ARUP

Infrastructure NSW

Powerhouse Ultimo Revitalisation

Noise and Vibration Impact Assessment

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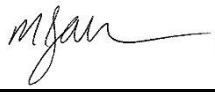
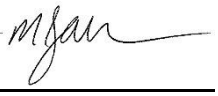
		Signature			
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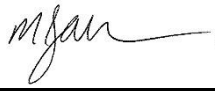
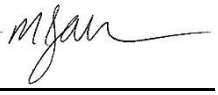
		Signature			
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1. Introduction

This report has been prepared on behalf of Infrastructure NSW to support a State Significant Development Application (SSDA) for alterations and additions to Powerhouse Ultimo at 500 Harris Street, Ultimo.

The Powerhouse Ultimo Revitalisation is a transformative investment by the NSW Government to establish a world-class museum that will significantly contribute to an important and developing part of Sydney. The renewed Powerhouse Museum in Ultimo will deliver a dynamic applied arts and applied science program, presenting exhibitions that showcase the Powerhouse collection, international exclusive exhibitions and programs that support the creative industries.

1.1 Process

The Powerhouse Ultimo Revitalisation project is for the purposes of an 'information and education facility' with a capital investment value of more than $30 million, and such is classified as State Significant Development (SSD) pursuant to Section 13(1) of Schedule 1 of *State Environmental Planning Policy (Planning Systems) 2021*.

1.2 Site Description

Powerhouse Ultimo is situated upon the lands of the Gadigal people of the Eora Nation. It is located within the City of Sydney Local Government Area and its primary address is 500 Harris Street, Ultimo. The site comprises part Lot 1 DP 631345; Lot 3 DP 631345; Lot 1 DP 770031; Lot 1 DP 781732; and Lot 37 DP 822345.

The site contains two heritage-listed buildings, being the 'Ultimo Powerhouse' (c.1899-1905) and the 'Former Ultimo Post Office including interior' (c.1901), both of which are listed on the State Heritage Register under the *Heritage Act 1997*.

Other buildings within the site include the 1988 museum building fronting Harris Street (Wran Building). A café building has been constructed immediately to the south of the Powerhouse at the northern end of the Ultimo Goods Line. Located at the corner of Harris Street and Macarthur Street is a forecourt that acts as the main public entrance to the site, but provides limited activation and is disconnected from higher-quality urban spaces including the Ultimo Goods Line.

The primary focus of the Powerhouse Ultimo Revitalisation project is the museum to the north of Macarthur Street and bounded by Harris Street, Pier Street and the light rail corridor.

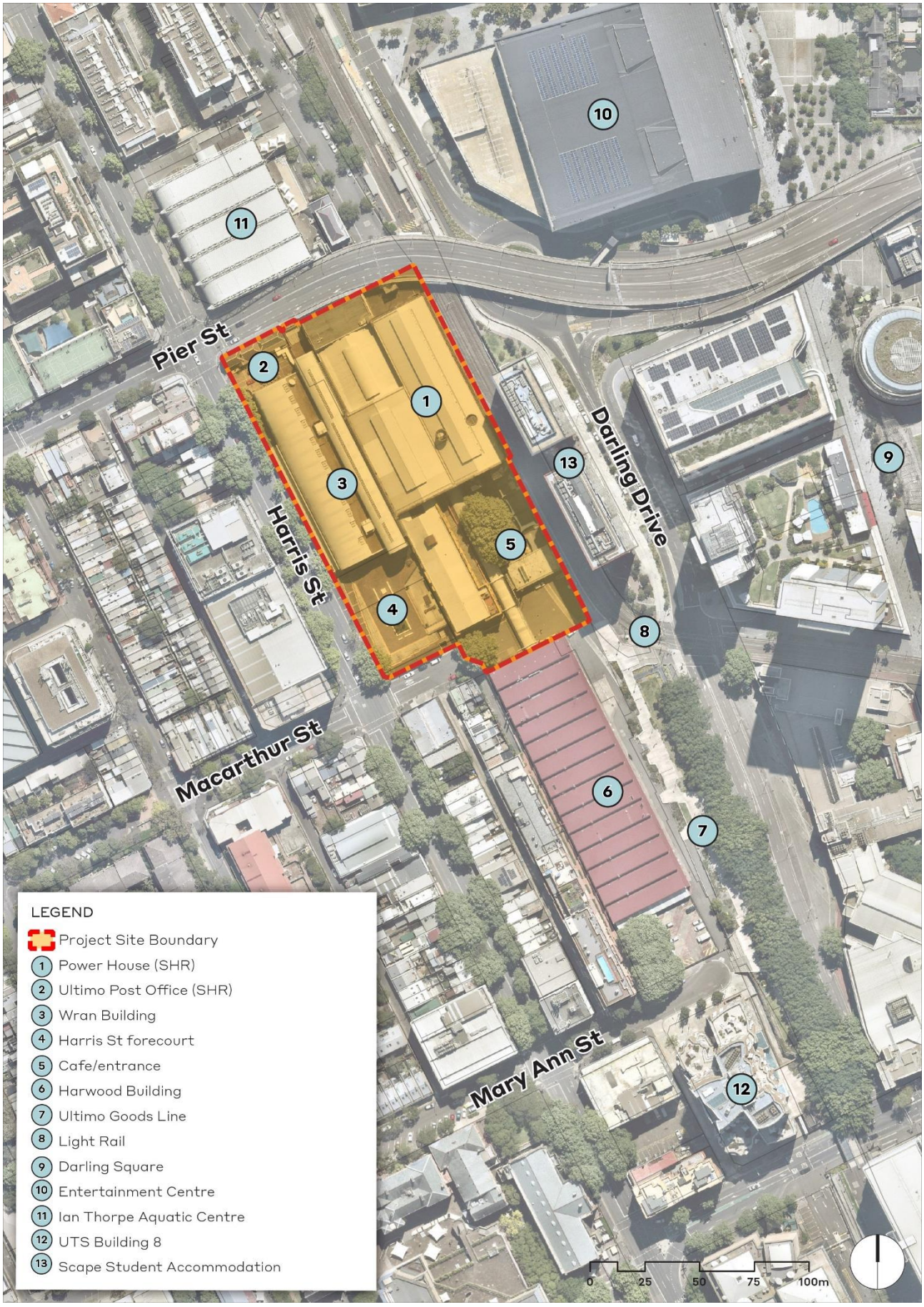

Figure 1: Site boundary, key existing features and immediate local context. Source: Ethos Urban

1.3 Overview of Proposed Development

The SSDA seeks consent for the design, construction and operation of the proposed Powerhouse Ultimo. Specifically, approval is sought for the following:

- Site preparation works, including site services and infrastructure works, tree removal, earthworks, remediation and the erection of site protection hoardings and fencing.
- Demolition of existing structures on the site, including:
  - Harris Street forecourt.
  - Structures in the forecourt entrance at the Goods Line, including the café.
  - Internal demolition of non-heritage elements of the Ultimo Powerhouse building
- Construction and use of a new museum spaces along the Harris Street frontage, including the following uses:
  - Loading dock and other back of house spaces.
  - Creative industry studios.
- Conservation and adaptive reuse of the existing Ultimo Powerhouse and Ultimo Post Office heritage items for museum purposes.
- Alterations to the Wran Building spaces to upgrade the auditorium and exhibition spaces.
- Construction of a new public open spaces including:
  - At the south-eastern corner of the site to connect with the Ultimo Goods Line.
  - An internal courtyard garden wrapped by the building fronting Harris Street.
  - A creative courtyard between the Post Office and Wran Buildings.

Full details of the proposed development are set out in the Architectural Drawings and Landscape and Public Domain Drawings accompanying the SSDA.

1.4 Assessment requirements

The Department of Planning and Environment (DPE) has issued Secretary's Environmental Assessment Requirements (SEARs) to the applicant for the preparation of an Environmental Impact Statement (EIS) for the proposed development. This report has been prepared having regard to the SEARs as shown in Table 1.

Table 1: SEARs requirements:

Environmental Assessment Requirement	Where addressed
Provide a noise and vibration assessment prepared in accordance with the relevant NSW Environment Protection Authority (EPA) guidelines. The assessment must detail construction and operational noise and vibration impacts on nearby sensitive receivers and structures and outline the proposed management and mitigation measures that would be implemented. Provide a noise and vibration assessment prepared in accordance with the relevant NSW Environment Protection Authority (EPA) guidelines. The assessment must detail construction and operational noise and vibration impacts on nearby sensitive receivers and structures and outline the proposed management and mitigation measures that would be implemented.	Section 2 to 4

This report also addresses the following Strategic Policy, Technical Guidelines and National Standards:

- Interim Construction Noise Guideline (Department of Environment & Climate Change, 2009) [1]
- Assessing Vibration: A technical guideline (Department of Environment and Conservation (NSW) 2006) [2]
- BS 6472-1:2008 Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting (British Standards, 2008) [3]
- BS 7385-1:1990 - Evaluation and measurement for vibration in buildings. Guide for measurement of vibrations and evaluation of their effects on buildings (British Standards, 1990) [4]
- DIN 4150 - Part 3 'Structural vibration in buildings - Effects on Structure' (German Institute for Standardisation, 1999) [5]

- AS 2436-2010 - Guide to noise and vibration control on construction, demolition and maintenance sites (Standards Australia, 2010) [6]
- NSW Noise Policy for Industry (Environment Protection Authority, 2017) [7]
- NSW Road Noise Policy (Environmental Protection Authority, 2011) [8]
- AS/NZS 2107:2016 Acoustics - Recommended design sound levels and reverberation times for building interiors (SAI Global Limited, 2016) [9]

2. Existing acoustic environment

The site is located adjacent to Harris Street to the west, William Henry Street to the north, Macarthur Street to the south and L1 Light Rail Line to the East.

The main noise sources in the local environment are:

- Road Traffic along Harris Street
- 'Urban hum'
- Rail noise from the L1 Light rail

The ambient acoustic environment has been quantified in accordance with NSW EPA policies [7] and is outlined in this section.

2.1 Surrounding land-use

Maps presenting the location of the site and its surrounds are included in Section 2.2 below. Types of land use surrounding the site is identified in Figure 2. The area around the site is a mixed-use zoning area, with commercial, residential, recreational, and educational receivers in the immediate vicinity.

Figure 2: Surrounding Noise & Vibration Sensitive Receivers

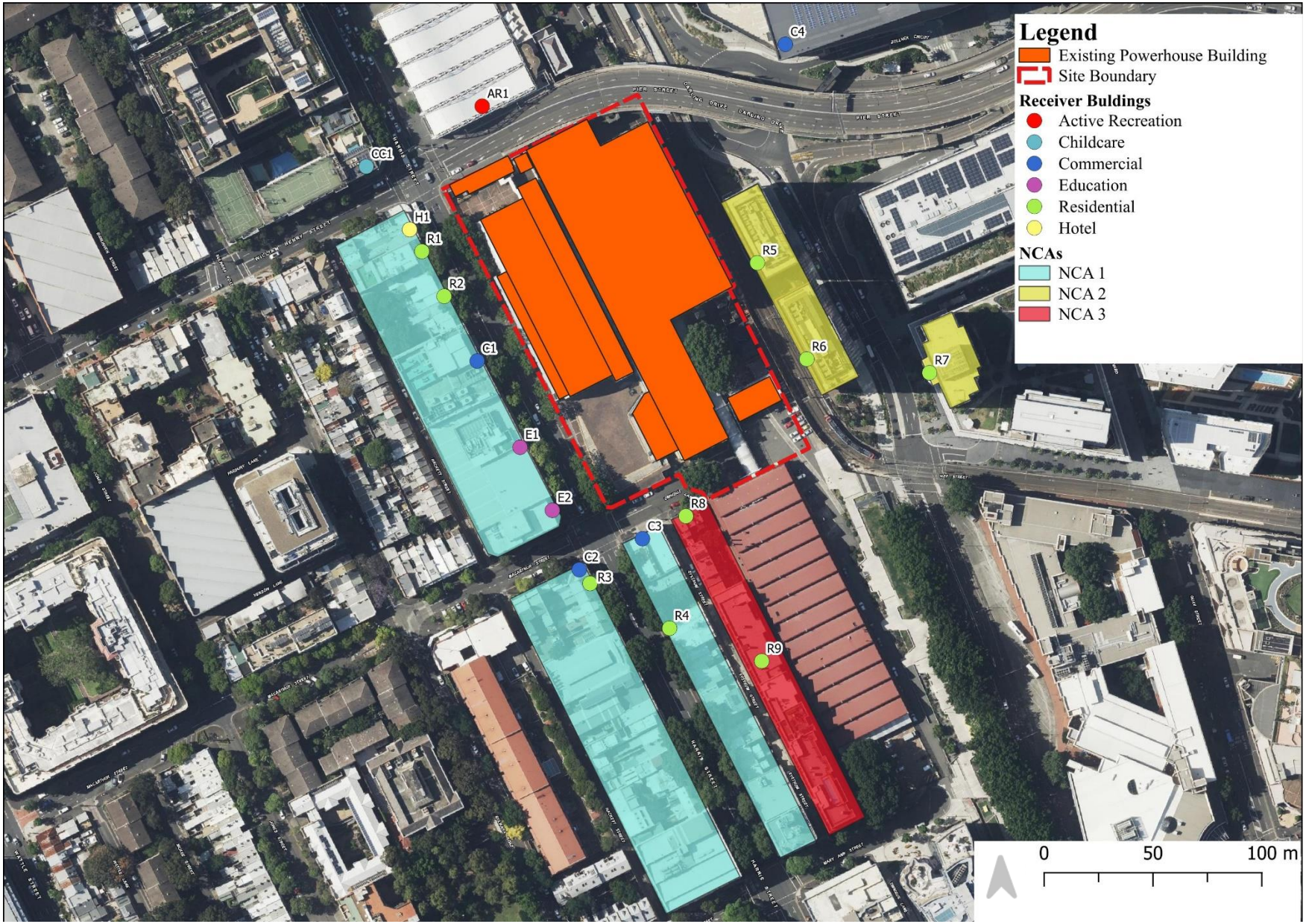

Figure 3: Assessment Locations

For residential receivers, where noise targets are established from background levels, Noise Catchment Areas (NCA) have been defined. The NCA boundaries have been determined from site observations and attended measurements, which are detailed in Section 2.4.

Classifications of NCAs as 'Urban' are based on on-site observations, and based on the NSW Noise Policy for Industry (NPfI) definitions, given that these areas have *'through-traffic with characteristically heavy and continuous traffic flows during peak periods'* and are *'near commercial districts or industrial districts'*.

2.2 Noise catchment areas

Receivers potentially affected by the noise and vibration associated with the Proposal have been classified into three noise catchment areas according to their existing noise environments. A description of the receivers within each NCA is described in Table 2.

Table 2: Noise Catchment Area (NCA) descriptions

NCA	Description
1	West of study area, including receivers along Harris St. Bordered by Harris St, William Henry Street, Hackett St and Mary Ann St. Receivers within this NCA include residential dwellings, commercial receivers and the JMC Academy. The noise environment is dominated by traffic on Harris Street.
2	East of the study area and includes the two "Scape" student accommodation residential buildings. Dominant noise sources in the area are transport noise from Darling Drive, the tram line and other industrial sources
3	South of the study area and includes the strip of residential dwellings bordered by Macarthur St, Systrum Street, the Harwood Building and Mary Ann St. The noise environment is made up of ambient industrial sources with lesser traffic from Harris St.

2.3 Noise sensitive receivers

In accordance with the NPfI the reasonably most-affected receivers have been identified. Table 3 presents the most potentially noise and vibration affected residential receivers and mixed-use receivers in each NCA. Table 4 presents the non-residential noise sensitive receivers within the study area. Mixed-use receivers are defined as residences located in the same building as a commercial premise. Figure 3 shows the receivers where noise and vibration impacts were assessed within this report.

Table 3: Reasonably most-affected residential receivers

Receiver ID	NCA	Address	No. of floors
R1	1	543 Harris Street, Ultimo	2
R2	1	531-533 Harris Street, Ultimo	6
R3	1	599 Harris Street, Ultimo	2
R4	1	576A Harris Street, Ultimo	2
R5	2	39 Darling Drive, Sydney	21
R6	2	41 Darling Drive, Sydney	21
R7	2	1 Steam Mill Lane, Haymarket	29
R8	3	81-85 Macarthur Street, Ultimo	2
R9	3	13-17 Systrum Road, Ultimo	4

Table 4: Non-residential receivers

Receiver ID	Name	Address	No. of floors
Hotel			
H1	Glasgow Arms Hotel[1]	527 Harris Street, Ultimo	2
Commercial			
C1	Optus Data Centre	549 Harris Street, Ultimo	4

Receiver ID	Name	Address	No. of floors
C2	The Q on Harris	597 Harris Street, Ultimo	2
C3	Commercial Tenancy	562-570 Harris Street,	2
C4	International Convention Centre Aware Super Theatre	458 Harris Street, Ultimo	1
Child Care Centre			
CC1	Ultimo Community Centre[2]	40 William Henry Street, Ultimo	5
Active Recreation			
AR1	Ian Thorpe Aquatic Centre	458 Harris St, Ultimo NSW 2007	1
Education			
E1	JMC Academy	561 Harris St, Ultimo NSW 2007	3
E2	Academy of Film, Theatre and Television	579 Harris St, Ultimo NSW 2007	7

Note:

1. The first floor has been identified as a licenced premises while the second floor is operating as a Hotel. This report classified the entire building as Hotel as the most conservative approach
2. It has been identified that Ultimo Community Centre has a range of receiver types within the building including active recreation, childcare and commercial. This report classifies the entire building as a Childcare as the most conservative approach.

2.4 Ambient noise level measurements

This report adopts the results of a noise monitoring campaign conducted by RWDI and documented in the Stage 1 NVIA for The Powerhouse Ultimo [10] dated 17 May 2022.

Arup has proposed changes to the NCA's presented within the RWDI documentation based on a review of locations and a site walk conducted to understand the acoustic environment. A summary and justification of the changes are listed below:

- All residential lots along Harris St are believed to have a similar background noise level and as such have all been categorised as NCA1
- Residences 81-85 Macarthur street have been categorised into NCA3 due to setback from Harris Street resulting in an altered ambient environment

Ambient noise monitoring was undertaken between 5-19 April 2022. This is included both unattended, long-term monitoring and short-term attended measurements.

A summary of key information relevant to this assessment is reproduced below. Details of noise monitoring methodologies, results and details undertaken by RWDI should be viewed in the correpsonding report [10].

2.4.1 Noise measurement locations

Noise measurements are ideally carried out at the nearest or most potentially affected locations surrounding a development. An alternative, representative location should be established in the case of access restrictions or if a safe and secure location cannot be identified. Furthermore, representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

The short-term and long-term measurement locations conducted by RWDI are outlined in Table 5 and shown in Figure 4.

Table 5: Measurement summary

ID	NCA	Measurement location	Measurement type	Comment on location suitability
Meas. 1a	1	Old Post Office Courtyard, on Harris Street	Long term	Considered representative of the worst affected receivers, located along Harris Street.
Meas. 1b	1	Harris Street	Short term	
Meas. 2	2	Ultimo Powerhouse Café Rooftop	Long and short term	Considered representative of the worst affected receivers in NCA 2
Meas. 3	3	Staff Courtyard, Mary-Ann Street	Long and Short term	Considered representative of the worst affected receivers in NCA 3
Meas. 4	3	Corner of Macarthur Street and Omnibus Lane	Short term	Used to validate that the results of long term measurements taken in Meas 3 for receivers between 81-85 Macarthur Street.

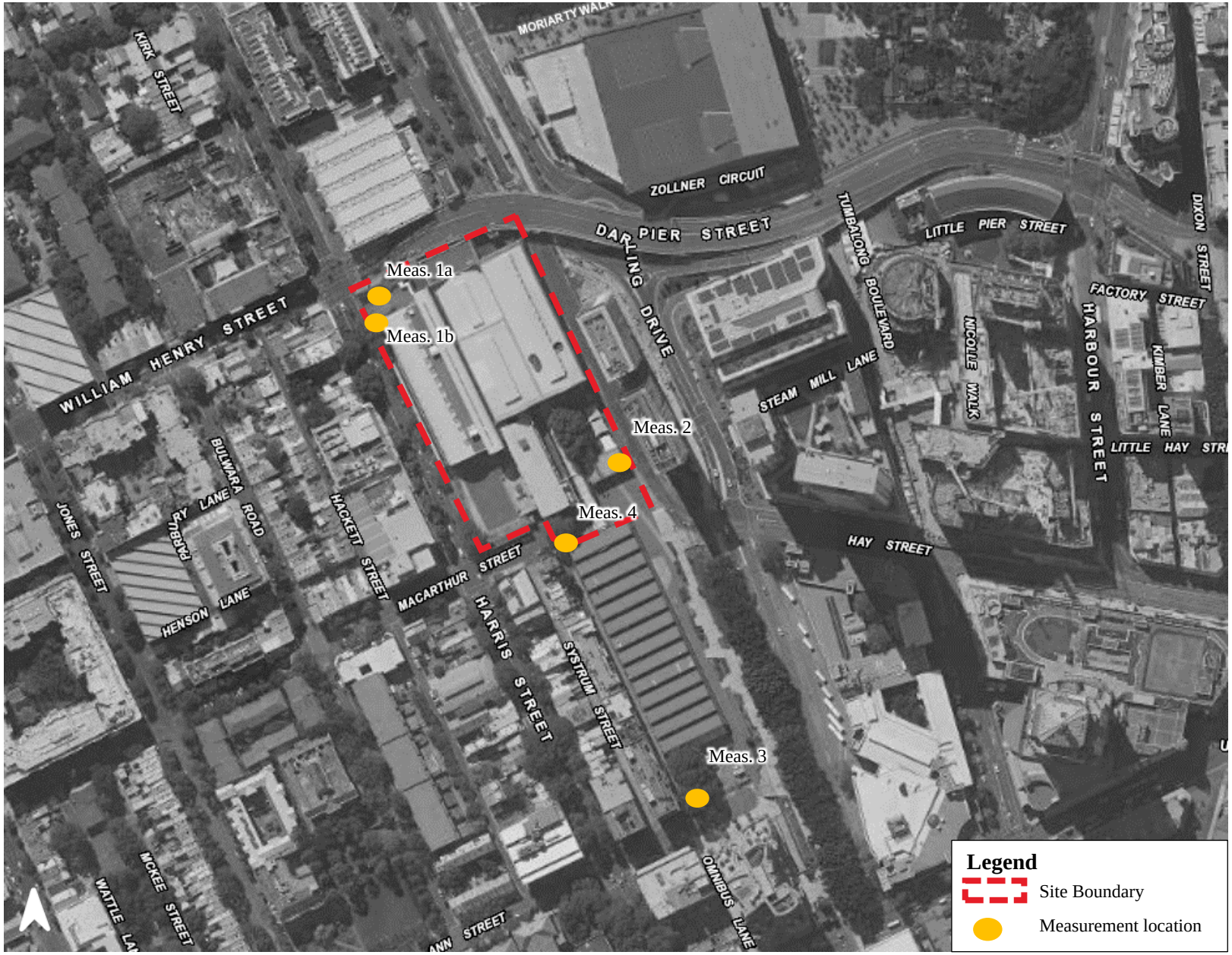

Figure 4: RWDI Measurement locations

2.4.2 Unattended noise measurements

Noise monitoring was conducted by RWDI to determine existing background noise levels at sensitive receivers. Noise loggers were placed at the locations indicated in Figure 4. Noise loggers monitored noise levels continuously from 5-19 April 2022. The ambient noise environment in the area is typical of an urban environment and has not changed significantly since the measurements were undertaken. The noise monitoring undertaken is therefore considered representative of existing ambient levels and suitable for deriving project specific criteria.

The loggers measured the noise levels over the sample period and then determined L_{A10}, L_{A90}, L_{Amax}, and L_{Aeq} levels of the noise environment. The L_{A10} and L_{A90} noise levels are the levels exceeded for 10 percent and 90 percent of the measurement period respectively. The L_{A90} is taken as the background level. The L_{Amax} is indicative of the maximum noise levels due to individual noise events such as the pass-by of a heavy vehicle. The L_{Aeq} level is the equivalent continuous sound level and has the same sound energy over the sample period as the actual noise environment with fluctuating sound levels.

The L_{A90} noise levels were analysed to determine a single assessment background level (ABL) for each day, evening and night period in accordance with the NSW Noise Policy for Industry (NPfI) [7], for each monitoring location. The ABL is established by determining the lowest ten-percentile level of the L_{A90} noise data acquired over each period of interest.

The background noise level or rating background level (RBL) representing the day, evening and night-time assessment periods are based on the median of individual ABLs determined over the entire monitoring period, and are presented in Table 6.

Table 6: Long-term noise monitoring results conducted by RWDI [10]

Measurement Location	Day[1]	Evening[1]	Night[1]
NCA1a – Old Post Office Courtyard			
Rating background level, dBL_{A90}	56	57	49
Log Average, dBL_{Aeq}	69	69	65
NCA2 – Café rooftop			
Rating background level, dBL_{A90}	49	49	44
Log Average, dBL_{Aeq}	55	54	50
NCA3 – Staff courtyard, Mary-Ann Street			
Rating background level, dBL_{A90}	47	50	45
Log Average, dBL_{Aeq}	57	56	52

Notes:

1. Day is defined as 7:00 am to 6:00 pm, Monday to Sunday & Public Holidays.
   Evening is defined as 6:00 pm to 10:00 pm, Monday to Sunday & Public Holidays.
   Night is defined as 10:00 pm to 7:00 am, Monday to Sunday & Public Holidays.

A full set of monitored results along with graphical noise logging results are presented in the RWDI report [10] including periods where data has been omitted.

2.4.3 Attended noise monitoring

Attended monitoring was conducted by RWDI at the three unattended monitoring locations, along with an additional location between on the 5th, 19th and 20th April 2022. The ambient noise environment in the area is typical of an urban environment and has not changed significantly since the measurements were undertaken. The noise monitoring undertaken is therefore considered representative of existing ambient levels. Each measurement was conducted over a 15-minute period.

A summary of attended measurement results is re-produced below in Table 7

Table 7: Attended measurement results conducted by RDWI [10]

ID	NCA	Measurement location	Date / time	Description of noise environment	Attended measurement results, dB(A)	
					$L_{eq,15\ min}$	$L_{90,15\ min}$
Meas. 1	1	Harris Street	5/04/2022 12:53 PM	– Traffic on Harris Street LAF 64-76	70	61
Meas. 2	2	Café Rooftop	5/04/2022 11:22 AM	– Traffic on Darling Drive LAF ~56 – Mechanical Sources including discharge on roof of Site LAF 52 – Tram passby (far track) LAF 58	54	52
			19/04/2022 2:38 PM	– Mechanical Sources including discharge on roof of Site LAF 52 – Pedestrian noise from Site LAF 47 – Traffic on Darling Drive, Harris Street, Pier Street, each LAF ~56 – Motorbikes on Darling Drive LAF 70-74 – Tram passby (far track) LAF 59 – Tram passby (near track) LAF 60-81	58	53
Meas 3	3	Corner of Omnibus Lane and Mary Ann Street	5/04/2022 12:29 PM	– Mechanical noise from UTS building LAF 53 – Traffic on Darling Drive LAF 55-60 – Traffic on Harris Street LAF 55-60	56	54
			19/04/2022 4:06 PM	– Traffic from Harris Street LAF 54-59, – Heavy vehicle passby on Harris Street LAF 64 – Motorbike passby on Harris Street LAF 71 – Cars on Mary Ann Street LAF 60-62 – Pedestrians talking LAF 47 – Mechanical noise from UTS building LAF 53	58	53

ID	NCA	Measurement location	Date / time	Description of noise environment	Attended measurement results, dB(A)	
					$L_{eq,15\ min}$	$L_{90,15\ min}$
			20/04/2022 11:04 PM	– Crickets – Traffic from Harris Street LAF 53-56 – Walk lights on Harris Street LAF 52 – Traffic from Darling Drive LAF 51 – Car door slam LAF 52 – Cement truck on Harris Street LAF 63, – Tram passby LAF 48	52	47
Meas 4	3	Corner of Macarthur Street and Omnibus Lane	5/04/2022 2:17 PM	– Traffic from Harris Street LAF 55-62 – Low speed light vehicle passby in Macarthur Street LAF ~63 – Truck activity in Site loading dock LAF ~66-76 – Truck reversing beeper LAF 71 – Pedestrian noise from Site LAF ~51 – Intermittent work on corner of Harris and Macarthur LAF 58-66	61	56
			19/04/2022 4:28 PM	– Traffic on Harris Street LAF 55-62 – Car leaving omnibus lane carpark LAF 63 – Tram passby LAF 52 – Industrial noise from Site LAF 51 – Aeroplane pass over LAF 59-62 – Car horn LAF 64 – Bicycle passby LAF 57-62 – Van and car low speed passby LAF 62 – Car idling in Macarthur Street LAF 60 – Leaves rustling	58	53

ID	NCA	Measurement location	Date / time	Description of noise environment	Attended measurement results, dB(A)	
					$L_{eq,15\ min}$	$L_{90,15\ min}$
			20/04/2022 11:26 PM	– Industrial hum, main sources rooves in omnibus lane and Powerhouse roof – Powerhouse ground level AC discharge LAF 59 – Occasional traffic from Darling Drive LAF 53 – Traffic from Harris Street LAF 52-58 – Truck passby LAF 63-70 – Pedestrian crossing lights LAF 49 – Tram passby (far track, at speed) LAF 50-58 – Tram passby (near track, braking) LAF 50-54 – Light Vehicle departure LAF 65 – Cyclist passby LAF 59	53	49

3. Construction noise & vibration

This Section addresses the noise and vibration associated with construction of the Powerhouse Ultimo Revitalisation project.

3.1 Hours of work

Construction works will be undertaken within the hours outlined in Table 8, in accordance with ICNG standard hours of construction

Table 8: Proposed Hours of Construction

Day	Standard construction hours
Monday to Friday	7.00 am to 6:00 pm
Saturdays	8.00 am to 1:00 pm
Sundays or Public Holidays	No construction

In some additional cases, after-hours permits may be sought from the relevant authorities where special requirements exist, for example oversized deliveries.

3.2 Construction noise criteria

The ICNG [1] provides recommended noise levels for airborne construction noise at sensitive land uses. The ICNG provides construction management noise levels above which all 'feasible and reasonable' work practices should be applied to minimise the construction noise impact. The ICNG works on the principle of a 'screening' criterion – if predicted or measured construction noise exceeds the ICNG levels then the construction activity must implement all 'feasible and reasonable' work practices to reduce noise levels.

The ICNG sets out management levels for noise at noise sensitive receivers, and how they are to be applied. The determination of management noise levels for residential receivers is outlined in Table 9 with the project specific levels summarised in Table 10. Noise management levels for other sensitive receivers are presented Table 11.

Table 9: Construction noise management levels at residential receivers

Time of day	Management level [1] $L_{Aeq\ (15\ min)}$	How to apply
Recommended standard hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	Noise affected RBL + 10dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.

Time of day	Management level [1] $L_{Aeq\ (15\ min)}$	How to apply
	Highly noise affected ≥75dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: • times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences • if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours[2]	Noise affected RBL + 5dB	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5dBA above the noise affected level, the proponent should negotiate with the community. For guidance on negotiating agreements see section 7.2.2 of the ICNG.

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.
2. See Table 8 for definition of outside standard hours definitions. No construction work is currently proposed outside of standard hours.

Table 10: Noise Management Levels at residential receivers

NCA	Highly noise affected[1]	Noise Management Level $dBL_{Aeq(15\ min)}$			
		Standard construction hours[2]	Outside of standard hours – day[3]		
			Day	Evening	Night
1	75	66	61	62	54
2	75	59	54	54	49
3	75	57	52	55	50

Note:

1. In accordance with the ICNG, the highly noise criteria affected applies to residential properties only
2. Standard construction hours presented in Table 8
3. The NPfI defines day, evening and night time periods as:
    - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays.
    - Evening: the period from 6 pm to 10 pm.
    - Night: the remaining period.
4. Outside standard hours are defined as:
    - Day: Sundays and public holidays 8 am to 6 pm, Saturday 7 am to 8 am and 1 pm to 6 pm
    - Evening: Monday to Saturday 6 pm to 10 pm, Sunday and public holidays – 6 pm to 10 pm
    - Night: Monday to Saturday 12 am to 7 am and 10 pm to 12 am,
    - Sundays and public holidays 12 am to 8 am and 10 pm to 12 am

Table 11: Noise Management Levels at other noise sensitive land uses

Land use	Where objective applies	Noise Management level $dBL_{Aeq(15\ min)}$[1]
Active recreation areas	External noise level	65
Educational institutions[2]	Internal noise level	45
Commercial premises	External noise level	70

Note:

1. Noise management levels apply when properties are in use.
2. Inclusive of Childcare

3.2.1 Project construction noise targets

Construction noise criteria are set based on noise catchment areas relative to proposed construction works. These catchment areas are defined for the project in Section 2.2

Measured noise data obtained at the logger location most representative of each noise catchment area has been used to derive appropriate noise management levels for the project. These are summarised in Table 10.

Noise Management Levels for residential and non-residential receivers are presented in Table 12 and Table 13 respectively.

Table 12: Residential Noise Management Levels during intended working hours

Rec. ID	Address	Assess. location	External NML, $dBL_{Aeq\ 15minute}$				
			Standard hours	Out of standard hours			Highly noise affected
				Day	Evening	Night	
Residential							
R1	543 Harris Street, Ultimo	External	66	61	62	54	75
R2	531-533 Harris Street, Ultimo	External	66	61	62	54	75
R3	599 Harris Street, Ultimo	External	66	61	62	54	75
R4	576A Harris Street, Ultimo	External	66	61	62	54	75
R5	39 Darling Drive, Sydney	External	59	54	54	49	75
R6	41 Darling Drive, Sydney	External	59	54	54	49	75
R7	1 Steam Mill Lane, Haymarket	External	59	54	54	49	75
R8	81-85 Macarthur Street, Ultimo	External	57	52	55	50	75
R9	13-17 Systrum Road, Ultimo	External	57	52	55	50	75

Table 13: Non-residential Noise Management Levels during intended working hours

Rec. ID	Name	Time period	Assess. location	External NML, $dBL_{Aeq\ 15minute}$
Hotel				
H1	Glasgow Arms Hotel	When in use	External	70
Commercial				
C1	Optus Data Centre	When in use	External	70
C2	The Q on Harris	When in use	External	70
C3	Commercial Tenancy	When in use	External	70
C4	International Convention Centre Aware Super Theatre	When in use	External	70

Rec. ID	Name	Time period	Assess. location	External NML, $dBL_{Aeq\ 15minute}$
Child Care Centre				
CC1	Ultimo Community Centre	When in use	External	55[1]
Active Recreation				
AR1	Ian Thorpe Aquatic Centre	When in use	External	65
Education				
E1	JMC Academy	When in use[2]	Internal	55[1]
E2	Academy of Film, Theatre and Television	When in use	Internal	55[1]

Note:

1. External noise levels have been determined by assuming a 10dB reduction through an open window
2. JMC Academy is expected to contain noise sensitive spaces such as recoding studios and performance spaces. Whilst classified as 'Educational' it may require detailed consultation to agree on appropriate objectives and management approach that best suits the use.

3.3 Construction Traffic

Increased traffic generated on the surrounding road network due construction activities is assessed in accordance with the NSW Road Noise Policy (RNP). Table 3 of the RNP sets out the assessment criteria for particular types of project, road category and land use, as shown in Table 14 below.

Table 14: Road traffic criteria for traffic generating development - residential receivers

Road category	Type of project / land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	**Night (10:00pm-7:00am)**
Freeway/arterial/ sub-arterial roads	Existing residences affected by additional traffic on existing freeways / arterial / sub-arterial roads generated by land use developments	$L_{Aeq,(15\ hour)}$ 60 (external)	$L_{Aeq,(9\ hour)}$ 55 (external)
Local roads	Existing residences affected by additional traffic on existing local roads generated by land use developments	$L_{Aeq(1\ hour)}$ 55 (external)	$L_{Aeq(1\ hour)}$ 50 (external)

Notes: These criteria are for assessment against façade corrected noise levels when measured in front of a building façade.

Regarding the application of the assessment, the RNP states:

> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

3.4 Construction vibration criteria

Vibration criteria for construction works are established in the following sections. Vibration management measures have been recommended in Section 3.6.1.

3.4.1 Human comfort

The NSW EPA's *Assessing Vibration – A Technical Guideline* [2] provides vibration criteria for maintaining human comfort within different space uses. The guideline recommends 'preferred' and 'maximum' weighted vibration levels for both continuous vibration sources, such as steady road traffic and continuous

construction activity, and for impulsive vibration sources. The weighting curves are obtained from BS 6472-1:2008 [3].

For intermittent sources (e.g. passing heavy vehicles, impact pile driving, intermittent construction), the guideline uses the vibration dose value (VDV) metric to assess human comfort effects of vibration. VDV considers both the magnitude of vibration events and the number of instances of the vibration event. Intermittent events that occur less than 3 times in an assessment period (either day, 7 am to 10 pm, or night, 10 pm to 7 am) are counted as 'impulsive' sources for the purposes of assessment.

As noted in the Guideline, situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances, such as a construction or excavation projects. Notwithstanding, the recommended vibration limits for maintaining human comfort in residences and other relevant receiver types are given for continuous/impulsive and intermittent vibration in Table 15 and Table 16 respectively.

Table 15: Preferred and maximum weighted root-mean-square (rms) values for continuous and impulsive vibration acceleration (m/s²) 1-80 Hz

Location	Period	Preferred Values		Maximum Values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Continuous Vibration					
Critical areas[1]	Day- or Night-time	0.005	0.0036	0.01	0.0072
Residences	Daytime 0700-2200h	0.010	0.0071	0.020	0.014
	Night-time 2200-0700h	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
Impulsive Vibration					
Critical areas[1]	Day- or Night-time	0.005	0.0036	0.01	0.0072
Residences	Daytime 0700-2200h	0.30	0.21	0.60	0.42
	Night-time 2200-0700h	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

1. Criteria for sensitive areas are only indicative, and have been provided as guidance to acceptable vibration levels for the use of sensitive equipment.

Table 16: Acceptable vibration dose values for intermittent vibration (m/s$^{1.75}$)

Location	Daytime 0700-2200 h		Night-time 2200-0700 h	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Critical areas[1]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80

1. Criteria for sensitive areas are only indicative, and there may be a need to assess intermittent vibration against impulsive or continuous criteria.

3.4.2 Building damage

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard 7385 Part 2-1993 and/or German Standard DIN4150-3. British Standard 7385 Part 1: 1990, defines different levels of structural damage as:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in mortar joints of brick/concrete block construction.*
- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

Table 1 of BS7385-2 sets limits for the protection against cosmetic damage, however the following guidance on minor and major damage is provided in Section 7.4.2 of the Standard:

> *7.4.2 Guide values for transient vibration relating to cosmetic damage*
>
> *Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 1* **[not reproduced]**. *In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm (zero to peak) should be used.*
>
> *Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 1, and major damage to a building structure may occur at values greater than four times the tabulated values.*

Within DIN4150-3, damage is defined as “any permanent effect of vibration that reduces the serviceability of a structure or one of its components” (p.2). The Standard also outlines:

> *"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if*
>
> - *cracks form in plastered surfaces of walls;*
> - *existing cracks in the building are enlarged;*
> - *partitions become detached from loadbearing walls or floors.*
>
> *These effects are deemed ‘minor damage." (DIN4150.3, 1990, p.3)*

While the DIN Standard defines the above damage as 'minor', the description aligns with BS7385 cosmetic damage, rather than referring to structural failures.

British Standard BS7835-2

BS7385-2 [4] is based on peak particle velocity and specifies damage criteria for frequencies within the range 4–250 Hz, and a maximum displacement value below 4 Hz is recommended. Table 17 sets out the BS7385 criteria for cosmetic, minor and major damage. Regarding heritage buildings, British Standard 7385 Part 2 (1993, p.5) notes that “*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*”.

Table 17: BS 7385-2 structural damage criteria

Group	Type of structure	Damage level	Peak component particle velocity, mm/s[1]		
			4 Hz to 15 Hz	15 Hz to 40 Hz	40 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic	50		
		Minor[2]	100		
		Major[2]	200		
2		Cosmetic	15 to 20	20 to 50	50

Group	Type of structure	Damage level	Peak component particle velocity, mm/s[1]		
			4 Hz to 15 Hz	15 Hz to 40 Hz	40 Hz and above
	Un-reinforced or light framed structures Residential or light commercial type buildings	Minor[2]	30 to 40	40 to 100	100
		Major[2]	60 to 80	80 to 200	200

Notes

1. Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.

2. Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

All levels relate to transient vibrations in low-rise buildings. Continuous vibration can give rise to dynamic magnifications that may require levels to be reduced by up to 50%.

3.4.3 Buried services

DIN 4150-2:1999 [5] sets out guideline values for vibration effects on buried pipework and reproduced in Table 18 below.

Table 18: Guideline values for short-term vibration impacts on buried pipework

Pipe material	Guideline values for vibration velocity measured on the pipe, mm/s
Steel (including welded pipes)	100
Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
Masonry, plastic	50

Note:

For gas and water supply pipes within 2m of buildings, these limits should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

In addition, specific limits for vibration affecting high-pressure gas pipelines is provided in the UK National Grid's Specification for Safe Working in the Vicinity of National Grid High Pressure Gas Pipelines and Associated Installations – Requirements for Third Parties (report T/SP/SSW/22, UK National Grid, Rev 10/06, October 2006). This specification states that no piling is allowed within 15 m of a pipeline without an assessment of the vibration levels at the pipeline. The PPV at the pipeline is limited to a maximum level of 75 mm/s, and where PPV is predicted to exceed 50 mm/sec the ground vibration is required to be monitored.

Other services that may be encountered include electrical cables and telecommunication services such as fibre optic cables. While these may sustain vibration velocity levels from between 50 mm/s and 100 mm/s, the connected services such as transformers and switchgear may not. Where encountered, site specific vibration assessment in consultation with the utility provider should be carried out.

3.4.4 Heritage structures

Heritage structures which have been identified in the vicinity of the Powerhouse Ultimo are presented in Figure 5.

Figure 2-4: SHR listings in and surrounding the study area (Source: Curio 2021 from HNSW Shapefile, over Nearmaps aerial 2021)

Figure 5: Surrounding State Heritage Registered (SHR) structures. Source: Curio Projects

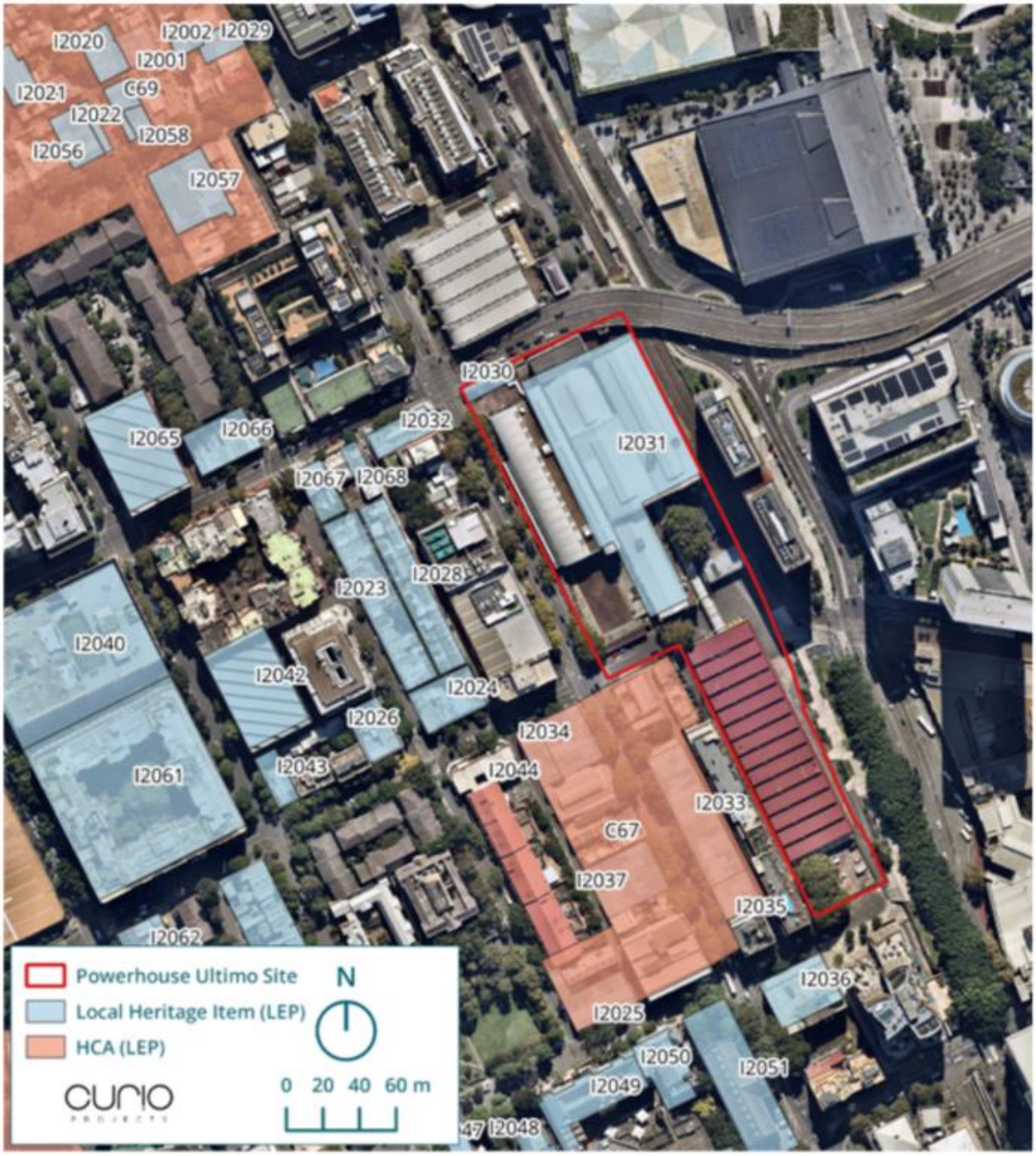

Figure 2-5: Sydney LEP 2012 listed items in and surrounding the study area (Source: Curio 2021 from HNSW Shapefile, over Nearmaps aerial 2021)

Figure 6: Surrounding Local Heritage structures and Heritage Conservation Areas (HCA). Source: Curio Projects

The nearest heritage listed items located within the site boundary, directly adjacent to the construction site boundary, include:

- Ultimo Post Office
- The Ultimo Powerhouse

The nearest heritage listed item outside the site boundary is the Sewerage Pumping Station 1 and is approximately 20m from the site boundary

As discussed in Section 3.4.2, a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Pending existing condition survey, should these heritage structures be found not to be structurally unsound, the relevant Group criteria in BS7385-2 [4] would apply.

3.5 Construction noise assessment

The construction noise assessment including the locations of the equipment modelled has been undertaken based on inputs derived from the Powerhouse Ultimo Redevelopment Preliminary Construction Management Plan dated February 2023 (CMP) and demolition plans as part of the SSDA Drawing set.

3.5.1 Activities

The construction phases proposed as part of the Powerhouse Ultimo development are outlined in Table 19.

Table 19: Construction phases

Construction phase	Duration
Site Establishment	1 month
Demolition	2 months
Bulk/detailed excavation and piling	2 months
Construction	19 months

Assumed construction equipment to be used for redevelopment works are provided in Table 20. Two scenarios have been modelled, a worst case scenario representative of the maximum expected noise impacts at each receiver and a ‘typical’ scenario more representative of impacts to be expected during the majority of each respective construction phase.

Equipment sound power levels have been determined by reference to AS2436 [6], DEFRA [11], and Arup’s measurement database. The equipment below has been assumed to operate concurrently however equipment sound power levels have been adjusted according to its usage in a worst case 15-minute period, and penalty corrections for impulsive noise characteristics.

Table 20: Construction equipment usage and associated sound power levels (L_w)

Plant item	Sound power level - L_w, dB(A)	Penalty[1], dB	% of use in worst case 15 mins	Standard construction hours					
				Site Establishment	Demolition – Ground Level	Demolition - Wran and Galleria Roof	Bulk/detailed excavation and piling	Construction - Ground Level	Construction - Wran and Galleria Roof
				Anticipated highest / typical number of plant operational within 15 min period.					
Chainsaw - petrol	114	0	25	1 / 1					
Circular Saw (Hand-held)	115	0	25	1 / 0		1 / 0		1 / 0	1 / 0
Hand Tools (Pneumatic)	117	0	25	1 / 0		1 / 0		1 / 0	1 / 0
Hand Tools (Electric)	110	0	50	1 / 1		1 / 1		1 / 1	1 / 1
Excavator (15t)	101	0	50		1 /1		1 / 1		
Excavator (40t)	115	0	50		1 / 0		1 / 0		
Rock Breaker	118	5	50		1 / 1				
Truck (>20 Tonne)	107	0	50		1 / 0		1 / 0	1 / 0	
Jack Hammer	121	5	25		1 / 0				
Loaders - Skisteer (Bob-cat) (1t)	110	0	50		1 / 1		1 / 1		
Scraper	116	0	50				1 / 0		
Compactor	115	5	50				1 / 0		
Grader	115	0	50				1 / 0		
Piling rig (Impact)[2]	129	5	10				1 / 0		
Crane (Tower)	105	0	50					1 / 1	
Crane (Mobile)	113	0	50					1 / 0	
Concrete Pump	109	0	50					1 / 0	
Total sound power level (Lw) – dBA				**115 / 111**	**123 / 120**	**114 / 107**	**126 / 108**	**116 / 108**	**114 / 107**

Notes

1) 5dB penalty applied for impulsive nature of noise.
2) Piling method dependent on ground conditions, yet to be determined, impact piling assumed.

3.5.2 Assessment methodology

Noise emissions from construction activities associated with Powerhouse Ultimo have been assessed to criteria outlined in Section 3.2

Noise emissions have been modelled using SoundPlan 8.1 in accordance with ISO9613-2 algorithms. The model included:

- Construction noise sources listed in Table 20;
- Surrounding buildings;
- Receivers listed in Section 2.3; and
- Ground terrain and absorption.

3.5.3 Modelling assumptions

The following assumptions have been made in the development of the noise model:

- Construction activities, duration of activities and equipment to be used in the assessment (presented in Table 20) have been discussed and confirmed with INSW.
- No construction noise mitigation measures were included in the assessment
- The location of equipment will be spread evenly across the site, modelled at a height of 1m with the exception of the 'Wran and Galleria roof' sources as listed in Table 20. These sources are modelled at a height to represent works occurring to the Wran PS9 and Galleria roof.

The results shown in the following section are indicative only and are considered to be conservative.

3.5.4 Noise prediction results

Predicted construction noise levels at surrounding residential receivers along with the relevant NML for the intended working hours are presented in Table 21.

Predicted noise levels are presented as a range based on the construction equipment usage in Table 20. The lower levels present noise levels that would be typically expected within each construction phase while the higher levels represent worst case operating scenarios over a 15minute assessment period.

It is noted that the predicted construction noise levels are generally conservative and do not represent a constant noise emission that would be experienced by the community on a daily basis throughout the project construction period. Construction noise levels at surrounding receivers will vary greatly depending on the location of equipment and what pieces of equipment are operating.

Graphical representations of construction noise emissions for worst case scenarios are presented in Appendix B.

Table 21: Predicted construction noise levels – Highest and typical operation scenarios dBL$_{Aeq\ (15\ min)}$

Receiver	NML	Construction phase			
		Site Establishment	Demolition	Bulk /Detailed Excavation & Piling	Construction
Standard construction hours - Anticipated highest / typical number of plant operational within 15 min period.					
R1 - 543 Harris Street, Ultimo	66	66 - **70**	**77 - 81**	65 - **83**	**70 - 77**
R2 - 531-533 Harris Street, Ultimo	66	65 - **69**	**77 - 81**	64 - **82**	**70 - 77**
R3 - 599 Harris Street, Ultimo	66	65 - **69**	**74 - 77**	61 - **79**	63 - **70**
R4 - 576A Harris Street, Ultimo	66	51 - 55	59 - 62	45 - 63	48 - 56
R5 - 39 Darling Drive, Sydney	59	**66 - 70**	**75 - 78**	**64 - 82**	**66 - 73**
R6 - 41 Darling Drive, Sydney	59	**72 - 76**	**81 - 84**	**70 - 88**	**70 - 78**

Receiver	NML	Construction phase			
		Site Establishment	Demolition	Bulk /Detailed Excavation & Piling	Construction
R7 - 1 Steam Mill Lane, Haymarket	59	**60 - 64**	**68 - 71**	56 - **74**	59 - **66**
R8 - 81-85 Macarthur Street, Ultimo	57	**72 - 76**	**80 - 83**	**67 - 85**	**68 - 76**
R9 - 13-17 Systrum Street, Ultimo	57	**62 - 66**	**71 - 74**	**58 - 76**	**61 - 69**
Hotel					
H1 - Glasgow Arms Hotel	70	65 - 69	**77 - 80**	64 - **82**	69 - **76**
Commercial					
C1 - Optus Data Centre	70	67 - **71**	**78 - 82**	65 - **83**	**72 - 79**
C2 - The Q on Harris	70	67 - **71**	**76 - 79**	63 - **81**	65 - **73**
C3 - Commercial Tenancy	70	**71 - 75**	**80 - 83**	67 - **85**	68 - **76**
C4 - International Convention Centre Aware Super Theatre	70	46 - 50	59 - 64	45 - 63	56 - 63
Childcare Facilities					
CC1 - Ultimo Community Centre	55	**60 - 64**	**72 - 76**	**59 - 77**	**66 - 73**
Educational Facilities					
E1 - JMC Academy	55	**71 - 75**	**80 - 84**	**67 - 85**	**71 - 78**
E2 - Academy of Film, Theatre and Television	55	**70 - 74**	**79 - 82**	**66 - 84**	**69 - 76**
Active Recreation					
AR1 - Ian Thorpe Aquatic Centre	65	61 - 65	**70 - 74**	59 - **77**	64 - **71**

Notes:

- Levels in **BOLD BLACK** indicate a notional exceedance of NMLs based on the worst-case assumptions noted above.
- Levels in **BOLD RED** represent 'highly affected' noise levels of 75dBA or above. Applicable to residential receivers only

Results indicate that residential receivers to the west across Harris Street (R1, R2, R3), east on Darling Drive (R5, R6), and south across Macarthur Street (R7, R9) are worst affected due to proximity to site and no intervening shielding. All receivers with the exception of R7 have the potential to be highly noise affected, with exceedances of NMLs of up to 29 dB predicted during worst case scenarios. Receivers located behind the first row of intervening structures are shielded from the highest construction noise impacts.

Predictions based on more typical construction plant use are lower than predicted worst case levels by as much as 8 dB, with a reduced number of receivers predicted to be 'highly affected'. While the demolition stage is predicting the highest number of residential receivers highly noise effected during typical operations, this will only be for a 2 month period within the total 24 month construction timeline.

Results indicate comparable levels to the nearest affected non-residential receivers, with the exception of C4 which is somewhat shielded by intervening terrain. Exceedances of up to 15 dB during the anticipated worst case periods are predicted at surrounding commercial premises along Harris and Macarthur Streets (C1-C3). During typical construction operations, exceedances of up to 10 dB are predicted.

During worst case periods, exceedances of up to 30 dB are predicted for educational facilities directly across Harris Street (E1-2). The childcare centre (CC1) across William Henry Street is predicted to exceed by up to 20 dB. The Aquatic Centre (AR1) is predicted to exceed by up to 12 dB. For each of these locations, external criteria are considered very conservative as it is likely that internal noise levels would be attenuated by a closed façade.

Mitigation measures, discussed in Section 3.8 could be undertaken to further mitigate the impact on nearby receivers.

3.5.5 Discussion

High predicted noise levels are attributed to a small number of high noise activities including jackhammers and piling. Piling and demolition are predicted to produce levels up to 88dB and 84dB respectively at the nearest residential receiver during both scenarios for a duration of up to two months. The assessment has compared the difference in predicted noise levels between when these pieces are and are not operating through assessment of worst case and typical construction operation scenarios. Furthermore, the noise generated by piling will be dependent on whether impact piling or bored piling will be required, to be determined following ground composition surveys. Predicted noise levels may therefore be conservative as noise impacts due to bored piling will likely be lower than those modelled.

During construction, plant and equipment will move through the Project area as the Project progresses, changing noise impacts in relation to the nearby individual sensitive receivers. The noise levels experienced at a particular location will rise and fall in accordance with the varying offset distance of the works, the intensity and location of construction activities, the intervening terrain and structure and the type of equipment used. It is unlikely that all construction equipment will be operating at their maximum sound levels simultaneously. In any given period, typically construction equipment would be used with maximum sound levels for only a brief amount of time and at other times the equipment may emit lower sound levels carrying out activities.

In general, construction works are temporary in nature therefore potential noise impact on the community and the surrounding environment will not be permanent or continuous. Where the predicted $L_{Aeq(15min)}$ noise level is greater than the noise management levels all feasible and reasonable work practices should be applied, as recommended below.

3.5.6 Construction noise management

Indicative noise reduction for different noise mitigation measures relevant to construction activities for the project have been obtained from the guidance of AS2436 - Guide to Noise and Vibration Control on Construction, Demolition and Maintenance Sites [6] and BS5228.1 - Code of Practice for Noise and Vibration Control on Construction and Open Sites - Noise [12], and are summarised below in Table 22 for reference.

Table 22: Indicative noise reduction provided by noise mitigation measures

Construction equipment	Noise mitigation measure	Indicative noise reduction	Source
Jackhammer	Muffler and screen	20 dBA	Table C2 AS2436:2010
Compressor Cement mixers Hand-held tools	Screening	5 dBA	Table C3 AS2436:2010
Excavators/loaders Trucks Mobile cranes Asphalt paver Bulldozers Road graders Rollers/compactors	Residential-grade silencer	10 dBA	Table C2 AS2436:2010 Table B1 BS5228.1:2009
Excavator with hammer attachment	Residential-grade silencer Screening of hammer attachment	15 dBA	Table C2 AS2436:2010
Piling impact	Resilient pad (dolly) between pile and hammerhead	10 dBA	Table C2 AS2436:2010 Table B1 BS5228.1:2009

Table 23 below provides a summary of the anticipated project specific community consultation measures to be put in place depending on the extend of the exceedances of the NMLs. This table has been informed by the Construction Noise and Vibration Strategy (CNVS) [13] and should be reviewed and refined for the development of the Construction Noise and Vibration Management Plan (CNVMP) for the project to be developed by the contractor.

Table 23: Indicative community consultation measures

Construction hours	Receiver perception	Above NML	Management Measures[1,2,3,4]
Airborne noise			
Standard hours (day)	Noticeable	<= NML (Compliant)	-
	Clearly audible	<= NML + 10	-
	Moderately intrusive	<= NML + 20	N
	Highly intrusive	> NML + 20	N
	Highly noise affected (75 dBA or greater)	>= 75 dBA	N, SN, RP
Outside standard hours (night)[5]	Noticeable	<= NML (Compliant)	-
	Clearly audible	<= NML + 10	N
	Moderately intrusive	<= NML + 20	N, SN
	Highly intrusive	> NML + 20	N, SN, AA, RP
	Highly noise affected (75 dBA or greater)	>= 75 dBA	N, SN, AA, RP

Notes:

1. N: Notifications (such as letter box drops)
2. SN: Specific notifications such as individual briefings or phone call
3. AA: Alternative accommodation
4. RP: Respite Period
5. No works outside of standard hours is proposed. Management measures are for information only.

3.6 Construction vibration assessment

The use of impact piling may generate significant adverse vibration impacts at receivers immediately adjacent and in close proximity to the site. The use of impact piling is yet to be confirmed, however recommended minimum work distances and construction vibration management recommendations are provided in Section 3.6.1 to minimise the risk of adverse vibration impacts. Where feasible and practicable, bored piling should be explored as an alternative due to proximity of sensitive receivers and structures.

Should vibration intensive equipment, such as rock hammers, vibratory rollers or compactors be required for the works, it is recommended that site specific minimum work distances be developed to minimise the risk of adverse vibration impacts, and noise and vibration monitoring may be required if work is required within these distances.

Works directly adjoining heritage buildings on site (i.e. former Power House buildings and Post Office) will require specific management to safeguard against cosmetic damage. As noted, the heritage nature of these buildings is not taken to mean they are structurally unsound. The construction of the existing Wran Building adjoining the heritage halls also demonstrates precedent of construction taking place. Condition surveys and monitoring of vibration intensive works are recommended due to proximity of these works in particular. Further discussion of vibration monitoring is provided in Table 27.

3.6.1 Construction vibration management

As a guide, the recommended minimum working distances for vibration intensive plant in Table 3 (which has been derived from the TfNSW CNVS [14]) provide an indication of the possibility of impact due to vibration generating plant and equipment onto nearby receivers. While the minimum working distances are

indicative only and will vary depending on the item of plant and local geotechnical conditions, if a receiver is located within the minimum working distance, vibration monitoring might be required, and equipment selection and/or method of construction might have to be reviewed.

Table 24: Recommended minimum working distances for vibration intensive plant

Plant item	Rating / description	Minimum working distance (m)			
		Cosmetic damage – screening criteria			Human response
		BS 7385 Line 1 - 25 mm/s	BS 7385 Line 2 - 7.5 mm/s	DIN 4150 Line 3 - 3 mm/s	
Vibratory roller	< 50 kN (~ 1 to 2t)	2 m	5 m	11 m	15 m to 20 m
	< 100 kN (~ 2 to 4t)	2 m	6 m	13 m	20 m
	< 200 kN (~ 4 to 6t)	5 m	12 m	26 m	40 m
	< 300 kN (~ 7 to 13t)	6 m	15 m	31 m	100 m
	> 300 kN (~ 13 to 18t)	8 m	20 m	40 m	100 m
	> 300 kN (> 18t)	10 m	25 m	50 m	100 m
Hydraulic hammer – Small	300 kg / 5 to 12t excavator	1 m	2 m	5 m	7 m
Hydraulic hammer – Medium	900 kg / 12 to 18t excavator	3 m	7 m	15 m	23 m
Hydraulic hammer – Large	1600 kg / 18 to 34t excavator	9 m	22 m	44 m	73 m
Piling – Vibratory	Sheet piles	9 m	22 m	44 m	73 m
Piling – Bored	⩽ 800 mm	1 m (nominal)	2 m	5 m	10 m
Piling – Hammer	12t down force	6 m	15 m	30 m	50 m
Jackhammer	Hand-held	1 m (nominal)	1 m (nominal)	3 m	5 m

Note:

1. Based on TRL document [15] using Godio et al formula, equation 24

The safe working distances presented are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions.

The contractor will be required to manage vibration as well as noise and make use of best practice in the management of vibration using simple and practicable techniques such as avoiding dropping heavy items.

Where vibration intensive works are required within the minimum working distances outlined in Table 24, vibration monitoring at the nearest potential affected building should be considered, where real-time alerts can be generated when measured vibration levels exceed criteria.

Given the structures immediately adjacent to the site, adverse effects to both human comfort and structural damage are likely if management measures are not adhered to. Mitigation and management measures are discussed in Section 3.8.

3.7 Construction traffic assessment

Construction vehicles will be used for deliveries and to remove waste from the site, with the proposed access point located on Powerhouse grounds at the end of Macarthur Street. All construction traffic is proposed to travel to and from site along Macarthur Street via Harris Street. The likely nearest affected receivers are identified as houses located at 81-85 Macarthur Street (R8). The main source of existing road traffic noise at receiver locations is due to significant traffic flows along Harris Street.

Daily construction traffic volumes expected for the development have been provided by JMT Consulting and presented in Table 25.

Table 25: Proposed and current daily construction generated traffic volumes

Phase	Heavy vehicles	Light vehicles
Existing – Harris St[1]	108	2042
Existing – Macarthur[1]	3	47
Construction – additional[2,3]	40	10

Notes:

1. 2017 classified intersection count for Harris St/Macarthur St.
2. Additional traffic to be added to the existing counts both Macarthur and Harris St
3. Assumed 2 movements per vehicle, one arriving at and one leaving site

The assessment of construction related traffic noise is presented in Table 26.

Table 26: Construction traffic assessment

Traffic route	Likely most affected residential receiver	Predicted increase in road traffic noise, L_{Aeq}	Criteria – Relative increase	Comply
Harris Street	R3 - 599 Harris Street	0.3 dB[1]	< 2 dB	Yes
Macarthur Street	R8 - 81-85 Macarthur Street	1.4 dB[2]	< 2 dB	Yes

Notes:

1. 15 hour Leq, based on daytime traffic proportion of 85% and HV% of 5. Peak traffic scaled to 24Hr using factor of 10.
2. 1hr Leq factoring combined contribution of traffic on Harris and Macarthur Streets.

Considering the high existing traffic numbers along Harris Street and the low number of construction generated vehicles, the additional construction traffic created by construction is predicted to increase existing road traffic noise levels by 0.3 dB at Harris St properties. This is less than the 2 dB 'minor impact' criteria, and therefore represents minor impact that is considered barely perceptible to the average person. While the proportional increase from construction traffic is greater along Macarthur Street (1.4 dB), the overall increase when factoring contribution from existing traffic on Harris St is still below 2dB for worst affected receivers.

3.8 Construction noise and vibration mitigation and management measures

In addition to Section 3.5.6 and 3.6.1 a summary of recommended construction noise and vibration mitigation and management measures are presented in Table 27. All mitigation and management measures are proposed for consideration where feasible and reasonable, taking into account that specific construction methodology is not yet defined at this stage of the project. Specific details and accompanying Construction Noise and Vibration management Plan is to be developed by the Contractor.

Table 27: Summary of construction noise and vibration mitigation and management measures

Item	Detail	Timing
Construction - Noise and vibration management plan	A Construction Noise and Vibration Management Plan (CNVMP) shall be prepared prior to the issuing of a Construction Certificate. This will specify the actual plant to be used and will include updated estimates of the likely levels of noise and the scheduling of activities. The CNVMP should include but not be limited to the following: • Roles and responsibilities • Noise and vibration sensitive receiver locations and structures • Identify works that have the potential to cause impact, accompanied by an appropriate assessment (predictive assessment or risk evaluation) • Mitigation and management strategy	Pre-construction

Item	Detail	Timing
	• Monitoring methodology (as relevant) • Community engagement strategy.	
Construction - Staffing	• Appoint a named member of the site staff who will act as the Responsible Person with respect to noise and vibration. • Site managers to periodically check the site and subjectively assess emissions to nearby receivers to proactively manage works. • All employees, contractors, and subcontractors to receive an environmental induction which should include: – Standard noise and vibration mitigation measures – Limitations on high noise and vibration generating activities – Location of nearest sensitive receivers • Regularly train workers and contractors (such as at toolbox talks) to reinforce good work practices and communicate any received complaints, responses and changes to work practices where relevant. • Document and communicate methods for use and maintenance of equipment to minimise noise and vibration. • Avoid dropping of items, particularly from height. • Avoid the use of radios or stereos outdoors. • Avoid the overuse of public address systems. • No swearing or unnecessary shouting. • No slamming of doors.	During construction
Construction - Plant and equipment	Use quieter and less vibration emitting construction methods where feasible and reasonable. For example: • Rotary bored or vibro-piling where consistent with the pile design. • Diaphragm wall construction techniques, in lieu of sheet piling. • Use of pulverisers in lieu of excavator mounter breakers/hammers during demolition. • Use of static or oscillating rollers rather than vibratory rollers. • Use of electric / hydraulic equipment • Use rock/concrete sawing to minimise vibration transfer to adjacent structures • Use of non-tonal reversing beepers (or an equivalent mechanism) for all construction vehicles and mobile plant regularly used onsite. Note, the use of non-tonal reversing alarms is recommended to minimise noise impacts however WHS requirements must be fully satisfied. • Use only the necessary size and power of equipment. • Select attenuated equipment/activities, such as: • Dampened jackhammers and hydraulic hammers (such as ‘City’ Model Rammer Hammers) • Where impact/percussive piling is required, use a resilient pad (dolly) between pile and hammer head and enclosing the hammer head in a temporary acoustic shroud. • Sound damping of chutes and bins used for waste disposal • Use of residential grade mufflers • Rubber wheeled plant • Provide appropriate vibration attenuation to fixed plant items on site. • Limit use of activities with potentially ‘annoying’ or intrusive characteristics such as impulsive, tonal or excessive low frequency sources.	During construction

Item	Detail	Timing
	• Ensure plant is regularly maintained, and repair or replace equipment as necessary (e.g. ensure air lines on pneumatic equipment do not leak). • Turn off all vehicles, plant and equipment when not in use.	
Construction - Scheduling	• Works to be scheduled taking into account approved works hours, any restrictions relevant to specific equipment/activities and respite periods etc. • Highest noise generating activities should be scheduled for the least sensitive times, where practicable. • The acceptability for any out-of-hours works should be confirmed with authorities (e.g. delivery of oversized items, where road closures are required or for emergency works). • For approved out-of-hours work, noisy activities should be scheduled early in the night to minimise the impact on adjacent residents. Limit number of consecutive nights receivers are impacted. Ensure periods of respite are provided in the case of unavoidable maximum noise level events.	During construction
Construction - Work site training	'Toolbox talks' will be held at regular intervals with the contractor workers, including discussion of noise and vibration mitigation, monitoring and assessment. These topics will also be covered under induction processes. Operate two way radios at the minimum effective volume, and avoid shouting or whistling at the site. Identification of all reasonable and feasible noise mitigation methods will be conducted by the Responsible Person on a daily basis during noisy works. The Responsible Person will have the authority to modify work practices in response to complaints, where this is considered appropriate.	During construction
Construction - Community liaison	Community consultation should occur prior to, and during works as follows: • Discuss with affected neighbours any atypical sensitivities (such as vibration sensitive equipment/processes in research or medical establishments, or exam periods for education establishments) to inform determination of criteria and where scheduling of activities may aid to minimise impacts • Seek to establish long-term contact personnel or processes to aid notification of planned activities and expected disruption/effects and their duration. Notifications should be as specific as practicable with regarding to nature, timing of works and any scheduled respite periods. • Advise neighbours of mitigation and management processes and complaints handling procedures. Where respite periods may be warranted, discuss community preferences in terms of respite vs shorter overall works duration. Where respite is to be provided, seek to align with receiver preferences. • Keep a register of any complaints, including details such as date, time, contact number, complainant location, description of complaint and action taken. • Provide quick response to complaints, both to aid understanding the cause of the complaint and reduce extended impacts.	Pre-construction and during construction

Item	Detail	Timing
Construction - Reversing alarms	The use of audible movement alarms of a type that would minimise noise impacts on surrounding noise sensitive receivers must be implemented. Where practicable, broadband, non-tonal reversing alarms should be utilised on site equipment. Ensure that the difference in volume between the reversing warning devices and the base machine noise level (at maximum governed speed under no load at any given test location) is minimised (in accordance with International Standard ISO9533:1989), and ensure that warning devices are no more than 5 dB above the Australian Standard level;	During construction
Construction - Material handling	Avoid dropping equipment/materials from a height or into trucks. Where practicable, use sound dampening material to cover the surfaces on to which any materials must be dropped.	During construction
Construction - Equipment Location	Site noisy equipment away from noise-sensitive areas. Plant known to emit noise strongly in one direction is to be orientated so that the noise is directed away from noise-sensitive areas; Locate site access roads and site compounds as far away as possible from noise sensitive receptors; Plan truck movements to avoid residential streets where possible;	During construction
Vibration monitoring	• Vibration monitoring should be conducted where works are proposed within the 'minimum working distance' to a sensitive receiver/structure/utility with respect to cosmetic damage. Refer to Table 24 • Preliminary attended monitoring should be carried out to evaluate risk of works exceeding relevant limits. Screening measurements should be carried out with plant operating outside the minimum working distance, and progressively move closer. • Where works are at risk of exceeding criteria, establish long-term monitoring. The monitors should provide 'real-time' alerts (SMS messages and/or flashing lights) when vibration criteria are exceeded. A warning level (below the relevant criteria) should be set in addition to the criteria limit. • In the event that the vibration criterion is exceeded, works should cease. Where relevant, the project archaeologist and structural engineering advisor should be notified and requested to attend site. A visual inspect of the buildings or structures should be undertaken to determine whether any damage has been sustained. • An exceedance of the vibration criterion may necessitate a change in work method. This could include: – Re-evaluation of the vibration criterion based on results of the initial condition investigation and inspections of the structure following the commencement of works. – Maintain vibration monitoring throughout works within 'minimum working distances'. – Reduce the size of demolition and construction equipment and develop alternative methodologies to minimise vibration. – Use less vibration emitting demolition methods if necessary closer to the sensitive building or structure Balance variable speed vibrating plant and operate at speeds that do not produce resonance.	During construction

4. Operational noise & vibration

4.1 Overview

The primary operational noise sources with the potential to impact upon surrounding noise sensitive receivers include:

- Patron and amplified sound including music from both internal and external spaces
- Patrons arriving at and leaving the site
- Building services and external plant
- Loading dock operations & waste and recycling collection
- Traffic generated by operation of the site

4.1.1 Operational vibration impacts

The most significant sources of operational vibration would be loading of large exhibition pieces in both the loading dock and Presentation Spaces. The resulting vibration impacts at surrounding receivers is not anticipated to be high enough to affect human comfort or structural damage at surrounding premises. No vibration mitigation measures are therefore considered necessary.

4.2 Noise criteria

4.2.1 Daily operation noise

Noise level criteria for the Powerhouse Ultimo have been established in accordance with the NPfI [7], which is primarily concerned with controlling intrusive noise impacts in the short-term for residences and maintaining long-term noise level amenity for residences and other land uses.

The NPfI sets out the procedure to determine the project noise trigger levels relevant to an industrial development. The project noise trigger level is a level that, if exceeded would indicate a potential noise impact on the community and so 'trigger' a management response.

Intrusive noise trigger level

The intrusiveness noise trigger level is applicable to residential premises only and is summarised as follows:

- $L_{Aeq,15minute} \leq$ Rating Background Level (RBL) plus 5 dB

(where $L_{Aeq,15minute}$ represents the equivalent continuous noise level of the source)

Recommended and project amenity noise level

To limit continuing increases in noise levels from application of the intrusiveness level alone, the ambient noise level within an area from all industrial noise sources combined should remain below the recommended amenity noise levels specified in Table 2.2 of the NPfI where feasible and reasonable. An extract from the policy pertinent to this assessment is given below in Table 28.

Table 28: NPfI Recommended Amenity Noise Levels (RANLs)

Receiver	Noise amenity area	Time of Day[1]	Recommended amenity noise levels (RANLs) L_{Aeq}, dBA
Residential	Urban	Day	60
		Evening	50
		Night	45
Hotels	Urban	Day	65
		Evening	55
		Night	50
School classroom[2,3] – internal	All	Noisiest 1-hour period when in use	35 (see notes for table)
Active recreation area (e.g. school playground, golf course)	All	When in use	55
Commercial premises	All	When in use	65

Notes

1. The NPfI defines day, evening and night time periods as:
    - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays;
    - Evening: the period from 6 pm to 10 pm; and
    - Night: the remaining period.
2. In the case where existing schools are affected by noise from existing industrial noise sources, the acceptable L_{Aeq} noise level may be increased to 40 dB $L_{Aeq(1hr)}$
3. Inclusive of Childcare

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

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

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

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

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

The area surrounding the site can be categorised as Urban in accordance with the NPfI, discussed in Section 2.1. The NPfI sets the PANLs to $L_{Aeq(period(traffic))}$ minus 15 dBA in the case that the level of transport $L_{Aeq(period(traffic))}$ exceeds the RANL by 10 dB or more. In addition to the above criteria, the NPfI has simplified assessment for the amenity criteria, making a rudimentary assumption regarding the relationship between the $L_{Aeq(15min)}$ and $L_{Aeq(period)}$, applying a +3 dB correction to adjust $L_{Aeq(period)}$ Project Amenity Level to an $L_{Aeq(15min)}$. This correlates to assuming a noise source operates for half the period. This simplified adjustment has been adopted in this report. Project noise trigger levels (PNTL) are displayed in Table 29 and Table 30.

Table 29: Project Noise Trigger Levels

NCA	Time of day[1]	Existing Traffic $L_{Aeq(period)}$[2]	Intrusive Level $L_{Aeq(15minute)}$	RANL $L_{Aeq(period)}$	PANL $L_{Aeq(15minute)}$	PNTL $L_{Aeq(15minute)}$
Residential						
NCA 1	Day	69	61	60	58	58
	Evening	69	62	50	57[4]	57
	Night	65	54	45	53[4]	53
NCA 2	Day	55	54	60	58	54
	Evening	54	54	50	48	48
	Night	50	49	45	43	43
NCA 3	Day	57	52	60	58	52
	Evening	56	55	50	48	48
	Night	52	50	45	43	43
Hotels						
NCA 1	Day	69	N/A	65	63	63
	Evening	69		55	57[4]	57
	Night	65		50	53[4]	53
Education & Childcare[3]						
NCA 1	Day	69	N/A	45[5]	57[4]	57
	Evening	69		45[5]	57[4]	57
	Night	65		45[5]	53[4]	53

Notes

1. The NPfI defines day, evening and night time periods as:
    - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays;
    - Evening: the period from 6 pm to 10 pm; and
    - Night: the remaining period.
2. Based on long term unattended measurements displayed in Table 6
3. When in use
4. Traffic affected
5. External noise target derived by allowing 10dB attenuation through an open window. This is considered an extremely conservative approach as likely more significant attenuation would be achieved through a closed façade.

Table 30: Project Noise Trigger Levels – non-residential receivers

Receiver	PNTLs, dB $L_{Aeq(15minute)}$
Commercial receivers	
C1 - Optus Data Centre	63
C2 - The Q on Harris	63
C3 - Commercial Tenancy	63
C4 - International Convention Centre Aware Super Theatre	63
Active Recreation	
AR1 - Ian Thorpe Aquatic Centre	53

Sleep disturbance

The NSW NPfI recommends the following screening criteria for the assessment of potential sleep disturbance, for the period between 10 pm and 7 am:

- $L_{Aeq,15min}$ 40 dBA or the prevailing RBL plus 5 dB, whichever is the greater; and/or
- L_{AFmax} 52 dBA or the prevailing RBL plus 15 dB, whichever is the greater.

L_{Amax} sleep disturbance criteria based on RBL + 15 dB has been adopted.

Project Noise Trigger Levels (PNTLs) for residential receivers represent the lower of the intrusive criteria and the adjusted $L_{Aeq,15min}$ amenity criteria, shown in Table 29.

Emergency equipment

As emergency plant within the development will be tested for less than 200hrs per year, there are no provisions in NSW guidelines for associated noise impacts. In lieu of relevant criteria, the VIC EPA State Environment Protection Policy (SEPP) No. N-1 states:

> *Where the noise source under consideration is a standby generator, standby boiler or fire pump, the noise limit shall be increased by 10 dB for a day period and by 5 dB for all other periods.*

This is considered an appropriate provision for short and intermittent operation of equipment during testing such as standby generators and stair pressurisation fans.

Application of criteria to patron and amplified noise

In the absence of NSW noise criteria which addresses amplified sound or patron noise, the NPfI [7] Project Trigger Noise Levels (PNTLs) have been applied to give an indication of potential disturbance to the community. Compliance with these criteria would indicate that these activities are considered to have a 'low risk' of disturbance to the community.

Any exceedances of these criteria have been categorised as having a 'medium risk' or 'high risk', that would trigger additional mitigation and management measures to be adopted. Further discussion is presented in Section 4.3.2

Music low frequency noise

Low frequency noise has been assessed, however a more conservative approach has been adopted in the assessment of music noise, in which the predicted noise level has been penalised where the dBC level is more than 10 dB above the dBA level, rather than a 15 dB difference per Fact Sheet C of the NPfI. This approach has been adopted in consideration that music noise is not a feature of the existing acoustic environment and for low-frequency music to be potentially evaluated as impulsive in nature.

4.2.2 Operational road traffic

The Powerhouse Ultimo Revitalisation incorporates no provision for additional parking or vehicular access above and beyond the existing operation of the museum. Therefore no assessment has been undertaken of operational road traffic on the basis that no significant increase is expected as a result of the development. Assessment of loading dock activities is summarised in Section 4.4.

4.3 Patron and music noise assessment

A number of activities proposed to be held at the Powerhouse Ultimo may generate large crowds and include the provision of music, either in the form of background music or more focal entertainment. To facilitate assessment, a program outlining proposed activities to be held in each space of the Powerhouse Ultimo has been developed in conjunction with the design team and a description of these is presented in Table 31.

Table 31: Proposed activities and noise descriptions

Activity	Description of use	Primary noise sources	Overview of acoustic environment within activity space
Exhibition	Public exhibition of installations	Patron conversations Installations with sound	Low to moderate noise levels

Activity	Description of use	Primary noise sources	Overview of acoustic environment within activity space
Installation / de-installation of exhibitions	Loading / unloading and installation / de-installation of exhibition pieces	Staff conversations Loading and unloading noise	Typically low noise levels, with intermittent noise from loading / unloading activities.
Program	Conferences and symposiums	Amplified speech Patron conversations	Low to moderate noise levels.
	Film, performances and music (concerts)	Amplified music during concerts Amplified speech Noise from large crowd	Moderate to high noise levels possible, with highest noise levels associated with amplified music.
Commercial	Commercial use under lease, eg. corporate functions, Christmas parties, dinners	Amplified music during Christmas parties or functions Amplified speech Patron conversations	Medium to high noise levels.

A summary of the loudest proposed activities to be held within each space is provided in Table 32

Table 32: Highest intensity activities and modelled scenarios

Space	Description	Loudest activity assessed	Noise sources	Capacity based on event type[1]	Modelled scenario[2]
Exhibition Space 1	Internal space within heritage halls. Large extent of glazing on north, south and eastern facades. Assumed to be fully acoustically sealed between Exhibition Space 1 & 2	Program - Concert	Amplified music Crowd noise	1393	As-is construction and improved envelope
Exhibition Space 2				1688	As-is construction and improved envelope
Exhibition Space 3	Internal space with no large openings	Emissions to surrounding external receivers expected to be readily controlled by the building envelope design and therefore not assessed.			
Arrival and circulation space	Internal space with no large openings				
Powerhouse Program Space (Zone C)	Internal space with no large openings				
Powerhouse Program Space (Zone B) [3]	Internal space within Switch House building,				
Museum Program Space (Zone C, North)[3]	Internal space within existing Wran Building				
Exhibition Space 4	Internal space within Wran Building. Breakout from roof structure modelled.	Program - Concert	Amplified music	938	As-is construction and

Space	Description	Loudest activity assessed	Noise sources	Capacity based on event type[1]	Modelled scenario[2]
			Crowd noise		improved envelope
Roof terrace	Outdoor area on Level 3	Commercial – corporate function	Amplified pre-recorded music or acoustic live music	165	Patrons occupying the entire rooftop garden
			Crowd noise		
Courtyard (Zone C, Level 1)	Exhibition - Patron conversations	Patron conversations	Crowd noise	N/A[4]	Patrons occupying the entire garden

Notes:

1. Based on population numbers in 'Event' scenario in document "*20240130_Draft Population Rev A"* Transmitted by DBJ Architects on the 30/01/24.
2. Transmission losses used in calculations are summarised in Table 34 and Table 35**.**
3. Internal space within the existing structure that has not been assessed based on the relatively low proposed noise generating activity proposed.
4. Population numbers not provided.

4.3.1 Modelling methodology

Noise source spectra used in modelling of music and patron activity is presented in Table 33. Each source has been modelled separately to define potential impacts of different modes of operation. Spectra have been scaled to achieve compliance as discussed in Table 36 and Table 37.

Table 33 Modelled noise source spectra $dBL_{eq15min}$

Noise source	Octave Band Centre Frequency, Hz, dB							
	63	125	250	500	1k	2k	4k	8k
Amplified live music[1]	111	98	95	95	97	92	85	79
Indicative internal crowd[2]	53	56	65	71	70	66	60	50
Indicative outdoor crowd noise[3]	77	82	91	97	97	92	86	76

Notes:

1. Spectrum based on front of house measurements conducted in 2016 of Coldplay at Allianz Stadium, Sydney to capacity crowd. Spectrum has been adjusted to match the dBA levels in Table 36 and Table 37

2. Noise level and spectra calculated using Rindell [16]. Crowd noise levels have been calculated by adjusting the spectrum according to the sound power level for the corresponding crowd size in Table 36 and Table 37

3. Noise level calculated using Hayne et. al. [17], spectra adopted from Cushing et. al. [18]. Crowd noise levels have been calculated by adjusting the spectrum according to the sound power level for the corresponding crowd size in Table 36 and Table 37

The location of modelled noise sources are shown in Figure 8, Figure 9, Figure 10 and Figure 11, area noise sources are highlighted in red. Noise transmission via these elements are anticipated to be the highest contributors to noise at surrounding receivers. Noise transmission through other paths such as ventilation openings or smaller doors have not been considered in this assessment but all noise paths in the building envelopes shall be assessed and appropriately acoustically treated at detailed design stage. As audio system design has not been conducted at this time, point sources used to model indicative loudspeaker locations for external music at the Switch House Terrace are highlighted in blue.

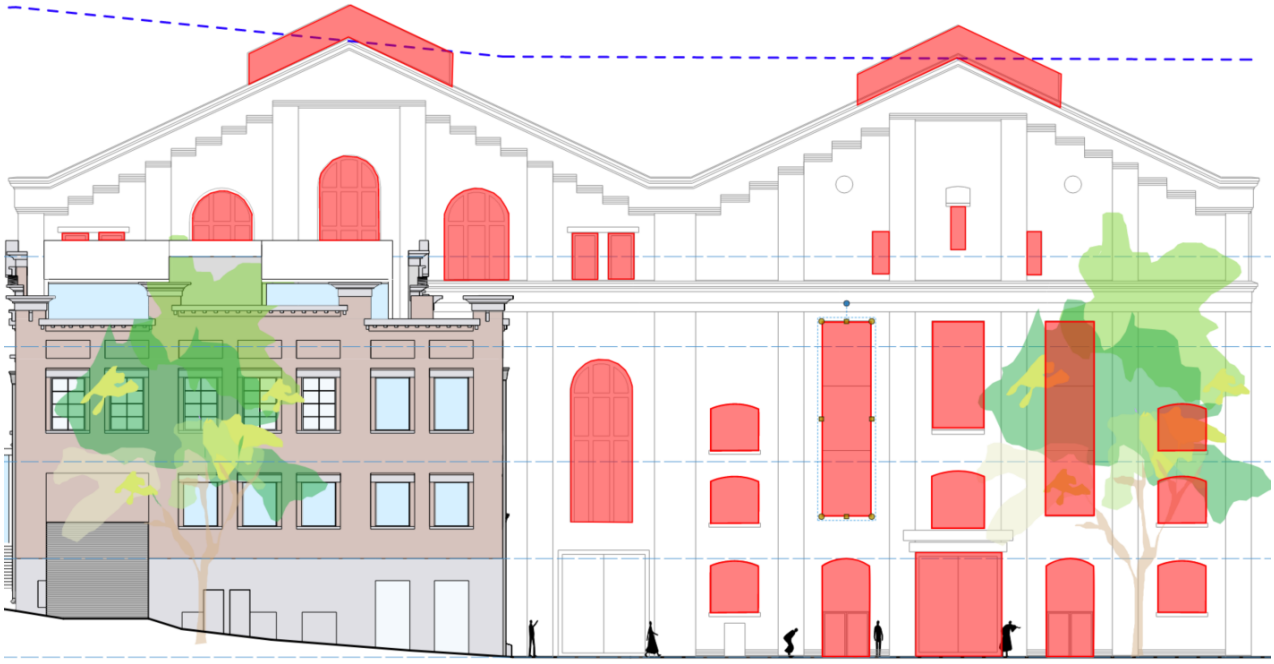

Figure 7: Noise source propagation areas in acoustic model – Exhibition Space 1 & 2 Southern Elevation

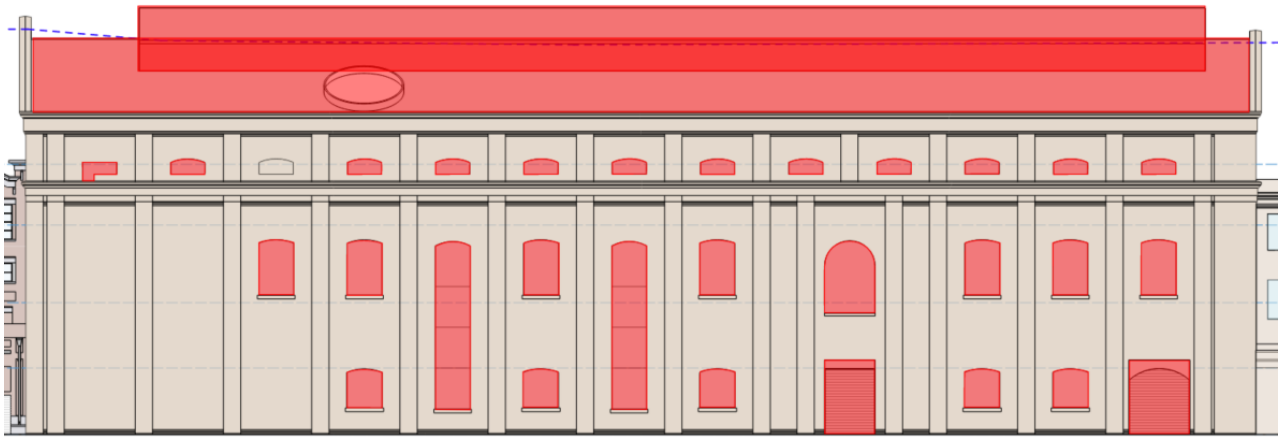

Figure 8: Noise source propagation areas in acoustic model – Exhibition Space 1 Eastern Elevation

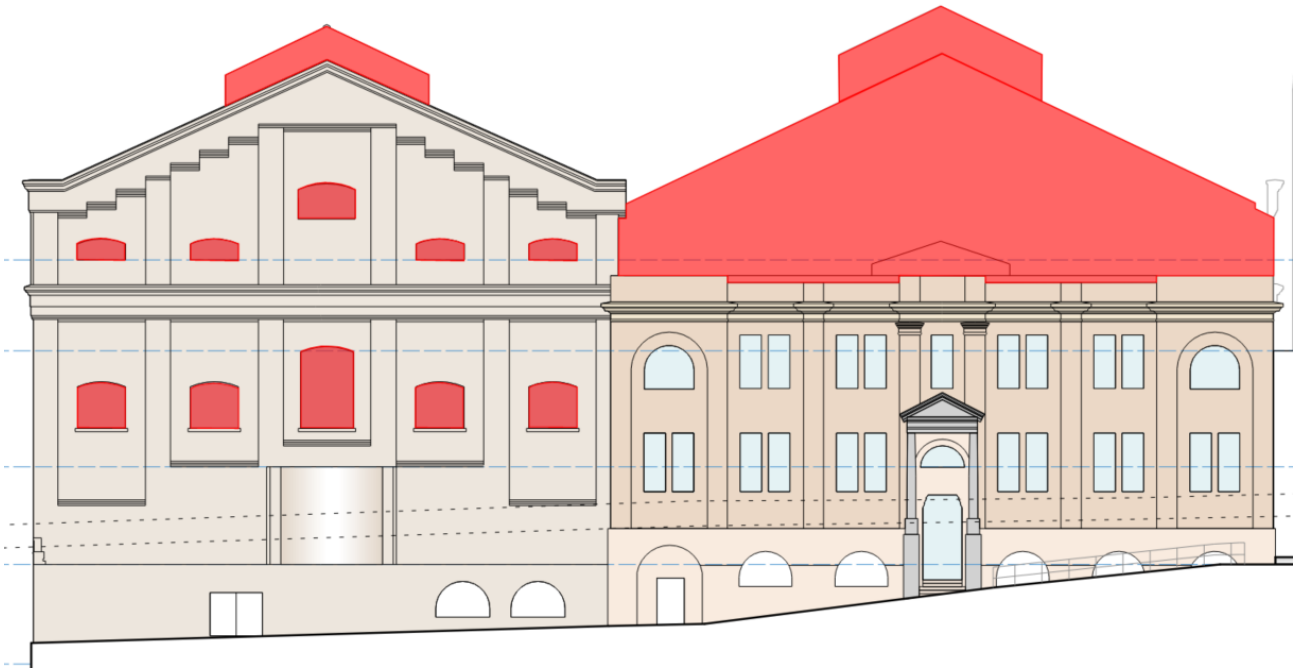

Figure 9: Noise source propagation areas in acoustic model – Exhibition Space 1 & 2 North Elevation

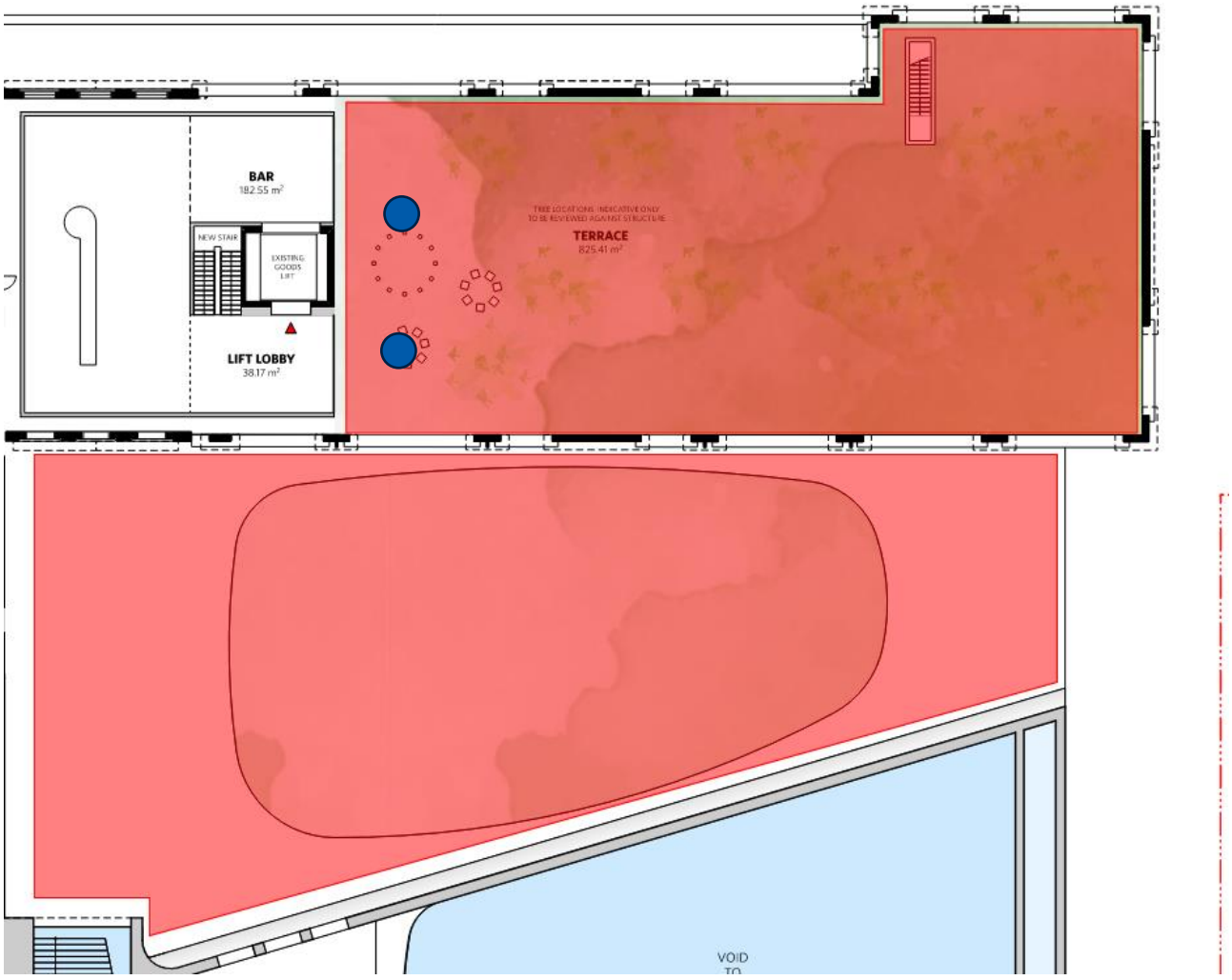

Figure 10: Noise source propagation areas and point sources in acoustic model - Rooftop Terrace and Courtyard

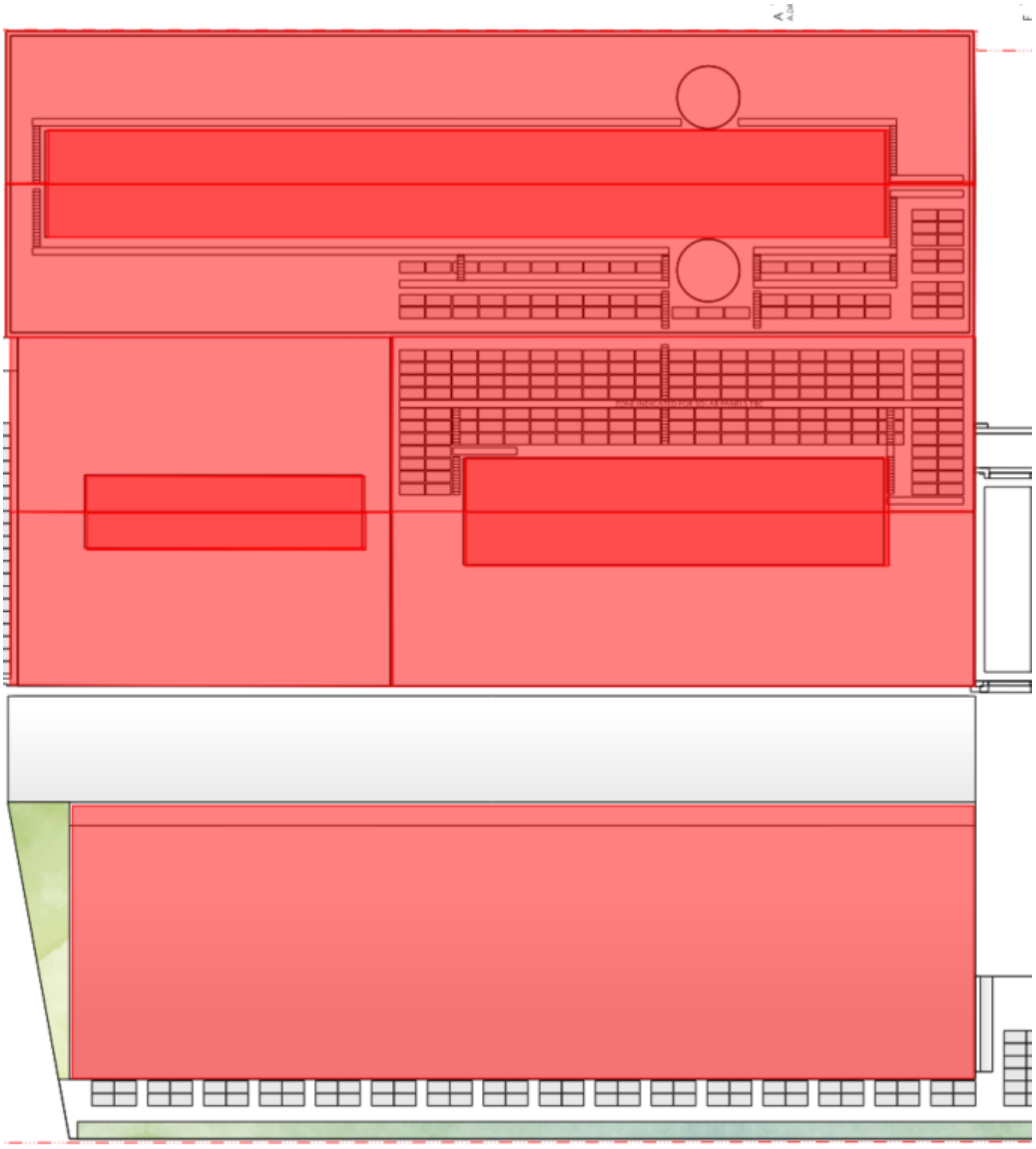

Figure 11: Noise source propagation areas in acoustic model – Exhibition Space 1, 2 and 4

Noise breakout from the existing heritage Exhibition Space 1, 2 and 4 spaces has incorporated an analysis of both existing and enhanced constructions. This has been done to demonstrate worst case and future potential scenarios. It is noted that future scenarios need to be confirmed through detailed design of the development.

Table 34: Modelled transmission losses – Existing construction

Transmission loss - Item	Construction	R_w	Transmission Loss, Octave Band Centre Frequency, Hz, dB							
			63	125	250	500	1k	2k	4k	8k
Exhibition Space 1, and 2 Roof	0.55mm steel sheet / 50mm steel stud / 50mm insulation 11 kg/m^3 / 6mm fibre cement	34	-15	-14	-22	-39	-54	-61	-58	-60
Exhibition Space 1 and 2 Glazing	Single glazing laminated 10.38mm	36	-23	-26	-27	-33	-35	-37	-45	-45
Exhibition Space 1 and 2 Operable Weather Louvre	N/A	3	-2	-2	-2	-2	-3	-3	-3	-3
Exhibition Space 4 Roof	0.55mm steel sheet / 600mm steel stud / 50mm insulation 11 kg/m^3 / 0.55mm steel sheet	33	-6	-14	-20	-35	-47	-54	-61	-66

Transmission loss - Item	Construction	R_w	Transmission Loss, Octave Band Centre Frequency, Hz, dB							
			63	125	250	500	1k	2k	4k	8k
Exhibition Space 1 Roller Doors	N/A	18	-4	-7	-13	-18	-21	-17	-16	-16
Exhibition Space 1 and 2 Glazed Doors	N/A	22	-8	-16	-19	-21	-22	-20	-30	-30

Table 35: Modelled transmission losses – Enhanced construction (indicative)

Transmission loss - Item	Construction	R_w	Transmission Loss, Octave Band Centre Frequency, Hz, dB							
			63	125	250	500	1k	2k	4k	8k
Exhibition Space 1, and 2 Roof	0.55mm steel sheet / 50mm steel stud / 50mm insulation min 11 kg/m^3 / 6mm fibre cement / min 100mm insulation 32kg/m^3 / 2x sound rated plasterboard min 16kg/m^2 on resilient fixings	57	-18	-32	-51	-67	-73	-74	-82	-82
Exhibition Space 1 and 2 Glazing	Laminated 10.38mm glazing / 100mm air gap / laminated 11.38mm glazing	51	-20	-33	-43	-49	-52	-54	-66	-66
Exhibition Space 1 and 2 Operable Smoke Vent[1]	Bottom hinged smoke vent with insulated panel	25	-3	-8	-16	-21	-27	-27	-24	-21
Exhibition Space 4 Roof	0.55mm steel sheet / 600mm steel stud / 50mm insulation 11 kg/m3 / 0.55mm steel sheet / 9mm fibre cement	50	-19	-30	-38	-51	-62	-67	-65	-74
Exhibition Space 1 Roller Doors	Double skin 80mm roller shutter	26	-14	-20	-20	-23	-24	-32	-37	-36
Exhibition Space 1 and 2 Glazed Doors[2]	6mm glass / 10mm airgap / 10.38lam Glass	37	-27	-28	-28	-33	-39	-42	-46	-46

Note:

1. Assumed transmission loss CS Group SRP-B Bottom Hinged Explovent Safety Vent
2. Assumed transmission loss CRL Entice HP + Glass Entrance System

Noise emissions have been modelled in SoundPlan 8.1 using the ISO 9613-2 algorithm, which is considered appropriate for this scenario as the nearest receivers are located within 100 metres of the noise sources. Results are based on individual assessment of music and patron noise respectively rather than cumulatively. This approach has been adopted to allow flexibility when analysing relative contributions.

The acoustic model included:

- Scaled activity noise source spectra listed in Table 33;
- Powerhouse Ultimo and surrounding buildings;
- Receivers listed in Section 2.3; and
- Ground terrain and absorption.

Modelled noise sources which represent the loudest activities in each space are presented in Table 36. These results assume envelope constructions are retained as per Table 34. Maximum patron capacities and music noise levels have been adjusted to achieve compliance at the nearest affected noise sensitive receivers. Refer to Section 4.3.2 for further discussion.

Table 36: Modelled noise sources: Existing Construction

Space	Source	Space capacity	Modelled parameters to achieve compliance[1]		
			Day	Evening	Night
Exhibition Space 1	Patrons	1393	330	170	100
	Music		Amplified live music – limited to 65dBA	Amplified live music – limited to 59dBA	Amplified live music – limited to 54dBA
Exhibition Space 2	Patrons	1688	625	325	190
	Music		Amplified live music – limited to 73dBA	Amplified live music – limited to 67dBA	Amplified live music – limited to 62dBA
Roof terrace	Patrons	165	100	40	18
	Music		Amplified pre-recorded music or acoustic live music – Limited to 62dBA	Amplified pre-recorded music or acoustic live music – Limited to 45dBA	Amplified pre-recorded music or acoustic live music – Limited to 23dBA
Courtyard (Zone C, Level 1)	Patrons	N/A	40	20	10
Exhibition Space 4	Patrons	938	938	938	938
	Music		Amplified pre-recorded music or acoustic live music – Limited to 85dBA	Amplified pre-recorded music or acoustic live music – Limited to 84dBA	Amplified pre-recorded music or acoustic live music – Limited to 79dBA

Notes:

1. Internal music levels are reverberant, external music levels are to be met at 10m from loudspeakers

Table 37 summarises potential increase to patron capacity and music levels with enhanced envelope constructions summarised for Exhibition Spaces 1,2 and 4. Façade constructions used in the assessment to derive these results are summarised in Table 35. This is provided for information and will be updated as the project progresses through detailed design.

Table 37: Modelled noise sources: Improved Construction

Space	Source	Space capacity	Modelled parameters to achieve compliance		
			Day	Evening	Night
Exhibition Space 1	Patrons	1393	1393	1393	1393
	Music		Amplified live music – limited to 82dBA	Amplified live music – limited to 76dBA	Amplified live music – limited to 71dBA
Exhibition Space 2	Patrons	1688	1688	1688	1688
	Music		Amplified live music – limited to 89dBA	Amplified live music – limited to 83dBA	Amplified live music – limited to 78dBA
Exhibition Space 4	Patrons	938	938	938	938
	Music		Amplified pre-recorded music or acoustic live music – Limited to 98dBA	Amplified pre-recorded music or acoustic live music – Limited to 97dBA	Amplified pre-recorded music or acoustic live music – Limited to 92dBA

4.3.2 Results and recommendations

Detailed tables of results for each receiver, across different time periods are summarised in Appendix C.

The patron and music noise levels displayed in Table 36 and Table 37 demonstrate the ability to comply with the NPfI PNTLs at all sensitive receivers identified in Table 29 and Table 30. Therefore, the proposed activities have been categorised as ‘low risk’ operations and considered reasonably permissible to occur on a

regular basis as long as the modelled parameters match the envelop construction type for Exhibition Space 1, 2 and 4.

Although noise emissions have been assessed to night time PNTLs, the risk of noise disturbance to the community at times between 12:00 am and 7:00 am is considered higher than other times. This is due to the communities higher sensitivity to noise during this period, therefore any activity which is proposed to extend beyond 12:00 am or begin prior to 7:00 am is automatically considered a 'medium risk' activity.

Potential disturbance to the community due to activities which have been categorised as medium or high risk would be dependent on a number of factors:

- Frequency of activity per year
- Magnitude to which patron numbers and/or music levels exceed those deemed as 'low risk'
- Duration of activities and operating hours

Definitions and requirements for each risk category are outlined below.

Low risk activities

Defined as:

- Occurring between 7:00 am and 12:00 am
- Patron numbers and music levels are equal to or below Table 36 / Table 37

Required mitigation measures

- Ensure patron numbers are equal to or below Table 36 / Table 37

Medium risk activities

Defined as:

- Extending beyond the period from 7:00 am to 12:00 am
- Patron numbers and music levels are equal to or below Table 36 / Table 37

Required mitigation measures

- Noise monitoring at nearest affected receivers for the duration of any 'medium risk' activities
- An Event Representative(s) shall be appointed for each activity at the Ultimo Powerhouse, with the responsibility and appointed authority to exercise control of noise emissions from the Ultimo Powerhouse.
- Provide details of the activity on the Powerhouse website, including date, time, duration, location and nature of event and noise sources.
- An information Hot Line would be available at all times during an activity. Details of the Hot Line will be provided via the Powerhouse website.

High risk activities

Defined as:

- Extending beyond the period from 7:00 am to 12:00 am
- Patron numbers or music levels exceed Table 36 / Table 37

Required mitigation measures

- All medium mitigation measures referred to above

- Written notification of the upcoming activity will be distributed by a letterbox drop to noise sensitive receivers within the notification boundary between 5 to 14 days prior to the activity.

Whilst not currently proposed, *if* medium and high-risk activities were to be undertaken (i.e. activities between midnight and 7am), it is recommended that a 'trial period' be put in place which would extend over the first 12 months of the Powerhouse Ultimo's operation. During the trial period, a comparison of PNTLs and measured noise levels at nearby receivers during 'medium' or 'high' risk activities shall be made to refine values in Table 36 and Table 37 and determine the appropriateness of the above mitigation measures.

The operational mitigation measures, including revised 'deemed to comply' conditions to be developed during detailed design, shall be incorporated into an Operational Noise Management Plan (ONMP). The ONMP shall be reviewed annually or more regularly on an 'as needs' basis. These reviews should consider any changes to the acoustic environment and whether additional noise monitoring is appropriate to re-establish NPfI PNTLs.

The review shall be conducted in consultation with an Accredited Acoustic Consultant.

4.4 Loading dock assessment

Loading is achieved from the Macarthur Street. Vehicular entry for the internal loading dock is integrated within the edge of the Switch House on the southern boundary of the building. At the end of the ramp, the Ground Floor Loading zone space contains the Security Control Room, fire pump room, comms and services rooms and a separate waste room. Noise breakout from activities within the loading dock are anticipated to be low as the loading dock doors will remain closed at all times when vehicles are not entering or leaving.

Additional loading for events and for loading directly into Exhibition Space 1 & 2 is allowed for in the layout of the Museum Entry Terrace – these external loading scenarios are assumed to occur infrequently (i.e. 1-2 times a year).

4.4.1 Loading dock noise modelling methodology

Two scenarios have been assessed to represent potential worst-case 15-minute period of loading activities relating to the Powerhouse Ultimo project:

Scenario 1 – Medium truck entering internal loading dock (daily)

- Defined as rigid truck which does not use air brakes, considered to be less than 10 tonnes
    - One truck entering the Powerhouse site, travelling to the loading dock door and stopping;

Scenario 2 – Large truck entering external loading area (~1-2 occurrences per month)

- Defined as vehicle which uses air brakes, considered to be truck 10 tonnes or greater, including semi-trailers and any articulated vehicles
    - One truck entering the Powerhouse site at the end of Macarthur St, travelling the length of driveway and stopping;
    - Releasing the air brake; and
    - Reversing into external park on Gathering Terrace outside Pump House.

Large truck entry is expected to generate higher noise levels than trucks leaving the external area, as trucks would be required stop and reverse while in the driveway.

The location of the internal loading dock and external modelled loading vehicle entry routes are presented in Figure 12.

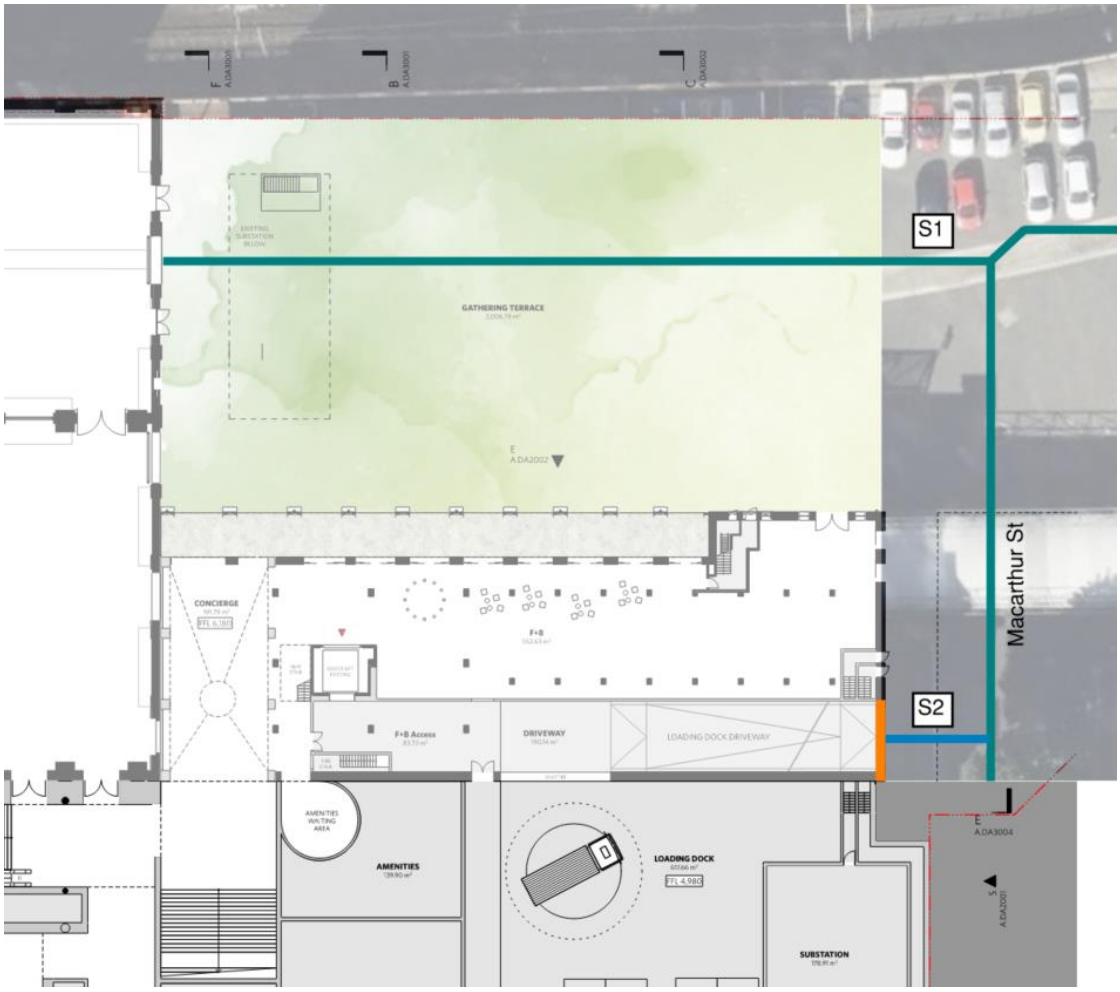

Figure 12 - Modelled loading routes. Medium truck path shown in BLUE, Large truck path shown in GREEN. Extent of loading dock door shown in ORANGE

Noise from internal loading activities is expected to be contained within the loading dock. It is understood the door is located at the top of the ramp to limit access to the loading area Table 38 summarises the modelled source noise levels.

Table 38: Sound power levels – loading dock activities

Noise Source	Descriptor	Broadband level, dB(A)	Octave Band Centre Frequency – Hz, dB								Quantity operating in worst case 15 minutes
			63	125	250	500	1 k	2 k	4 k	8 k	
Large truck											
Truck accelerating – Semi-trailer / large truck, L_w	$L_{Aeq(15min)}$ / metre	70	73	69	66	65	67	62	58	52	One truck travelling length of driveway, pulling up then reversing into external loading area
Large truck releasing air brake compression (single event), L_w	$L_{Aeq(15min)}$ / metre	71	73	69	64	60	61	67	63	63	One event at location truck pulls up
	L_{Amax}	116	118	114	109	105	106	112	108	108	
Truck reversing alarm[1], L_w	$L_{Aeq(15min)}$ / metre	69	75	74	65	63	62	64	53	44	Active while truck is reversing into loading dock
Medium truck											
Truck accelerating – Medium rigid truck, L_w	$L_{Aeq(15min)}$ / metre	67	72	66	65	63	63	60	55	49	One truck moving from site entry to stationary in front of internal loading dock door

Note:

1) Sound power level includes 5dB penalty for tonal noise in accordance with NPfI [7]

4.4.2 Loading dock prediction results

Results for residential receivers for day, evening and night-time periods are presented in Table 39 and Table 40 for large and medium truck movements respectively. Levels shaded in grey indicate an exceedance of PNTL. Results indicate compliance at non-residential noise sensitive receivers for all scenarios.

Table 39: Loading assessment – Large trucks to external loading area (1x arrival event in 15min time period)

Receiver	$L_{Aeq(15minute)}$ Assessment				Sleep disturbance assessment, L_{max}	
	Predicted Noise level	Project Noise Trigger Level			Predicted Noise level	Project Noise Trigger Level Night only
		Day	Evening	Night		
Residential receivers (including mixed use developments)						
R1 – 543 Harris Street, Ultimo	21	58	57	53	44	64
R2 – 531-533 Harris Street, Ultimo	21	58	57	53	43	64
R3 – 599 Harris Street, Ultimo	42	58	57	53	65	64
R4 – 576A Harris Street, Ultimo	28	58	57	53	46	64
R5 – 39 Darling Drive, Sydney	48	54	48	43	70	59
R6 – 41 Darling Drive, Sydney	54	54	48	43	77	59
R7 – 1 Steam Mill Lane, Haymarket	46	54	48	43	69	59
R8 – 81-85 Macarthur Street, Ultimo	54	52	48	43	72	60
R9 – 13-17 Systrum Road, Ultimo	45	52	48	43	61	60

Heavy vehicle loading activities are predicted to significantly exceed evening and night time PNTLs at the nearest affected receiver locations. R8 is predicting the highest exceedance being 2dB above the daytime criteria and 11dB above the night time criteria. These exceedances should be noted taking into account the anticipated infrequency of their occurrence and in the context of the urban site location (i.e. 1-2 events per year).

Table 40: Loading dock assessment – Scenario 2. Medium trucks to internal loading dock (1x arrival event in 15min time period)

Receiver	$L_{Aeq(15minute)}$ Assessment				Sleep disturbance assessment, L_{max}	
	Predicted Noise level	Project Noise Trigger Level			Predicted Noise level	Project Noise Trigger Level Night only
		Day	Evening	Night		
Residential receivers (including mixed use developments)						
R1 – 543 Harris Street, Ultimo	4	58	57	53	n/a	64
R2 – 531-533 Harris Street, Ultimo	5	58	57	53	n/a	64
R3 – 599 Harris Street, Ultimo	32	58	57	53	n/a	64
R4 – 576A Harris Street, Ultimo	18	58	57	53	n/a	64
R5 – 39 Darling Drive, Sydney	29	54	48	43	n/a	59
R6 – 41 Darling Drive, Sydney	33	54	48	43	n/a	59
R7 – 1 Steam Mill Lane, Haymarket	29	54	48	43	n/a	59
R8 – 81-85 Macarthur Street, Ultimo	44	52	48	43	n/a	60
R9 – 13-17 Systrum Road, Ultimo	35	52	48	43	n/a	60

Medium vehicle loading activities are predicted to comply with PNTLs at all locations during all time periods with a minor exceedance of 1dB predicted at R8 during the night time period.

Operational mitigation and management measures are discussed further in Section 4.6

4.5 Building services equipment

Building service equipment (e.g. mechanical, hydraulic and electrical equipment) for the development has not been selected at this stage of design. During ongoing design of the development, building services equipment will be selected and provided with noise and vibration attenuation measures as required to meet the project criteria summarised in Section 4.2.1.

Standard engineering noise control and mitigation measures are expected to be sufficient and may include the following:

- Specification of maximum sound power levels for all items of plant as part of the project documentation.
- Use of attenuators to control fan noise
- Acoustic louvres to control noise from plantroom ventilation openings
- Vibration isolators to reduce vibration input to the building structure
- Acoustic screens around external plant, where required
- Incorporation of sound absorptive treatments in plantroom spaces.

4.6 Operational noise and vibration mitigation and management measures

A summary of recommended operational noise and vibration mitigation and management measures are presented in Table 41.

Table 41: Summary of operational noise and vibration mitigation and management measures

Item	Detail	Timing
Operation – Loading dock doors	Assess noise transmission through loading dock doors, specify appropriate doors to meet PNTLs at surrounding receivers.	Detailed design
	No loading activities shall take place while loading dock doors are open.	During operation
Operation – Loading dock vehicles	Small and medium trucks entering the loading dock shall not idle outside the loading dock between 10pm and 7am.	During operation
	All trucks shall not queue within the driveway/Macarthur St and shall park off-site if awaiting entry to the loading dock between 10pm and 7am.	
	Minimise the use of tonal reversing alarms as far as practicable, instead employing broad band alternatives.	
Operation – Patron and music noise	The operational mitigation measures, including revised ‘deemed to comply’ conditions, shall be incorporated into an Operational Noise Management Plan (ONMP).	Prior to opening
	The ONMP shall be reviewed annually for the first 5 years of operation or more regularly on an ‘as needs’ basis. The review shall be conducted in consultation with an Accredited Acoustic Consultant.	Post-opening annually
Operation – Patron noise	Patron noise leaving the site after 10pm to be managed by staff directing patrons to keep noise to a minimum	During operation
Operation – Building services equipment	Acoustic mitigation measures for building services plant to meet PNTLs shall be developed at detailed design stage when equipment selections have been finalised and locations confirmed.	Detailed design

5. Conclusion

An assessment of noise and vibration impacts associated with the construction and operation of the Ultimo Revitalisation has been conducted in accordance with Secretary's Environmental Assessment Requirements and relevant Strategic Policy, Technical Guidelines and National Codes.

5.1 Construction

Noise generated during 'worst case' and typical scenarios for the various stages of demolition and construction have been predicted at surrounding noise sensitive receivers. This has been informed by guidance from the project Construction Management Plan. The results are indicative only and considered to be conservative.

A range of construction impacts have been presented based on an anticipated worst case scenario and more typical scenario of multiple plant items operating concurrently. During the worst case construction scenarios, all stages of work are predicted to exceed project Noise Management Levels at nearly all the nearest sensitive receiver locations. The majority of nearest affected residential receivers are also expected to experience noise impacts above the Highly Noise Affected threshold of 75 $dBL_{Aeq(15min)}$ during the majority of construction phases assuming the highest number of plant operating concurrently. The number of 'highly affected' receivers reduces assuming a lower, more typical list of operational plant.

It should be noted that while the demolition phase predicts the greatest number highly noise effected residences, the phase has a comparatively short duration of 2 months compared to the total 24 month construction timeline. Furthermore, noise impacts may reduce pending the piling method used.

Should construction require the use of impact piling, dependent on yet unknown factors such as ground composition, these works are predicted to generate the most significant noise impacts. The use of equipment such as excavators, circular and chainsaws, scrapers, compactors and graders are the highest contributors to noise emissions.

The likelihood of adverse vibration impacts as a result of proposed construction works will be dependent on the final construction methodologies, with impact piling potentially generating adverse impacts at receivers in close proximity. Mitigation should be considered where vibration intensive works are required closer than 'safe working distances' to sensitive receivers, presented in Table 24.

In-principle recommendations in Table 22, Table 23 and Table 24 are given for the control of construction noise for the periods where exceedances are predicted of relevant Noise Management Levels. Mitigation measures for the management of construction vibration relevant to activities and vibration sensitive receiver types are also detailed. The construction contractor is required to prepare a detailed Construction Noise and Vibration Management Plan once specific construction details are known.

5.2 Operation

Operation noise criteria have been established for noise emissions, which include:

- Traffic generated by operation of the site
- Building services and external plant
- Loading dock operations
- Patron and music from both internal and external spaces

Impacts due to the operational traffic and loading dock operations have been assessed, mitigation measures have been recommended where required.

Acoustic mitigation measures for building services plant will be developed to meet PNTLs at detailed design stage when equipment selections have been finalised and locations confirmed.

Activity noise from within the Ultimo Powerhouse due to patrons and music has been assessed to the NPfI PNTLs. Patron noise and music are strictly not addressed by the NPfI, however PNTLs have been adopted to indicate intrusive and amenity noise limits for activity noise in the absence of applicable policy. An assessment has been conducted for activity noise in spaces where compliance with PNTLs would not be easily achievable through building envelope design.

Patron numbers and music levels have been provided which are predicted to meet PNTLs at surrounding residences and would generally be considered to generate minimum disturbance to the community and are deemed ‘low risk’ activities. Should higher patron numbers or music levels than those stipulated to comply with PNTLs be proposed for activities within the Ultimo Powerhouse, or should activities extend beyond the 7:00 am to 12:00 am times, these activities would be considered ‘medium risk’ or ‘high risk’ activities, and mitigation measures have been provided to minimise the community disturbance from these activities. Definitions and parameters of each activity risk category, as well as mitigation measures, should be captured in an Operational Noise Management Plan.

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[17] M. Hayne, J. Taylor, R. Rumble and D. Mee, “Prediction of Noise from Small to Medium Sized Crowds,” in *Acoustics 2011*, Gold Coast, 2011.

[18] I. R. Cushing, F. F. Li, T. J. Cox, K. Worral and T. Jackson, “Vocal effort levels in anechoic conditions,” *Applied Acoustics*, vol. 72, pp. 695-701, 2011.

[19] Museum of Applied Arts & Sciences, “Powerhouse Ultimo - Design Competition Brief,” Museum of Applied Arts & Sciences, Sydney, 2022.

[20] British Standards, “BS 5228-2 Code of practice for noise and vibration control on construction and open sites - Vibration,” British Standards, 2009.

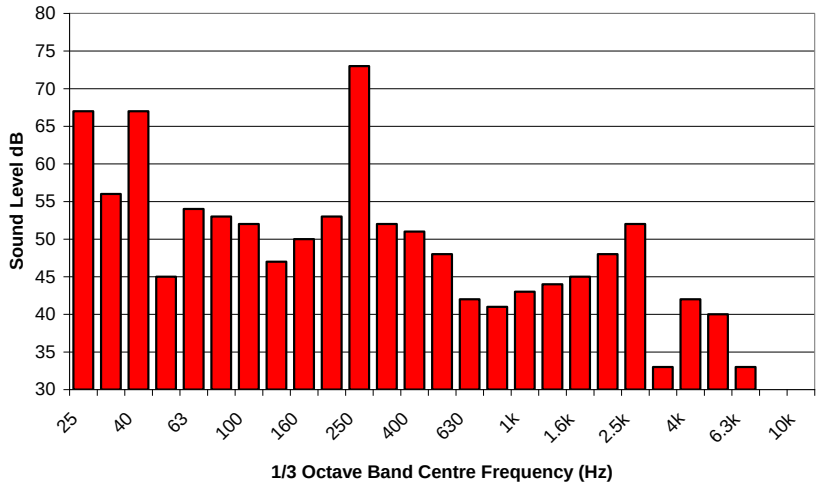
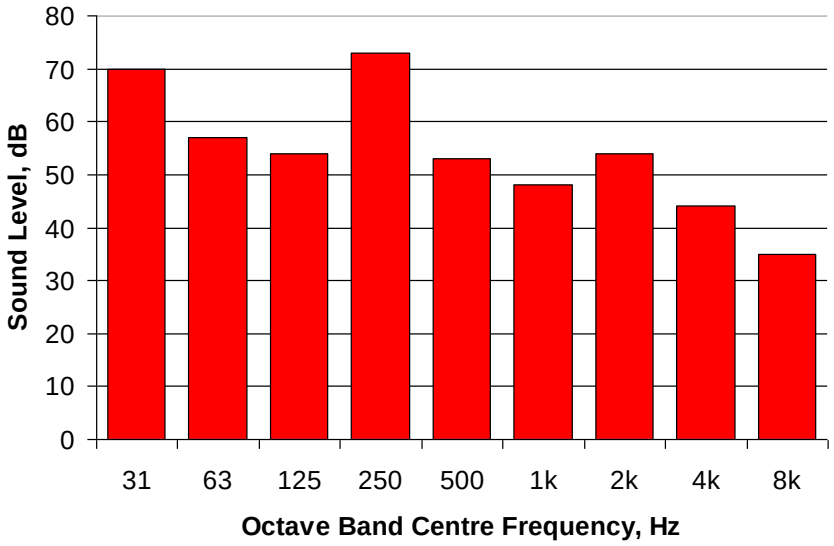
Appendix A

Acoustic Terminology

A.1 Acoustic Terminology

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 city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.
Background Noise Level	The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects. **Assessment Background Level (ABL)** A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time. **Rating Background Level (RBL / min $L_{A90,1hour}$)** A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey. This parameter is denoted RBL in NSW, and min $L_{A90,1hour}$ in QLD.
Decibel	The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore, a logarithmic scale, the decibel (dB) scale, is used to describe sound levels. An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.
dBA	dBA 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 dBA.

<table>
<tr><th>Term</th><th>Definition</th></tr>
<tr><td></td><td>Some typical dBA levels are shown below.
<table>
<tr><th>Sound Pressure Level dBA</th><th>Example</th></tr>
<tr><td>130</td><td>Human threshold of pain</td></tr>
<tr><td>120</td><td>Jet aircraft take-off at 100 m</td></tr>
<tr><td>110</td><td>Chain saw at 1 m</td></tr>
<tr><td>100</td><td>Inside nightclub</td></tr>
<tr><td>90</td><td>Heavy trucks at 5 m</td></tr>
<tr><td>80</td><td>Kerbside of busy street</td></tr>
<tr><td>70</td><td>Loud stereo in living room</td></tr>
<tr><td>60</td><td>Office or restaurant with people present</td></tr>
<tr><td>50</td><td>Domestic fan heater at 1m</td></tr>
<tr><td>40</td><td>Living room (without TV, stereo, etc.)</td></tr>
<tr><td>30</td><td>Background noise in a theatre</td></tr>
<tr><td>20</td><td>Remote rural area on still night</td></tr>
<tr><td>10</td><td>Acoustic laboratory test chamber</td></tr>
<tr><td>0</td><td>Threshold of hearing</td></tr>
</table></td></tr>
<tr><td>L_1</td><td>The L_1 statistical level is often used to represent the maximum level of a sound level that varies with time.
Mathematically, the L_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB $L_{A1,15min}$ is a sound level of 87 dBA or higher for 1% of the 15 minute measurement period.</td></tr>
<tr><td>L_{10}</td><td>The L_{10} statistical level is often used as the “average maximum” level of a sound level that varies with time.
Mathematically, the L_{10} level is the sound level exceeded for 10% of the measurement duration. L_{10} is often used for road traffic noise assessment. As an example, 63 dB $L_{A10,18hr}$ is a sound level of 63 dBA or higher for 10% of the 18 hour measurement period.</td></tr>
<tr><td>L_{90}</td><td>The L_{90} statistical level is often used as the “average minimum” or “background” level of a sound level that varies with time.
Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dBA or higher for 90% of the 15 minute measurement period.</td></tr>
<tr><td>L_{eq}</td><td>The ‘equivalent continuous sound level’, Leq, is used to describe the level of a time-varying sound or vibration measurement.
Leq is often used as the “average” level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dBA weighting is applied, the level is denoted dB LAeq. Often the measurement duration is quoted, thus LAeq,15 min represents the dBA weighted energy-average level of a 15 minute measurement.</td></tr>
<tr><td>L_{max}</td><td>The Lmax statistical level can be used to describe the “absolute maximum” level of a sound or vibration level that varies with time.
Mathematically, Lmax is the highest value recorded during the measurement period. As an example, 94 dB LAmax is a highest value of 94 dBA during the measurement period.
Since Lmax is often caused by an instantaneous event, Lmax levels often vary significantly between measurements.</td></tr>
</table>

Term	Definition
Frequency	Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as “pitch”. Sounds towards the lower end of the human hearing frequency range are perceived as “bass” or “low-pitched” and sounds with a higher frequency are perceived as “treble” or “high pitched”.  
Peak Particle Velocity (PPV)	Peak Particle Velocity (PPV) is the highest velocity of a particle (such as part of a building structure) as it vibrates. Most sound level meters measure root mean squared (RMS) values; it is common to approximate the PPV based on an RMS measurement. PPV is commonly used as a vibration criterion, and is often interpreted as a PPV based on the Lmax or Lmax,spec index.
Sound Power and Sound Pressure	The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (L_p) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.
Vibration	Waves in a solid material are called “vibration”, as opposed to similar waves in air, which are called “sound” or “noise”. If vibration levels are high enough, they can be felt; usually vibration levels must be much higher to cause structural damage. A vibrating structure (eg a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space. Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.

Appendix B

Construction Noise Contour Maps

A3

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Legend

- Site
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 85
- 85 - 90
- 90 - 95
- 95+

Coordinate System: EPSG:7856

--

0 25 50 75 100 m

Rev	Date	By	Chkd	Appd	Authd
A	07/03/2024	AT	NJ	--	--

ARUP

Level 5 Barrack Place,
151 Clarence St, Sydney
NSW 2000
www.arup.com

Client

Infrastructure NSW

Project Name

Powerhouse Ultimo Renewal

Drawing Title

Construction Noise: Site Establishment

Scale at A3

1:2000

Role

--

Suitability

--

Project Number

293119

Rev

A

Drawing Name

--

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A3

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Legend

Site	60 - 65	80 - 85
45 - 50	65 - 70	85 - 90
50 - 55	70 - 75	90 - 95
55 - 60	75 - 80	95+

Coordinate System: EPSG:7856

--

0 25 50 75 100 m

Rev	Date	By	Chkd	Appd	Authd
A	07/03/2024	AT	NJ	--	--

ARUP

Level 5 Barrack Place,
151 Clarence St, Sydney
NSW 2000
www.arup.com

Client

Infrastructure NSW

Project Name

Powerhouse Ultimo Renewal

Drawing Title

Construction Noise: Demolition

Scale at A3

1:2000

Role

--

Suitability

--

Project Number

293119

Rev

A

Drawing Name

--

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A3

07/03/2024 1:43 PM

Legend

- Site
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 85
- 85 - 90
- 90 - 95
- 95+

Coordinate System: EPSG:7856

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0 25 50 75 100 m

Rev	Date	By	Chkd	Appd	Authd
A	07/03/2024	AT	NJ	--	--

ARUP

Level 5 Barrack Place,
151 Clarence St, Sydney
NSW 2000
www.arup.com

Client

Infrastructure NSW

Project Name

Powerhouse Ultimo Renewal

Drawing Title

Construction Noise: Excavation and Piling

Scale at A3

1:2000

Role

--

Suitability

--

Project Number

293119

Rev

A

Drawing Name

--

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A3

07/03/2024 1:42 PM

Legend

- Site
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 85
- 85 - 90
- 90 - 95
- 95+

Coordinate System: EPSG:7856

--

0 25 50 75 100 m

Rev	Date	By	Chkd	Appd	Authd
A	07/03/2024	AT	NJ	--	--

ARUP

Level 5 Barrack Place,
151 Clarence St, Sydney
NSW 2000
www.arup.com

Client

Infrastructure NSW

Project Name

Powerhouse Ultimo Renewal

Drawing Title

Construction Noise: Construction

Scale at A3

1:2000

Role

--

Suitability

--

Project Number

293119

Rev

A

Drawing Name

--

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Appendix C

Patron and music noise predictions

Table 42: Patron and music noise predictions: Day

Receiver	NCA	Criteria	Exhibition Space 1		Exhibition Space 2		Roof terrace		Courtyard	Exhibition Space 4	
			Patron	Music	Patron	Music	Patron	Music	Patron	Patron	Music
Residential receivers (including mixed use developments)											
R1 - 543 Harris Street, Ultimo	1	**58**	38	37	41	42	34	38	26	42	58
R2 - 531-533 Harris Street, Ultimo	1	**58**	37	37	39	40	36	34	27	42	57
R3 - 599 Harris Street, Ultimo	1	**58**	34	33	39	39	43	49	42	28	46
R4 - 576A Harris Street, Ultimo	1	**58**	28	27	31	32	34	36	27	20	40
R5 - 39 Darling Drive, Sydney	2	**54**	54	54	54	54	51	51	44	31	48
R6 - 41 Darling Drive, Sydney	2	**54**	46	45	51	51	54	54	45	30	47
R7 - 1 Steam Mill Lane, Haymarket	2	**54**	26	25	35	36	45	39	37	25	43
R8 - 81-85 Macarthur Street, Ultimo	3	**52**	37	36	45	45	47	52	52	28	44
R9 - 13-17 Systrum Road, Ultimo	3	**52**	41	40	45	44	48	47	46	32	46
Hotel											
H1 - Glasgow Arms Hotel	1	**63**	39	38	40	41	32	31	25	41	56
Education											
E1 - JMC Academy	1	**57**	31	31	37	38	50	54	42	40	56
E2 - Academy of Film, Theatre and Television	1	**57**	38	37	43	43	53	51	45	37	53
Childcare											
CC1 - Ultimo Community Centre	1	**57**	40	39	45	45	37	32	28	39	54

Table 43: Patron and music noise predictions: Evening

Receiver	NCA	Criteria	Exhibition Space 1		Exhibition Space 2		Roof terrace		Courtyard	Exhibition Space 4	
			Patron	Music	Patron	Music	Patron	Music	Patron	Patron	Music
Residential receivers (including mixed use developments)											
R1 - 543 Harris Street, Ultimo	1	**57**	32	31	36	36	28	32	22	42	57
R2 - 531-533 Harris Street, Ultimo	1	**57**	31	31	33	34	30	28	23	42	56
R3 - 599 Harris Street, Ultimo	1	**57**	28	27	33	33	37	43	38	28	45
R4 - 576A Harris Street, Ultimo	1	**57**	22	21	25	26	28	30	22	20	39
R5 - 39 Darling Drive, Sydney	2	**48**	48	48	48	48	45	45	39	31	47
R6 - 41 Darling Drive, Sydney	2	**48**	40	39	45	45	48	48	40	30	46
R7- 1 Steam Mill Lane, Haymarket	2	**48**	19	19	29	30	39	33	32	25	42
R8 - 81-85 Macarthur Street, Ultimo	3	**48**	30	30	39	39	41	46	48	28	43

Receiver	NCA	Criteria	Exhibition Space 1		Exhibition Space 2		Roof terrace		Courtyard	Exhibition Space 4	
			Patron	Music	Patron	Music	Patron	Music	Patron	Patron	Music
R9 - 13-17 Systrum Road, Ultimo	3	**48**	34	34	39	38	42	41	41	32	45
Hotel											
H1 - Glasgow Arms Hotel	1	**57**	32	32	34	35	26	25	21	41	55
Education											
E1 - JMC Academy	1	**57**	25	25	31	32	44	48	37	40	55
E2 - Academy of Film, Theatre and Television	1	**57**	32	31	37	37	47	45	40	37	52
Childcare											
CC1 - Ultimo Community Centre	1	**57**	34	33	39	39	31	26	24	39	53

Table 44: Patron and music noise predictions: Night

Receiver	NCA	Criteria	Exhibition Space 1		Exhibition Space 2		Roof terrace		Courtyard	Exhibition Space 4	
			Patron	Music	Patron	Music	Patron	Music	Patron	Patron	Music
Residential receivers (including mixed use developments)											
R1 - 543 Harris Street, Ultimo	1	**53**	27	26	31	31	23	27	17	42	52
R2 - 531-533 Harris Street, Ultimo	1	**53**	26	26	28	29	25	23	18	42	51
R3 - 599 Harris Street, Ultimo	1	**53**	23	22	28	28	32	38	33	28	40
R4 - 576A Harris Street, Ultimo	1	**53**	17	16	20	21	23	25	18	20	34
R5 - 39 Darling Drive, Sydney	2	**43**	43	43	43	43	40	40	35	31	42
R6 - 41 Darling Drive, Sydney	2	**43**	35	34	40	40	43	43	36	30	41
R7 - 1 Steam Mill Lane, Haymarket	2	**43**	14	14	24	25	34	28	28	25	37
R8 - 81-85 Macarthur Street, Ultimo	3	**43**	25	25	34	34	36	41	43	28	38
R9 - 13-17 Systrum Road, Ultimo	3	**43**	29	29	34	33	37	36	37	32	40
Hotel											
H1 - Glasgow Arms Hotel	1	**53**	27	27	29	30	21	20	16	41	50
Education											
E1 - JMC Academy	1	**53**	20	20	26	27	39	43	33	40	50
E2 - Academy of Film, Theatre and Television	1	**53**	27	26	32	32	41	40	36	37	47
Childcare											
CC1 - Ultimo Community Centre	1	**53**	29	28	34	34	26	21	19	39	48

Table 45: Patron and music noise predictions: non-residential

Receiver	Criteria	Exhibition Space 1						Exhibition Space 2						Roof terrace						Courtyard			Exhibition Space 4					
		Day		Eve		Night		Day		Eve		Night		Day		Eve		Night		Day	Eve	Night	Day		Eve		Night	
		Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Music	Patron	Patron	Patron	Patron	Music	Patron	Music	Patron	Music
Hotel																												
H1	63	39	38	32	32	32	27	40	41	34	35	34	30	32	31	26	25	26	20	25	21	21	41	56	41	55	41	50
Commercial																												
C1	63	34	34	28	28	28	23	42	42	36	36	36	31	47	50	41	44	41	39	40	35	31	44	60	44	59	44	54
C2	63	31	31	25	25	24	20	37	37	31	31	31	26	43	44	37	43	37	38	42	37	33	34	48	34	47	34	42
C3	63	36	36	30	30	30	25	40	41	34	35	34	30	46	50	40	44	40	39	49	44	40	28	46	28	45	28	40
C4	63	44	43	37	37	37	32	40	40	34	34	34	29	21	31	15	25	15	20	18	13	14	19	40	19	39	19	34
Active Recreation																												
AR1	53	45	44	38	38	38	33	53	53	47	47	47	42	32	37	26	31	26	26	22	18	18	36	51	36	50	36	45