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DA ACOUSTIC REPORT

NOISE ASSESSMENT FOR PROPOSED MIXED-USE RESIDENTIAL & RETAIL DEVELOPMENT AT 77-79 WALDRON ROAD, CHESTER HILL

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Issue: v1.3

Report Ref: 170905 DA Acoustic Report v1.3

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DOCUMENT MANAGEMENT

Document	170905 77-79 Waldron Rd DA Acoustic Report v1.3
Ref	170905 DA Acoustic Report v1.3
Date	5 September 2017
Author	Osborn Fong
Reviewer	Glenn Leembruggen

Glenn Leembruggen

Document History			
Version	**Issue Date**	**Details**	**Authorisation**
V1.0	23rd June 2017	First Issue	Glenn Leembruggen
V1.2	25th August 2017	Second Issue	Glenn Leembruggen
V.13	5 September 2017	Third Issue	Glenn Leembruggen

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1. INTRODUCTION

Acoustic Directions has been retained by Hampton's Property Services to undertake an acoustic assessment of the proposed mixed-use retail and residential development at 77-79 Waldron Road, Chester Hill for their development application to City of Canterbury-Bankstown Council.

An assessment has been undertaken of i) the noise intrusion into the proposed building from external environmental noise and ii) the noise emissions from the use of the development to nearby residential properties.

Assessment of the vibration from trains impinging on the site has also be undertaken.

The major sources of environmental noise impacting the proposed development are traffic noise from Waldron Road and train noise from the adjacent rail corridor. Mechanical plant noise from external condenser units on apartment balconies is identified to be a noise source potentially affecting nearby receivers.

Goals for noise intrusion into the development have been established with reference to the following documents:

- Bankstown Development Control Plan 2015
- AS2021-2016 "Acoustics - Recommended design sound levels and reverberation times for building interiors"
- NSW Department of Planning "Development Near Rail Corridors and Busy Roads – Interim Guideline"
- State Environmental Planning Policy (Infrastructure) 2007 (SEPP 2007)
- Industrial Noise Policy (INP) issued by the NSW EPA.

The goal for vibration intrusion from trains has been established with reference to the following documents:

- Assessing Vibrations: a technical guideline (DECC 2006)
- Australian Standard AS 2670.2 1990

Goals for noise emissions to surrounding noise receivers have been established from NSW EPA Industrial Noise Policy (INP).

This assessment is based on our review of the following project documents:

- Architectural drawings by Project Tourism International Architecture Pty Ltd, project number P394 and dated 9 June 2017.

2. SITE DESCRIPTION

77-79 Waldron Road, Chester Hill is located in a suburban area zoned for high-density residential development (Zone Code R4). Currently, only low-density residential developments surround the proposed development. Houses immediately surrounding the proposed site are identified as the most-affected receivers of noise emitted from the development. These receivers are indicated in Figure 1 as Receivers A to D.

To the north of site is Waldron Road, which is classified as a State Road with an annual average daily traffic volume less than 20,000.

To the south of site is a rail corridor with frequent passenger and freight train movements.

Figure 1 below indicates the location of proposed site, nearby noise receivers, roads and rail corridors.

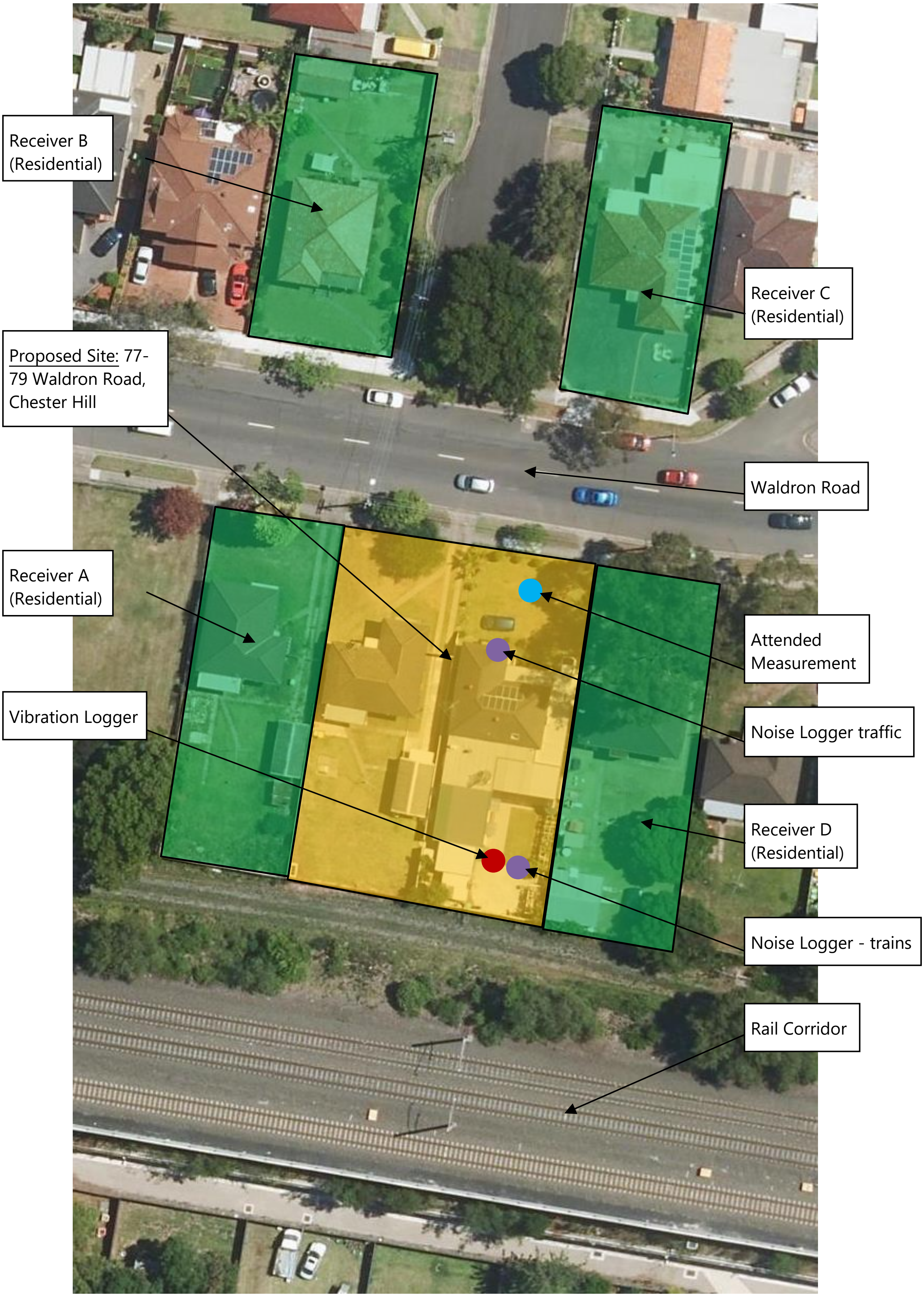


Figure 1. Aerial view of site with marked measurement locations, nearby noise receivers and nearby transportation noise sources.

3. EXISTING NOISE AND VIBRATION LEVELS AT SITE

3.1. Background Noise

Unattended automatic logging of background noise levels was conducted on site from 25th May 2017 to 1st June 2017 to quantify the existing background noise levels on site. The location of the logger is shown in Figure 1.

Noise data was acquired using an NTI-Audio XL2 with a Class 1 measurement microphone set to log data of each 15-minute interval. Calibration checks were done prior and after the logging to ensure the validity of data.

Background noise levels are presented as Rating Background Levels (RBL), which were calculated according to the procedure described in the NSW EPA Industrial Noise Policy. RBLs are commonly described for three time periods, which are day, evening and night. These periods are defined as follow:

a) Day – 7:00 am - 6:00 pm Monday to Saturday and 8:00 am - 6:00 pm for Sundays and Public Holidays.

b) Evening – 6:00 pm to 10:00 pm everyday

c) Night – remaining periods

Table 1 below shows the RBL for each period calculated from the site data,

Location	Time Period	Rating Background Level (RBL)
On site at 77-79 Waldron Road, Chester Hill	Day	50 dBA
	Evening	46 dBA
	Night	34 dBA

Table 1. Existing background noise levels at 77-79 Waldron Road, Chester Hill.

3.2. Traffic Noise

Traffic noise was measured on site to determine the acoustic treatment required for the proposed development to comply with the established traffic noise criteria.

A noise logger was installed on site from 25th May 2017 to 1st June 2017 to measure traffic noise from Waldron Road. The noise logger was placed at a location with a direct line-of-sight to Waldron Road at a distance of 12 m from the kerb. Logging was conducted using an NTI-Audio XL2 acoustic analyser with a Class 1 measurement microphone. Calibration checks were done prior and after the logging to ensure the validity of data.

Attended measurements were also made on site to verify the data obtained by the logger. Measurements were made using a Bruel and Kjaer 2250 acoustic analyser with a Class 1 measurement microphone. Calibration checks were done prior and after the attended measurements to ensure the validity of data. Measurements were made at the logger position and at positions 3 m from the kerb to provide a relationship between logger levels and the levels that would impinge on the building façade.

This relationship was used to adjust the logged levels upward by 7 dB to provide an equivalent façade level.

Traffic noise levels in Table 2 were found from measurements on site.

Representative location	Period	Highest 1-hour L_{Aeq} level
3 metres from Waldron Road curb at 77-79 Waldron Road, Chester Hill	24-hour	70 dB $L_{Aeq,1hour}$
	10:00 pm to 7:00 am	70 dB $L_{Aeq,1hour}$

Table 2. Traffic noise levels measured on site adjusted for a façade at 3 m from the kerb.

Inspection of the data showed that the loudest level occurs during the 6 am to 7 am period, which impacts the night-time period.

3.3. Rail Noise

Rail noise from train movements was measured on site to determine the level of impact it has on the proposed development.

A SVANTEK 958A noise logger was installed on site from 25th May 2017 to 1st June 2017 to measure noise generated by the rail corridor located to the south of the site. The logger was positioned with a direct view to the rail corridor at the location shown in Figure 1, 5 m north from southern site boundary.

Calibration checks were done prior and after the logging to ensure the validity of data.

Attended measurements were also made on site to verify the data obtained by the logger. Measurements were made using a Bruel and Kjaer 2250 acoustic analyser with a Class 1 measurement microphone. Calibration checks were done prior and after the attended measurements to ensure the validity of data.

The logger data was processed yielding the results presented in Table 3 below.

Parameter	Period	Noise level
$L_{Aeq,1hour}$	24-hour	Worst 1-hour period: 57 dB
	Night	Worst 1-hour period: 58 dB
Typical highest noise level of train pass-by (freight trains)	Anytime	76 dB L_{Amax}
Maximum noise levels	Anytime	Levels up to 90 dBA lasting 2 to 3 seconds were very occasionally recorded.

Table 3. Rail noise levels measured on site.

A detailed inspection was undertaken of the time history of the logger data in 1 second intervals to determine the frequency of occurrence of L_{Amax} levels above 76 dBA. Analysis showed levels exceeded 76 dBA for a total average period of 92 seconds per 24 hour period, or 4 seconds per hour. Over an eight-hour sleep period, this equates to a total of 31 seconds. The duration of the exceedances of 76 dBA ranged from 1 second to 9 seconds.

3.4. Rail Vibration

Vibration levels were logged on site from 25th May 2017 to 1st June 2017 using a SVANTEK 958A with SV84 ground vibration accelerometer. The accelerometer was rigidly bolted onto an existing concrete slab on site, and the equipment logged vibration data in three orthogonal axes (i.e., two directions in the horizontal plane, and one vertical).

Figure 1 indicates the location of vibration logging on site.

The vibration dose value (VDV) from the combined acceleration of the three triaxial accelerometers was calculated from the logged data and is presented in Table 4 below. The result is compared with the criterion established in Section 4.3.

Measured Location	Measured VDV	Most stringent VDV Criterion	Compliance
5 m from south boundary of 77-79 Waldron Road, Chester Hill	0.006 $m/s^{1.75}$	0.13 $m/s^{1.75}$	Compliant

Table 4. Vibration dose value (VDV) for vibration from trains measured on site.

4. GOALS FOR NOISE LEVELS AND VIBRATION

4.1. Goals - Traffic Noise Level

A review of Bankstown Development Control Plan 2015 did not reveal applicable criteria relating to traffic noise. Accordingly, Australian Standard AS 2107:2016 has been used to establish intrusion criteria for road noise impinging on the site.

Australian Standard AS 2107:2016 specifies the recommended design sound levels in Table 5 below.

Room Types	Design sound level range
Apartment common areas	45 to 50 dB $L_{Aeq,t}$
Living areas	30 to 40 dB $L_{Aeq,t}$
Sleeping areas (night time)	30 to 35 dB $L_{Aeq,t}$
Work areas	35 to 40 dB $L_{Aeq,t}$
Small retail stores	< 50 dB $L_{Aeq,t}$

Table 5. Recommendations from AS2107:2016.

We note that the standard does not define what constitutes "night time" for sleeping areas. The standard also does not specify the assessment period (t) for the $L_{Aeq,t}$ parameter.

We have interpreted "night time" to be 10:00 pm to 7:00 am, which is the definition in the EPA INP. We have also adopted a one-hour assessment period for $L_{Aeq,t}$ noise level.

Table 6 summarises the adopted traffic noise intrusion criteria.

Room Types	Period	Design sound level range
Apartment common areas	Any time	45 to 50 dB $L_{Aeq,1hour}$
Living areas	Any time	30 to 40 dB $L_{Aeq,1hour}$
Sleeping areas (night time)	10:00 pm to 7:00 am	30 to 35 dB $L_{Aeq,1hour}$
Work areas	Any time	35 to 40 dB $L_{Aeq,1hour}$
Small retail stores	Any time	< 50 dB $L_{Aeq,1hour}$

Table 6. Adopted traffic noise goals for the proposed site.

Comparison of the levels stated in Table 2**Error! Reference source not found.** with the internal noise-goals shows that traffic noise will likely disturb the noise amenity of occupants in the development if insufficient acoustic insulation is incorporated in the building envelope.

4.2. Rail Noise Intrusion Goals

4.2.1 Rail airborne noise

No applicable criteria relating to rail noise were found from a review of Bankstown Development Control Plan 2015. Therefore, goals have been adopted from AS 2107:2016 (see Table 5) and NSW Department of Planning "Development Near Rail Corridor and Busy Roads – Interim Guideline".

We note that the interpretations of AS2107:2016 made in Section 4.1 are similarly adopted for rail airborne noise criteria.

The NSW Department of Planning "Development Near Rail Corridor and Busy Roads – Interim Guideline" refers to Clause 87 of State Environmental Planning Policy (Infrastructure) 2007 (or referred to as Infrastructure SEPP) for maximum internal noise levels from rail noise.

According to Clause 87 of Infrastructure SEPP, the following L_{Aeq} noise levels must not be exceeded:

- 35 dBA in bedrooms between 10 pm to 7 am;
- 40 dBA for anywhere else at any time (other than a garage, kitchen, bathroom or hallway).

Table 7 outlines the adopted criteria for the proposed development considering the requirements from AS 2107:2016 and Department of Planning.

Room Types	**Interpreted AS2107:2016 $L_{Aeq,1hour}$**	**Department of Planning L_{Aeq}**	**Adopted Criteria for Rail Noise $L_{Aeq,1hour}$**
Residential Areas:			
Apartment common areas	45 to 50 dBA	N/A	Any time: 45 to 50 dBA
Living areas	30 to 40 dBA	Anytime: ≤ 40 dBA	Any time: 30 to 40 dBA
Sleeping areas (night time)	30 to 35 dBA	10 pm to 7am: ≤ 35 dBA	10:00 pm to 7:00 am: 30 to 35 dBA
Work areas	35 to 40 dBA	Anytime: ≤ 40 dBA	Any time: 35 to 40 dBA
Retail/Commercial Areas:			
Small retail stores	< 50 dBA	N/A	Any time: ≤ 50 dBA

Table 7. Rail noise criteria for the proposed development.

A. Rail-induced ground-borne noise

Structure-borne noise is typically of concern where buildings are constructed over a rail tunnel and the airborne noise component is not present. As the proposed development is adjacent to an exposed rail corridor, airborne noise intruding into the development from rail traffic will most likely mask the ground-borne noise component. Therefore, ground-borne noise is considered insignificant relative to airborne noise and has not been included in this assessment.

B. Sleep Disturbance

Rail movements from the adjacent rail corridor has the potential to cause sleep disturbance to occupants of the proposed development and must be assessed.

According to the enHealth Council 2004 report "The health effects of environmental noise – other than hearing loss" (May 2004), for good sleep over an eight-hour period, the maximum instantaneous internal sound level $L_{A,max}$ from short-term or transient noise events should not exceed approximately 45 dB more than 10 or 15 times per night.

Given the above, we have adopted a rail noise criterion of $L_{A,max}$ < 45 dBA within bedrooms to prevent sleep disturbance for the vast majority of rail noise events.

In the context of the measured duration of train-noise exceedances of 76 dBA ranging from 1 second to 9 seconds with a total duration of 31 seconds per eight-hours, the number of potential sleep disturbance events in an eight-hour period is likely to be substantially lower than ten times per night. As such, adoption of an external L_{Amax} level of 76 dBA (see Table 3) for design purposes represents a reasonable approach.

4.3. Rail Vibration Criteria

According to NSW Department of Planning "Development Near Rail Corridor and Busy Roads – Interim Guideline", rail-induced vibration criteria should be assessed according to NSW EPA Assessing Vibration: a technical guideline. This EPA guideline contain vibration criteria for intermittent vibrations such as those generated by train movements. According to the guideline, intermittent vibrations are assessed using vibration dose values (VDV).

Table 2.4 of the document outlines the acceptable VDV for intermittent vibration, which is presented in Table 8 below.

Location	Daytime (7.00 am to 10.00 pm)		Night-time (10.00 pm to 7.00 am)	
	Preferred value	Maximum value	Preferred value	Maximum value
Residences	0.20	0.40	0.13	0.26

Table 8. Acceptable vibration dose values for intermittent vibration taken from Table 2.4 of NSW EPA "Assessing Vibration – a technical guideline".

5. ASSESSMENT OF EXTERNAL NOISE INTRUSION AND RECOMMENDATIONS

5.1. Rail Vibration

Comparison of the VDV vibration data shown in Table 4 with the criterion in Table 8 shows that the VDV complies with the Department of Planning criteria for intermittent vibration for all time periods. Therefore, vibration isolation of the building is not required for the acoustic comfort of future occupants.

5.2. Noise Intrusion from Road Traffic and Trains

Traffic noise from Waldron Road and rail noise has the potential to impact residential amenity in the proposed development.

An assessment has been undertaken of the proposed building construction considering the following factors: Internal noise goals, external noise levels, proposed external constructions and their areas (i.e. roof, walls, windows and doors) distances of façades to the noise source, estimated internal reverberation times). From this process, recommended acoustic constructions were developed.

5.3. Recommendations

The following recommendations are required to ensure that noise intrusion from road traffic and trains into the development meets the adopted goals.

5.3.1 Windows and Glazed Elements

Table 9 below outlines the recommended thickness of glass along each façade.

Façade	Room Type	Glazing Thickness
North	Studio	10.38 mm laminated
	Retail	6.38 mm laminated
South	Studio	12.38 mm laminated
East	Studio	10.38 mm laminated
West	Studio	10.38 mm laminated
Common Areas (Lobby, Communal Room)		6 mm float

Table 9. Recommended glazing thicknesses.

A. Implementation Details

a) Acoustic seals are required for all openable windows and doors. Mohair seals are not acceptable.

a) Noise transmission through the gap between the sliding and fixed leaves of glass doors shall be minimised by a seal that is compressed when the sliding leaf is fully shut. This seal shall be located in a channel on the fixed leaf and shall be compressed by a corresponding sharp edge on the sliding leaf.

b) All large gaps between window & door frames and the masonry walls are to be sealed using acoustic foam (e.g. Hilti CP620). To seal larger gaps, glass wool batts can be used in conjunction with the foam.

c) Weep holes that can allow sound to be transmitted through window or door frames shall not be provided in windows or sliding doors.

d) In the installation of all doors and windows, all gaps around/between the frame and facade openings and the frame and the internal plasterboard lining shall be sealed air-tight with silicon or similar non-hardening mastic prior to fitting of weather strips and architraves.

e) Neoprene mountings shall be used for all glazed elements. Putty is not suitable for fixing of glazing to frames.

f) The construction of the glass is specified on the basis of its sound transmission vs frequency characteristic, and not the Rw rating of the system.

g) Standard double-hung windows cannot achieve the required acoustic rating unless fitted with seals fitted between the sashes where they meet and in within the beads. Casement or awning types are recommended.

h) The glazing details recommended in this report do not take account of other requirements such as structural adequacy, safety and all other Council and Building Code requirements.

i) All statutory and safety requirements are the responsibility of the builder and should be considered by others.

5.3.2 External Walls

a) The proposed masonry/concrete wall construction of minimum 190 mm thickness does not require acoustic treatment. All penetrations to the external wall must be treated to not degrade the wall's acoustic performance. All gaps must be acoustically treated and sealed with a flexible acoustically-rated sealant.

b) All wall constructions are to extend to the underside of the roof decking. All gaps at this interface are to be filled with flexible acoustic sealant. Eaves should be closed with 6 mm fibre cement sheeting.

c) The number of penetrations in the external walls that would de-rate the acoustic performance of the building should be minimised to the greatest possible extent. If penetrations are required, they shall be properly detailed to ensure that the acoustic performance is not compromised.

5.3.3 Roof

d) The proposed concrete roof does not require acoustic treatment. All penetrations to the roof must be treated so as not to degrade the acoustic performance of the wall. All gaps must be acoustically treated and sealed with a flexible acoustically-rated sealant.

6. ASSESSMENT OF NOISE EMISSIONS FROM MECHANICAL EQUIPMENT

6.1. Goals for Mechanical Noise Emissions

Mechanical noise generated from the development is required to comply with the NSW EPA Industrial Noise Policy (INP). This document specifies two criteria, namely intrusiveness and amenity, which in combination provide noise protection to surrounding receivers of a noise-emitting development. The two criteria are outlined below.

6.1.1 Intrusiveness criterion

The intrusiveness criterion only applies to residential noise receivers.

The intrusiveness of a noise source is generally considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (represented by the L_{Aeq} descriptor), measured over a 15-minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB.

The intrusiveness criterion can be expressed as follows:

$L_{Aeq, 15 minute}$ ≤ rating background level plus 5 dB (RBL+5dB)

where **$L_{Aeq, 15 minute}$** represents the equivalent continuous (energy average) A-weighted sound pressure level of the source over 15 minutes. This is to be assessed at the most-affected point on or within the residential property boundary.

The **rating background level (RBL)** is the short-term background noise level to be used for assessment purposes. The RBL is determined from monitoring the background noise level **$L_{A90, 15 minute}$** over the day, evening and night periods as defined in the EPA INP.

Table 10 outlines the relevant intrusiveness criterion for the site based on the background noise levels measured on site and stated in Table 1.

Type of Receiver	Time of Day	Rating Background Level	Intrusiveness Criterion, $L_{eq,15min}$
Residence - Suburban	Day	50 dBA	55 dBA
	Evening	46 dBA	51 dBA
	Night	34 dBA	39 dBA

Table 10. Intrusiveness Criterion applicable to surrounding noise-sensitive receivers to site.

6.1.2 Amenity criterion

The amenity criterion establishes a maximum noise level to protect the amenity of noise receivers against cumulative noise impact. The amenity criterion is expressed as an $L_{Aeq,period}$ descriptor, where period denotes either the daytime, evening or night time periods.

Table 11 outlines the relevant amenity criterion for the site.

Type of Receiver	Time of Day	Recommended Acceptable Noise Level. Leq,period
Residence - Suburban	Day	55 dBA
	Evening	45 dBA
	Night	40 dBA

Table 11. Amenity Criterion applicable to surrounding noise-sensitive receivers to site.

6.2. Mechanical Noise Assessment

Mechanical noise sources identified on site include toilet exhaust fans, kitchen exhaust fans and air conditioning outdoor condenser units.

Toilet exhaust fans and kitchen exhaust fans are located internally and typically have no impact to surrounding receivers provided quiet fans are selected. An assessment of internally located mechanical equipment should be conducted at CC stage after equipment selections are finalised.

Mechanical air conditioning systems are proposed to be installed on the north-facing and south-facing apartments on site, and the condensers are proposed to be placed on the balconies. Ceiling fans are proposed to be installed for the West-facing and East-facing apartments.

Mechanical equipment that is located externally has much greater likelihood of causing disturbance to surrounding receivers and exceedance to the INP criteria. Accordingly, a noise assessment of condenser noise has been undertaken, which is presented below.

6.2.1 Condenser noise assessment

Impact of noise from outdoor condensers to surrounding receivers has been assessed and is presented in this section.

To model the noise impact to surrounding receivers, we have made the following assumptions:

a) One condenser unit is located on the balcony area for each north- or south-facing apartment. i.e. six condensers on the north balconies and six condensers on the south balconies per level (36 condensers in total).

b) The condensers discharges air in lateral directions.

c) The condensers are 550 mm in height.

d) Modelling of the condenser noise is based on the noise data for Mitsubishi MUZ-GE42VAD. Using the noise data for this product, we assume that each condenser generates a noise level of 54 dBA when measured at one metre on axis from the unit with a noise spectrum shown in Table 12 below.

Octave-band frequency (Hz)		dBA	63	125	250	500	1000	2000	4000	8000
Sound Pressure Level Leq (dB)	normal mode	54	59	57	57	52	47	45	37	32

Table 12. Assumed condenser noise levels presented in octave-bands.

6.2.2 Prediction Method

a) Predictions of noise levels from condensers were made at the nearest receivers, indicated in Figure 1 as Receivers A to D.

b) The receivers are assumed to be located at heights ranging from 3 m to 10 m, to accommodate the possibility that future apartment developments will occur on each side of the site and over Waldron Rd.

c) All condensers were assumed to be running at maximum capacity.

d) The solid balustrades of the balconies provide partial acoustic barriers for condenser sound travelling towards the northern receivers.

e) The side wall and balustrades of the outer balconies provide partial acoustic barriers for sound from the most easterly and most westerly condensers for their closest receivers.

f) The internal dividing walls of the inner balconies provide substantial acoustic shielding for noise from their associated condensers for the eastern and western receivers.

To impose the most stringent criteria, condenser noise levels were predicted at these receivers and assessed against the night time criteria of the INP. The calculations incorporated distance loss and reflections.

6.2.3 Results

Results of the assessment with the acoustic barrier are presented in Table 13 below.

Receiver Location	Predicted Noise Level L_{Aeq}		Applicable Noise Criterion		Compliance?
	3 m high receiver	10 m high receiver	INP Intrusiveness	INP Amenity	
North Receivers (Receivers B and C)	37	37	39 (night)	40 (night)	Yes
West Receiver (Receiver A)	38	38	39 (night)	40 (night)	Yes
East Receiver (Receiver D)	38	38	39 (night)	40 (night)	Yes

Table 13. Predicted noise levels at receivers during night time.

From the predicted results, the noise levels comply with the noise criteria.

6.3. Recommendations - Condensers

The following recommendations are provided for compliance with the noise criteria adopted for this assessment.

a) Any modifications to the proposed layout should be reviewed by an acoustic consultant for approval. A full schedule of mechanical equipment including all fans located both externally and internally-should be reviewed by an acoustic consultant during CC stage.

b) All condensers shall have a maximum rated sound pressure level Leq of less than 55 dBA, measured at one metre from the unit with the spectrum listed in Table 12.

c) All condenser units shall be vibration isolated from the rooftop using rubber pad or spring mounts providing a static deflection of not less than 10 mm.

d) Only apartments with balconies facing north or south shall have air conditioners installed with laterally discharging condensers located on each balcony. Apartments facing east and west must not have air conditioner condensers installed on their balconies.

7. CONCLUSIONS

This report presents an acoustic assessment of the proposed mixed-use residential and retail development at 77-79 Waldron Road, Chester Hill.

Noise intrusion from road traffic noise from Waldron Road and rail noise from the rail corridor south of site has been assessed. Provided that external constructions are implemented according to the recommendations in Section 5.3, internal noise levels will comply with our selected criteria for internal noise levels.

Measurements of ground vibration due to passing trains has shown that vibration-isolation of the building structure is not required.

Our mechanical noise assessment has shown that externally located condensers proposed along the balconies have the greatest potential to cause impact to at nearby residential receivers. However, provided that the recommendations in Section 6.3 are implemented, noise at nearby receivers will meet EPA noise emissions criteria.

8. APPENDIX: GLOSSARY OF TERM

8.1. Index to Terms

The glossary is arranged alphabetically to assist readers to find the required information by clicking on the link.

8.2. Glossary

SOUND

Sound is an instantaneous fluctuation in air pressure over the static ambient pressure, and is transmitted as a wave through air or solid structures.

SOUND PRESSURE LEVEL

Commonly known as "sound level", the sound pressure level in air is the sound pressure relative to a standard reference pressure of 20 µPa (20x10-6 Pascals) when converted to a decibel scale.

DECIBEL (dB)

A scale for comparing the ratios of two quantities, including sound pressure and sound power.

The ratio of sound pressures which we can hear is a ratio of one million to one. To measure this huge range in pressure, a logarithmic measurement scale is used with the associated unit being the decibel (dB).

An increase or decrease of approximately 10 dB corresponds to an approximate subjective doubling or halving of the loudness of a sound. A change of 2 to 3 dB is subjectively a small change and may sometimes be difficult to perceive.

As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply to dB values.

The difference in level between two sounds s1 and s2 is given by 20 log10 (s1 / s2). The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20 µPa.

FREQUENCY

Frequency is the rate of repetition of a sound wave. The subjective equivalent of frequency in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to the number of cycles per second. A thousand hertz is often denoted kiloHertz (kHz), e.g. 2 kHz = 2000 Hz.

Human hearing ranges from approximately 20 Hz to 20 kHz.

OCTAVE BAND

The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the octave band below it. In subjective terms, it corresponds to a doubling of pitch.

For design purposes, the octave bands ranging from 31.5 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

A-WEIGHTED SOUND LEVEL dBA

The unit of sound level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies. The unit is generally used for measuring environmental, traffic or industrial noise is the A weighted sound pressure level in decibels, denoted dBA.

A weighting is based on the frequency response of the human ear at moderate and low sound levels and has been found to correlate well with human subjective reactions to various sounds.

Sound level meters usually have an A-weighting filter network to allow direct measurement of A-weighted levels.

C-WEIGHTED SOUND LEVEL dBC

As the sound level increases, the ear is better able to hear low frequency sounds, The C-weighting filter allow low frequencies to contribute to the measurement much more than the A weighting filter.

Z-WEIGHTING dBZ

The Zero-weighting is equivalent of non-frequency shaping or weighting the measured sound level, and as no filter is applied to the sound before measurement, it is sometimes referred to as "linear" weighting.

SOUND LEVEL INDICES

Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.

Examples of sound level indices are Leq,T Lmax, L90, L10 and L1, which are described below. The reference time period (T) is normally included, e.g. dBLA10, 5min or dBLA90, 8hr.

EQUIVALENT CONTINUOUS SOUND LEVEL (Leq)

Another index for assessment for overall noise level is the equivalent continuous sound level, Leq. This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. This allows fluctuating sound levels to be described as a single figure level, which assists description, design and analysis.

The Leq is often A-weighted to remove the contribution of low frequencies, which may be less audible and is written as LAeq. It can also have no weighting as LZeq or C-weighting as LCeq.

Lmax,T - MAXIMUM SOUND LEVEL

A noise level index defined as the maximum noise level during the measurement period duration T. Lmax is sometimes used for the assessment of occasional loud noises, which may have little effect on the overall Leq noise level but will still affect the noise environment. Unless described otherwise, it is measured using the 'fast' sound level meter response.

LA90,(T)

A noise level index. The LA90 is the sound pressure level measured in dBA that is exceeded for 90% of the time over the measurement period T. In other words, the measured noise levels during the period were greater than this value for 90% of the measurement time period.

L90 can be considered to be the "average minimum" noise level and in its A weighted form is often used to describe the background noise a LA90.

LA10(T)

A noise level index. The LA10 is the sound pressure level measured in dBA that is exceeded for 10% of the time interval (T). In other words, the measured noise levels during the period were only greater than this value for 10% of the measurement time period.

This is often referred to as the average maximum noise level.

LA1(T)

Refers to the sound pressure level measured in dBA, exceeded for 1% of the time interval (T). This is often used to represent the maximum noise level from a period of measurement, but is not the same as LAmax.

RATING BACKGROUND LEVEL (RBL)

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.

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 period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time.

SOUND POWER

The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (Lp) varies as a function of distance from a source or other factors such as shielding. However, the sound power level is an intrinsic characteristic of a source.

VIBRATION

Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structure borne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g. 1mms-1 or as a ratio on a logarithmic scale in decibels:

Vibration velocity level, LV (dB) = 20 log (V/Vref),

(where the preferred reference level, Vref, for vibration velocity = 10-9 m/s).

The decibel approach has advantages for manipulation and comparison of data.

SOUND ABSORPTION

This is the removal of sound energy from a room or area by conversion into heat.

SOUND ABSORPTION CO-EFFICIENT

Sound absorption co-efficient indicate the extent to which the material absorbs sound power at a specific frequency, and is expressed on a scale of 0 to 1, with a value of 1 representing the maximum possible absorption.

SOUND INSULATION

The sound insulation is the capacity of a structure such as a wall or floor to prevent sound from reaching a receiving location.

SOUND REDUCTION INDEX

This parameter is used to describe the sound insulation properties of a partition, and is the decibel ratio of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. It is usually measured in specific frequency bands, such as octave or one-third octave.

DnT,w

The single number quantity that characterises sound insulation between rooms over a range of frequencies with airborne sound..

Rw

Single number quantity that characterises the sound-insulating properties of a material or construction element over a range of frequencies with airborne sound.

REVERBERATION TIME

The time in seconds required for the sound at a given frequency to decay away (or reduce to) to one-thousandth of its initial steady-state value after the sound source has been stopped. This degree of reduction is equivalent to 60 decibels.

FREQUENCY RESPONSE

Subjective tonal balance is measured as a system's frequency response at each location. As the ear is very sensitive to the direct sound field (the first-arriving part of the sound before reflections arrive), the response of the direct field with speech must be as consistent as possible over the listening area in the frequency range of 100 Hz to 12 kHz.

EQUIVALENT ACOUSTIC DISTANCE

By amplifying a talker's speech, a sound system reduces the apparent acoustic distance between a talker and distant listener. The equivalent acoustic distance defines the resulting acoustic distance between the talker and listener and is a direct measure of the amount of voice amplification that the system can provide before the onset of acoustic feedback. Feedback is often heard as a strong colouration to the voice or howling sound.

We are accustomed to holding conversations in relatively close proximity, and to produce similar conditions in a courtroom and allow soft talkers to be heard, the EAD should be less than 2.2 m and typically 1.8 m without any trace of feedback or tonal ringing in the sound.

EAD is associated with speech intelligibility as it directly relates to the amount of speech amplification that the system can provide in order to deliver a satisfactory level of speech signal above the noise to each listener.

Factors affecting the EAD include:

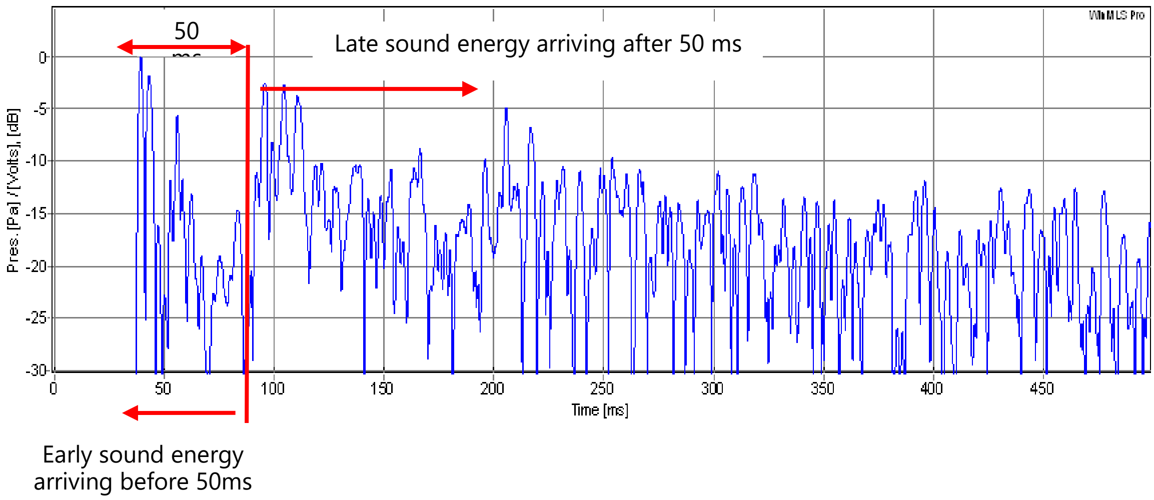
- The number of microphones switched on at any time.
- The relationships between the directional response characteristics of the microphone and loudspeaker.
- The sound level reaching the audience at the critical mid and mid-high frequencies.
- Room acoustic behaviour.

CLARITY RATIO

The clarity ratio is a metric that is used to assess the degradation in speech intelligibility due to the temporal effects of reverberation and echo. It is defined as the ratio of the sound energy of early-arriving sound that is useful for intelligibility to the energy of late-arriving sound which is not useful. Early-arriving sound consists of the direct sound and some reflections, while late arriving sound consists of reverberation and echoes.

Early-arriving sound consists of sound that arrives between the start of an extremely short pulse (an impulse) up to 50 ms after the start of the pulse, while late arriving sound is the total sound energy arriving later than 50 ms after the start of the pulse.

The following figure shows a typical impulse response and illustrates the dividing period of 50 ms between early and late arriving sound, which is used to compute the C_{50} clarity ratio.



Typical impulse response illustrating how the clarity ratio C_{50} is computed.

As the ear and therefore subjective intelligibility is sensitive to the amount of reverberation and echo at different frequencies, the C_{50} ratios must be as high as possible at all frequencies to maximise intelligibility.

STI - SPEECH TRANSMISSION INDEX

The Speech Transmission Index (STI) is one of the better available metrics to assess the capability of a transmission system to transmit intelligible speech. STI is a single number that ranges between 0 and 1. It attempts to assess the degradation in intelligibility caused by reverberation/echoes and background noise by measuring the reduction in modulation of the speech-like waveform. Phonemes in speech are produced by modulating vocal sounds in a specific pattern, and when perfect transmission of the modulation pattern is present at a listening location, the clarity is perfect. When modulations are corrupted by reverberation or noise, the time pattern of the phonemes is changed and the clarity is degraded.

However, STI has three fundamental weaknesses:

- It is almost blind to the effects of tonal balance on intelligibility.
- It is partially blind to the effects of echo on intelligibility.
- It reduces many complex factors (frequency/level/time) into to a single number, thereby concealing important and audible components that contribute to the degradation of speech intelligibility.

To accommodate these weaknesses in STI, Acoustic Directions uses two other metrics (clarity ratios and frequency response) in conjunction with STI to assess speech intelligibility produced by a sound system.

The STI value is computed from weighted MTI values, which represent the loss of modulation in each octave-wide frequency range. When assessing STI performance, it is instructive to assess the loss of modulation in each frequency range by inspecting the associated MTI values.

Given that the majority of speech sounds occur in the 250 Hz and 500 Hz frequency ranges, the MTI values in these frequency ranges are a direct indicator of the smearing or degradation in vowel sounds. In turn, this indicates the extent to which long vowel sounds will subjectively mask sounds with higher frequency content such as consonants.