band (e.g. 31.5 Hz), while being the summation of all frequencies between a defined lower and upper frequency.



$L_{10(period)}$ The sound level exceeded for 10% of the measurement period, or alternatively, the sound levels would be lower for 90% of the time.

The L_{10} is often defined as the 'average maximum' sound levels.

$L_{90(period)}$ The sound level exceeded for 90% of the measurement period.

The L_{90} is often defined as the 'average minimum' or 'background' noise level for a period of measurement. For example, 45 $dBL_{A90,15min}$ indicates that the sound level is higher than 45 dB(A) for 90% of the 15-minute measurement period.

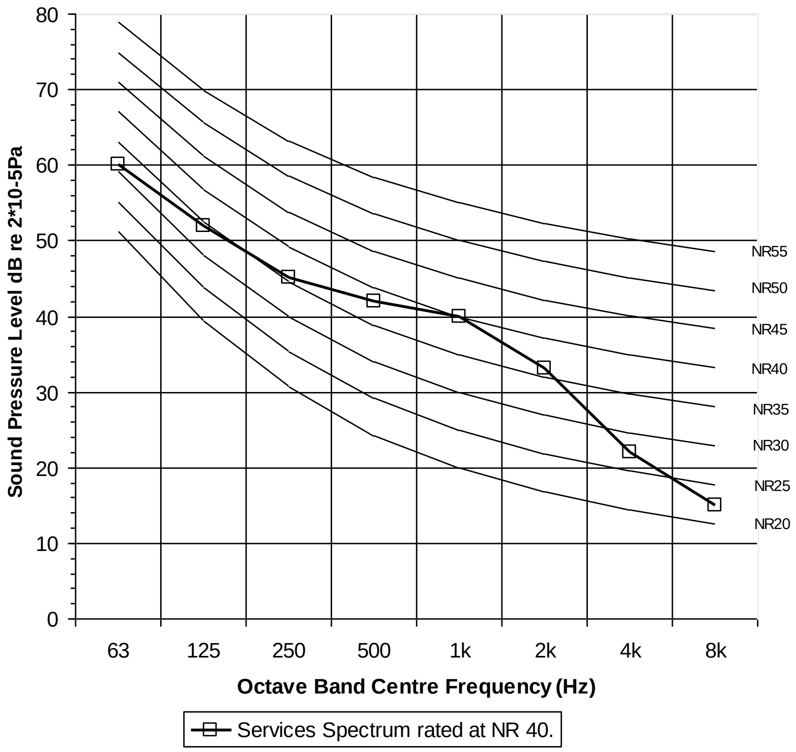
$L_{eq(period)}$ The equivalent ('eq') continuous sound level, used to describe the level of a time-varying sound or vibration measurement.

The L_{eq} is often defined as the 'average' level, and mathematically, is the energy-average level over a measurement period – i.e. the level of a constant sound that contains the same sound energy as the measured sound.

L_{max} The L_{max} is the 'absolute maximum' level of a sound or vibration recorded over the measurement period.

As the L_{max} is often caused by an instantaneous event, it can vary significantly between measurements.

Noise Rating (NR) Curves A set of internationally-agreed octave band sound pressure level curves, based on the concept of equal loudness. The curves are commonly used to define building services noise limits. The 'NR' value is obtained by plotting the octave band spectrum on the set of standard curves. The highest value curve which is reached by the spectrum is the NR value. Shown below is a mechanical plant noise spectrum at NR 40.



PLANNING and ENVIRONMENT ACT
BAROONDARA PLANNING SCHEME

CONSENT UNDER CLAUSE 52.20
VPP2101334
ENDORSED PLAN
Sheet 24 of 26

Signed: for
MINISTER FOR ENERGY, ENVIRONMENT AND CLIMATE CHANGE
Date: 5 Nov 2021

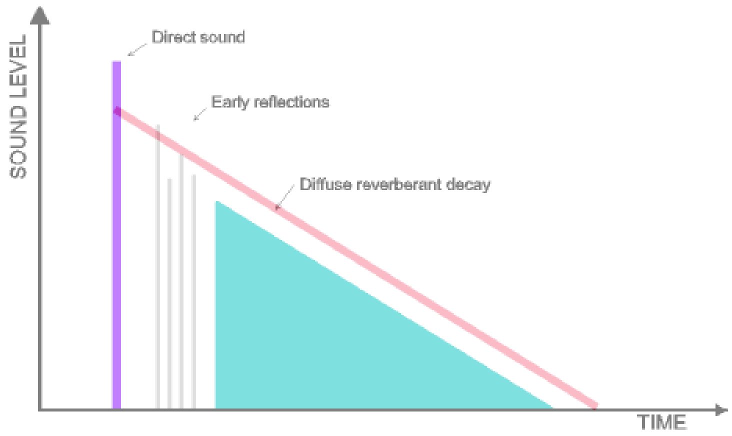
Reverberation Time (T_{60})

The time, in seconds, taken for a sound within a space to decay by 60 dB after the sound source has stopped is denoted at the reverberation time (RT).

The RT is an important indicator of the subjective acoustic within a space. A long RT subjectively corresponds to an acoustically ‘live’ space, while a short RT subjectively corresponds to an acoustically ‘dead’ space.

Examples of typical design reverberation times are provided below:

Mid-frequency reverberation time, s	Example
< 0.1	Anechoic – little to no reverberation
0.1 – 0.4	Call centres
0.4 – 0.6	Library
0.6 – 0.8	Offices / board rooms
0.8 – 1.0	Small auditorium for speech
1.0 – 1.2	Music studios
1.2 – 1.5	Chamber music venues
1.5 – 2.0	Orchestral music venues
2.0 – 3.0	Church
3.0 – 8.0	Cathedral



Sound Level Difference (D)

Used to quantify the sound insulation between two spaces and is equal to the difference in sound level between the rooms within a particular frequency band. For example, if the sound level in the source room is 100 dB and the sound level in the adjacent room is 75 dB, the sound level difference is 25 dB for that frequency band.

The **weighted sound level difference**, D_w, as defined in AS/NZS ISO 717.1, is used to provide a single-number descriptor to describe the overall performance of a partition across multiple frequency bands. Note however that D_w is only calculated over a frequency range from 100 Hz to 3.15 kHz and hence sound outside of this range is excluded from calculation of D_w – particularly low frequency (bass) sound below 100 Hz.

Also used are the **weighted normalised level difference** ($D_{n,w}$), which corrects the measured sound level difference to a reference sound absorption area in the receiving room, or the **weighted standardised level difference** ($D_{nT,w}$), which corrects the measurements to a reference reverberation time in the receiving room.

These single numbers are determined by comparing the spectral sound insulation test results (as defined in ISO 140-4) with reference values, as outlined in AS/NZS ISO 717.1.

Sound Reduction Index (R)

A measure of the sound level loss through a material for a particular frequency band. Sound reduction index is sometimes also referred to as **transmission loss.** It is a property of the component, unlike the sound level difference, which is affected by the common area between the rooms and the acoustics of the receiving room. R is the ratio (expressed in decibels) of the sound energy transmitted through the building element to the sound energy incident on the building element for a particular frequency band.

The **weighted sound reduction index**, R_w, is a single figure description of sound reduction index across multiple frequency bands and is defined in BS EN ISO 717-1: 1997. R_w values are calculated from measurements in an acoustic laboratory. Note however that R_w is only calculated over a frequency range from 100 Hz to 3.15 kHz and hence sound outside of this range is excluded from calculation of R_w – particularly low frequency (bass) sound below 100 Hz.

Sound insulation ratings derived from site measurements are referred to as **apparent sound reduction index** (R'_w) ratings.

Structureborne noise

The transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, i.e. expansion joints and floating floors.

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 (e.g. 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.